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**Systems of Innovation and Human
Capital in African Development**

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ABSTRACT

In this paper, we propose that historically generated institutions and persistent pattern of human capital formation conditions the emergent systems of innovation in Africa. These effectively determine the development trajectory of the region. We advance the notion of dynamic and non-dynamic systems of innovation, the latter describing the African condition. In doing this, we combine the strand of literature on institutions and their persistence in shaping industrialisation with the literature on evolutionary theory and systems of innovation. We provide evidence of the colonial origins of skewed schooling enrolment, at variance with the industrialisation and wealth creation 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 capital 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 by the human capital variables even though we did not attempt to investigate all variables making up the system of innovation. Our findings suggest that Africa's present underdeveloped system of innovation in part has its roots in both the past and present poor pattern of human capital formation. This is a first tentative attempt to explore long-run development in Africa within the systems of innovation framework.

Keywords: systems of innovation, Africa, human capital, path-dependency

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1.0 INTRODUCTION

This paper explores the human capital root of the slow pace of development in Africa within the system of innovation 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: 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 Sokoff 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 emphasised (Sandberg 1982; Abramovitz and David 1994).

¹ See Easterly and Levine (1995, 1997) and Sachs and Warner (1997) among others. However, none of these studies work within the system of innovation framework and none situate their analysis within the evolutionary technological change theory where emphasis is placed on institutions supporting innovative activities.

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 the 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 system of innovation framework. Given its pivotal importance, the question is why there has been so little consideration of the issue. One explanation could be that human capital is considered parametric in the analysis of innovation system, as studies have been carried out largely in industrialised economies where technological and scientific capabilities are taken as given. The other explanation could be that the role of human capital has been treated more implicitly within the notion of dynamic learning in firms. If this proves to be a valid point, this approach will leave us with more of the *skills effect* that is only indirectly related to schooling and formal training.

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 systems of innovation 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” (ibid: 225). The concept, they argue is highly relevant also for the South. To this end, a broad approach where innovations are conceived as activities rooted in the daily routines of firms as well as in the capabilities of managers and engineers would be the preferred research programme.

The paper is organized as follows: The next section calls attention to the need for a broadening of the concept of SI while section 2 reviews the role of education and human capital in development, followed by a review of the institutional origin of Africa's present systems of innovation. Section 3 analyzes the formation of human capital over time in Africa, followed by an analysis of the persistence and discontinuity of state and institutional capabilities in Africa. Section 4 presents empirical tests of the link between human capital and elements of systems of innovation followed by a concluding section.

1.1: A Broader Conceptualization of Innovation Systems

As Abramovitz (1986) observed capital accumulation and increase in the labor force are not enough to explain variation in economic growth. “Social capability”, that is, the capacity to create and manage institutional changes specifically, the variants that support innovation, is important in fostering effective systems of innovation.

Latecomers² in particular need a supportive system of innovation as examples from the acquisition of semi conductor, steel and chemical industry in Korea show (Freeman 2002). The plant scale advantage, which latecomers could exploit, impose exacting requirements in the form of high-level skills as well as a network of engineering, R&D and testing facilities, among others. All of these take time and efforts to build as List (1841) aptly summed up more than two centuries ago:

“The present state of the nations is the result of the accumulation of all discoveries, inventions, improvements, perfection and exertion of all generations which have lived before us: they form the intellectual capital of the present human race, and every separate nations is productive only in the proportion in which it has known how to appropriate those attainments of former generations and to increase them by its own acquiresments” (Quoted in Freeman 2002: 193).

List therefore anticipated the way in which innovation system³ would build on past innovations and the learning efforts that need to accompany imitation by later comer’s technological efforts.

While some developing countries have succeeded dramatically in building up technological capabilities, African countries have been generally unsuccessful. We propose the notion of dynamic and non-dynamic latecomer systems of innovation (SI) to describe the successful and the not so successful countries learning to imitate and industrialize. Early industrializers developed dynamic SIs and have a long history of technical (not necessarily formal scientific) culture as well as institutions supportive of entrepreneurship and a mix of skill, experience and knowledge, codified in human capital. As Lall (1992, 2001) points out, successful systems of innovation are characterized by a certain optimal skills structure in engineering, mathematics and sciences that support industrial development. It is not enough for a country to produce

² A “latecomer” is a country that industrialized initially by borrowing foreign technology, Amsden (1989).

³ Viotti (2001) suggests that developing countries should rather adopt the notion of national learning systems since they do not undertake innovation and because current application of the concept excessively dwell on R&D as a measure of innovation capability. We see no reason for a change in nomenclature in as much as innovation is broadly defined to include routine incremental activities on the shop floor. Secondly, our operative concept is the phrase system of innovation, rather than take the two words apart, which causes confusion, we suggest they be so understood. Systems are sets of elements standing in interaction (von Bertalanffy 1968). Nations, technical systems and sectors consist of elements and interact in certain complex fashions, which we need to explain. Whether advanced as in human systems or simple as in amoeba, systems are a different matter.

manpower but the right kinds for its level of development. While general knowledge acquired from formal educational institution forms an important component of a nation’s human capital, firm-level training, R&D and production are necessary for the idiosyncratic knowledge bases of firms. Freeman (2002) cites the human capital base of dynamic SIs, which we contrast with non-dynamic SIs in Sub Saharan Africa (SSA) (See Appendix Table A1).

The notion of human capital regards education as directly contributing to the formation of knowledge and skills in productive work. Human capital is the sum total of the skills level of a country's entire workforce which includes managers and administrators. We make a distinction here between formal education, which is clearly very important, and formal education upon which has been built pertinent knowledge, skills and experience. The potential real income per capita of a country is a function of the productivity of its labor (Sandberg 1982; Tortella 1994).⁴ More importantly, this experience and skills is located within an organized system, which in this case, we take to be the modern industrial enterprise. *The firm is thus the strategic locus within which organized human capital produces new products and processes and thereby advances the productivity of nations.* The firm itself is located within a network of other economic agents. Systems effectiveness is a result of the competencies of actors and their interaction within the particular system.

The very important contribution of human capital can be illustrated with the simple relations showing the sources of growth as follows⁵:

$$\begin{aligned}
 \text{Labor productivity growth} &= \text{Contribution of physical capital per worker} \\
 &+ \\
 &\text{Contribution of economic efficiency growth}
 \end{aligned}$$

⁴ See Tortella (1990) for various country studies that examine this issue.

⁵ See World Bank (1993) for examples of East Asia’s sources of productivity.

2.0 EDUCATION, HUMAN CAPITAL AND DEVELOPMENT

Easterlin (1981) and Sandberg (1982) have all presented systematic analyses of the linkage between basic education, economic growth and industrialization. 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”.⁶ Wolff (2001: 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. Easterlin (1974) aptly captures the intellectual and knowledge basis of long-run development:

“The source (of modern economic growth) is the secular, rationalistic and materialistic trend of intellectual thought that evolved from the Renaissance and Reformation – that in rejecting the authority of the medieval Church, humanity ultimately took up a new “religion of knowledge”, whose churches are the Schools and universities of the world, whose preachers are teachers and whose creed is belief in science” (quoted in Moore 1994: 160).

At the heart of Easterlin’s analysis is the impact of education on technological change and the institutional structures and incentives – the national system – that facilitate or constrain progress. There are a number of important factors identified by these authors. 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 of these regions.

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

⁶ 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 percent of

“A country with a pre-existing disproportionately 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” (Sandberg 1982: 2).

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 S&T 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 base of human capital as well as the nature of institutions inherited by African states set the tone for future development of their national systems 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. We are not testing for all variables such as R&D in large part because the lack of reliable and systematic data.

2.1 Institutional Origins of Systems of Innovation

Institutions are conceptualized narrowly or broadly⁷ 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 et al. 1997; North 1989).⁸ For these

the growth in US national income per person between 1948 and 1973 is attributable to the educational levels of the labor force.

⁷ 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.

⁸ 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 behaviors that are collectively shared (from

reasons, institutions are necessary for innovation for two reasons. First, is the uncertainty that characterize 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 organization (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 1998:7). Clark (2001) 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.

Three institutionally induced phenomena are said to explain the observed development of the SI in Africa. First is the pre-existing level and pattern of postcolonial education enrollment as a proxy of human capital, a strong determinant of national technological capacity. Secondly, factor endowment, which had been the starting point for wealth creation in other regions, may well be obstacles to development.⁹ Factor endowments have strongly determined the course of investments and subsequently, the path of endogenous technical change. Conceived as the “rules, enforcement, characteristics of rules, and norms of behavior that structure repeated human interaction” (North et al. 1988), we suggest that institutions strongly influence the pattern of endogenous technical development. In an increasingly interdependent global context, institutions may not necessarily be endogenous to regions and societies; they may be, and are often, imported.¹⁰

routines to social conventions to ethical codes); and (c) negative norms and constraints (from moral prescriptions to formal laws).

⁹ The term “resource curse” has been used to describe the lack of growth-generating effect of natural resources in developing countries, see Mikesell (1997) and Aunty (1998).

¹⁰ For instance, the system of organized R&D within laboratories is an invention of the West. See Rosenberg and Birdzell (1986).

While analysts agree on the role of institutions, our knowledge of the origins of institutions in Africa is limited. The literature identifies three distinct institutional forms shaped largely by national resource endowments, which are said to have created three kinds of “societies”. They have been classified as enclave societies, industrializing “Western” societies (including Japan) and colonial societies (Engerman and Sokoloff 2000). In enclave societies, factor endowments pattern the evolution of institutions leading to high-income inequalities and skewed levels of human capital, which tend to favor certain groups. Enclave economies are created by a combination of local political interest and foreign investment in agriculture, and minerals resources with a strong export orientation. These sectors are characterized by “extensive scale economies” requiring exacting technological capabilities in investment and production.¹¹

Enclave driven institutional structures are found in mineral producing countries of Africa such as Zambia, Nigeria, South Africa and Ghana, and the Sugar Islands and Latin America. The resource profile of enclave economies exhibits broadly similar characteristics, consisting of plentiful land to support plantations (tea, coffee, banana, and sugar), or minerals (copper, gold, diamond, iron ore, bauxite). Capital and technology intensiveness are normally higher than average in setting up mineral processing complexes, and so are skill requirements. While specialization grows, the imperative for manufacturing through alternative industrial organizations such as small and medium enterprise is reduced. Institutions supporting enclave production system often get locked in, with a strong exclusionary effect. Alternative modes of industrial organization are foreclosed and the dominant institution exhibits persistence and self-reinforcing attributes.

The second type of society is well known. Rosenberg and Birdzell (1986) trace the evolution of western scientific and technology society that culminated in the pattern of the extant innovation system in much of the OECD countries today. The third type has two broad variants, which we may broadly classify as dynamic latecomers, and non-dynamic latecomer systems of innovation.¹²

The weaknesses of institutions as well as the pattern of evolution of institutions in Africa have been identified as major casual factors in Africa’s development (Aron 1996; Engelman and

¹¹ This necessary conjunction of domestic and international partnerships is referred to as “disproportionate political influence” and “extensive scale economies” by Engerman and Sokoloff (2000).

¹² The first variant is made up of the “Asian Tigers”: South Korea, Singapore, and Taiwan, and following closely, India, Brazil, and China. The second variant consists of the “newly industrialising countries” for example, Thailand, and Malaysia, countries relying on foreign direct investment for the development of their systems of innovation. The third variant is largely found in Africa and South Asia. These societies have strong colonial legacies, low levels of technology, a rudimentary system of R&D and an industrial structure based on low value products requiring non-complex technologies.

Sokoloff 2001; Clark 2000). There is a plethora of literature on the slow and episodic development of Africa's economy but we know of no empirical studies that have attempted to identify the technological roots of the co-called "Africa's growth tragedy" (Easterly and Levine 1997). Yet, African economies had initial technical conditions that might have provided the basis for building endogenous technological capabilities.¹³ However, in the four decades since colonialism, African economies have failed to do so.

Again, while poor institutions have been identified as central to the growth crisis, few studies have identified the nature and type of such institutions. Endogenous institutions have shaped the path of development and have in turn, been deeply molded by development.

Kenwood and Longheed (1992) noted that the immediate changes to aboriginal institutions included the reorganization of laws and institutions according to the interests of metropolitan entrepreneurs and states. British colonial policies systematically pursued policies that created "extractive institutions" as did the Portuguese, and the Dutch.¹⁴ The political structure, which constitutes part of the broad system of innovation, as different from the narrow restriction to organizations (R&D, university, etc.), experienced considerable changes as a result of external influences. Quoting from Manning (1988):

"In Europe the theories of representative democracy won, out over the theorists of absolutism... But in Africa, the European conquerors set up absolutist governments, based on reasoning similar to that of Louis XIV" (ibid: 84).¹⁵

As Acemoglu et al. (2000) observe, institution building was far from the strategy pursued under a colonial policy, which primary objective was to exploit natural resources. The institutions of property rights, law and order that took root in the colonies of Australia, Canada, New Zealand

¹³ For example, around 1500, major centers in Sub-Saharan Africa (SSA) had higher rates of urbanization than North America. According to Bairoch (1988:58):

"Leading examples of urbanization around the time of 1500 are to be found in the Kingdoms of Ghana, Songhai, Benin, Congo, Zimbabwe and the Yoruba States. Around 1500, the city of Benin had a population in the range of 60-70,000 and was a well ordered urban centre with a system of water conduits and a sizable artisanry working at an advanced technical level".

Moreover, Acemoglu et al. (2000) noted:

"There were sizable cities in Black Africa by 1000 BC, if not earlier". In the Middle Ages, Kano City (in modern Nigeria) had a population of 30,000 while Yorubaland (in Nigeria) had a dozen towns with population of over 20,000 and its capital, Ibadan had possibly 70,000 inhabitants" (ibid: 9).

¹⁴ For example, the philosophy of King Leopold of Belgium was patterned after that of the Dutch in Indonesia, which was that "the colonies should be exploited, not by the operation of a market economy, but by state intervention and compulsory cultivation of cash crops to be sold to and distributed by the state at controlled prices" (Acemoglu et al. 2000: 9). A classic illustration of the disruptive policy of colonialization is a statement by a French official:

"The European commandant is not posted to observe nature .. he has a mission... to impose regulations, to limit individual liberties... to collect taxes" (Young 1994: 101).

¹⁵ For further information on this issue, see Manning (1988).

and the U.S. persisted till today; and so did colonial institutional legacy, and its variant, the extractive-induced institutions, in African countries. The nature of these institutions essentially turned the colonies into sources of primary products while discouraging the growth of potentially competitive manufacturing industries.¹⁶

Institutional discontinuity¹⁷ in the colonies therefore patterned the trajectory of industrial evolution in non-trivial ways. Meanwhile institutional continuity, which is the hallmark of the long-term cumulative accumulation of industrial capacity in Britain resulted in sustained export advantage:

“During the nineteenth century the development and utilization of labour resources provided the British cotton industry with its unique sources of competitive advantage..... No other cotton industry in the world could readily acquire Britain’s highly productive labour force; no other industry in the world had gone through the century-long development process that had produced the experienced, specialized and cooperative labour force that Britain possessed” (Mass and Lazonick 1990, cited in Freeman 2002: 197).¹⁸

African states are not *new* states but a continuation of old societies as well as “successors to the colonial regime inheriting its structures, its quotidian routines and practices, and its more hidden normative theories of governance” (Young 1994: 283). Institutions persist even as they evolve, but they take their cue from initial conditions.¹⁹ In an account by Wittfogel (1957), control structures erected by large empires of China, Russia and the Ottoman Empire persisted for over 500 years into the twentieth century. Unlike in other African countries, French settlers in Mauritius supported the institutions of property rights and gave strong backing to business, and later, expanded the country’s export-processing zones. Mauritius success is in large part traceable to these institutions.

¹⁶ Pre-colonial India, for instance, had a thriving textile industry, which was practically destroyed in order for India to be a major source of cotton for British industry. This policy was uniformly applied in most of the colonized areas in Africa such as Kenya, Nigeria and Ghana.

¹⁷ We define institutional discontinuity after (North 1988), as a major change to the routines, rules, and norms of behavior that repeatedly structure human interaction in a society. Major reversals to institutions require equally massive organisational and technical investments to learn and sustain the new institutional routines.

¹⁸ In other words, while British colonial policy might have been responsible for industrial continuity in its conquered territories, there was more to its long-term success. The System of Innovation that evolved in Britain robustly supported production. It is for this very reason that institutional reversal in the colonies could be an explanatory variable since curtailment of export and the promotion of primary products specialization could be said to have effectively killed export capacity. See Acemoglu et al. (2000).

¹⁹ Persistence of institutional forms have been documented by Wittfogel (1957), Engerman and Sokoloff (1997) and North, Summerhill and Weingast (1998). Citing Vishny (1998, 1999), Acemoglu et al. (2000) provide strong evidence that colonial institutions persist.

2.2 The Persistence of Initial Conditions

The notion of hysteresis has been applied to the persistence of initial conditions in Africa (e.g., Aron 1996). It is particularly relevant to the process of industrialization, which takes place over a long time. Insights into how unequal opportunities resulted from different institutional structures come from the divergent evolution of countries in the Americas in the last three centuries (e.g., Engerman and Sokoloff 1997, 2000). For example, Mexico, Barbados, Cuba and other colonies were either richer than, or had similar per capita incomes with the United States in the sixteenth century. Today, in a process that started with the Industrial Revolution, has seen the United States become the richest country in the world while these countries, formerly rich in natural resources, fall behind. Two sets of explanations are offered, the first is the role of technological innovations and the rapid productivity growth of industry in the United States and Canada. Secondly, institutions that promote technical innovations and wider participation through mass literacy and human capital flourished in the US and Canada and much less so in the other countries. Limiting access to education effectively restricts the advance of entrepreneurship and subsequently, industrialization.²⁰

Initial institutional conditions therefore seem to shape the pattern of institutional changes over time and thereafter shape the outcome of the State and individual efforts.

Another important outcome of initial conditions is the creation of *discontinuity* in the nature of institutional power structures, the social processes of learning and knowledge accumulation. Based on historical and econometric evidence, Acemoglu et al. (2000) show that European colonialism not only led to major change in the organization of these societies, but also an “institutional reversal”. European colonialism led to the development of relatively better institutions in previously poor areas, while introducing *extractive institutions*²¹ or maintaining existing bad institutions in previously prosperous places.

The kernel of their thesis is that interaction between institutions and the opportunity for wider participation in the industrialization process through human capital accumulation was important to the long-run development of former European colonies such as the United States and Canada. The initial conditions such as geography and natural resources were instrumented to the earlier higher rates of per capita income in many countries. However, the process of industrialization changed the path of development resulting in the central role of institutions in development.

²⁰ By the mid-1800s, countries in Latin America had a fraction of the literacy rates of those in the United States and Canada, since Latin American countries did not provide universal primary education until the 20th century.

²¹ The term, extractive institutions means the rules and norms that support the concentration of political power in the hands of the small elite that appropriate wealth from natural resources. On the other hand, institutions of private property encourage wider spread of opportunities to all citizens to take advantage of industrialization opportunities.

The research challenge for scholars working within the evolutionary technology framework is to establish a theoretical basis for understanding the direct links between the main elements of the system of innovation and human capital. For instance how is investment in schooling at all levels related to production and innovation performance in firms ? How is formal human capital formation (at the secondary and tertiary levels) correlate with research and development (R&D) capacity at the firm level ? Specifically how do skills contribution at the primary and secondary levels differentially impact innovation performance of firms? For instance McMahon (1998) concluded that investment at the primary and secondary school levels contributed more to growth, while Psacharopoulos (1994) found that primary education had far greater impact on growth in developing than in developed countries. These findings have significant implications for education and industrial policies.

3.0 PATH DEPENDENCE IN 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, using 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: 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 missionaries, in concert with the metropolitan powers, implemented a highly academic, subject-centered 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 British and French colonial elite with their classical education and lack of technical knowledge, viewed academic education as the sole means of social and economic mobility.²²

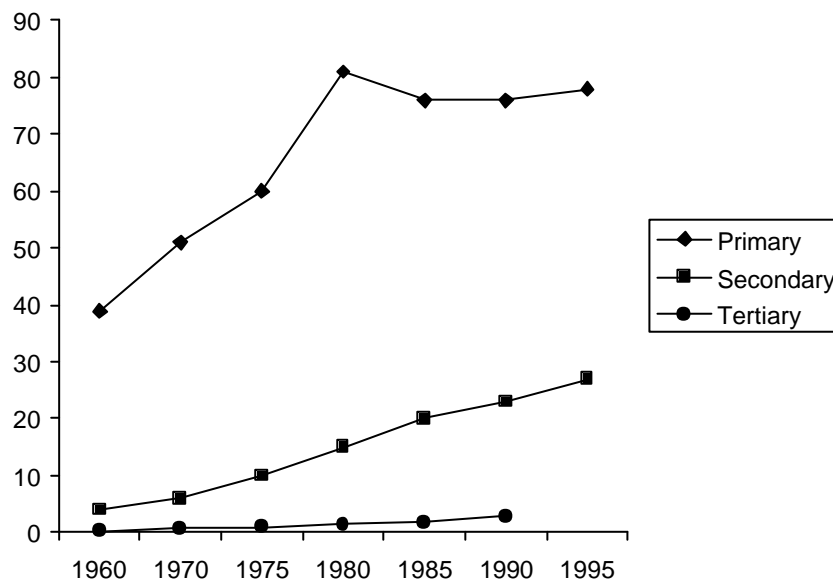
Only a privileged minority benefited from this elite education. In 1960, the gross primary enrolment in all of Sub-Saharan Africa was a mere 36 per cent. This was roughly half the levels found in Latin America (73 percent) and Asia (67 percent) (World Bank 1988). It appears the

²² Western education also disrupted power relations in Africa’s traditional societies. In some cases, traditional leaders were more unwilling than their subjects to send their sons to school. However, over the course of colonialism, the status hierarchy in Africa changed from the traditional ascriptive one based on lineage to the Western achievement one of education. Indeed, the most educated increasingly replaced the chiefs as the elite. Their education and occupational achievement gave them status in the eyes of the local population according to the emerging hierarchy of values. See Blakemore and Cooksey (1982: 42-44).

colonial governments, in an attempt at social control, deliberately limited access to education, particularly secondary education, among the Africans. For example, Lord Lugard postulated that 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: 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 Diagram 1 demonstrates, their performance has been impressive. Within two decades, the gross primary enrolment ratio²³ tripled from 39 percent in 1960 to an astounding 81 percent in 1980. This ratio subsequently declined by 8 percent in 1999. However, gross secondary and tertiary enrolment steadily increased during the period reviewed. Secondary enrolment ratios rose six-fold during the years, 1960 to 1995, while tertiary enrolment ratios increased seven-fold during the years, 1960 to 1990.

Diagram 1: Gross Enrollment Ratios in Africa, 1960 to 1995



Source: World Development Indicators (CD-ROM).

Enrollment levels vary considerably at the three levels, with the largest variation found at the tertiary level and smallest at the primary level. Diagram 2a-c shows the mean, standard deviation and the coefficients of variation of the enrollment ratios at the primary, secondary and tertiary levels. The last variable, the coefficient of variation, is a relative measure of variation

²³ Enrollment 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.

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 to 1980, declined over the next ten years before rising again, while the coefficient of variation declined over the 1960 to 1990, showing a tendency of a rising mean enrollment. For both secondary and tertiary enrollment, standard deviation rose over the whole period, with the coefficient of variation for secondary enrollment first declining sharply in the first ten years, then rising and assuming a steady but slight decline between 1970 to 1990, again showing a steady rise in mean enrolment. Changes at the tertiary level were not as significant, however.

Diagram 2a: Primary Education: Mean, Standard Deviation and Coefficient of Variation

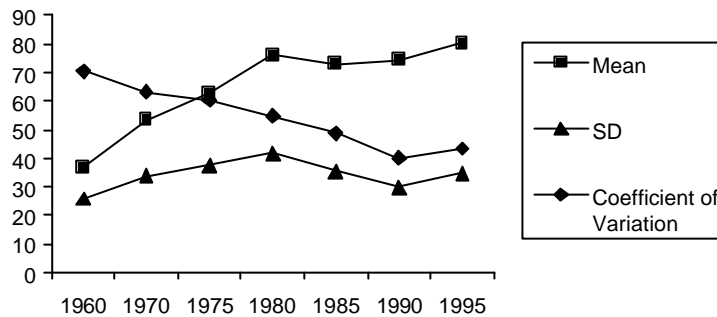


Diagram 2b: Secondary Education: Mean, Standard Deviation and Coefficient of Variation

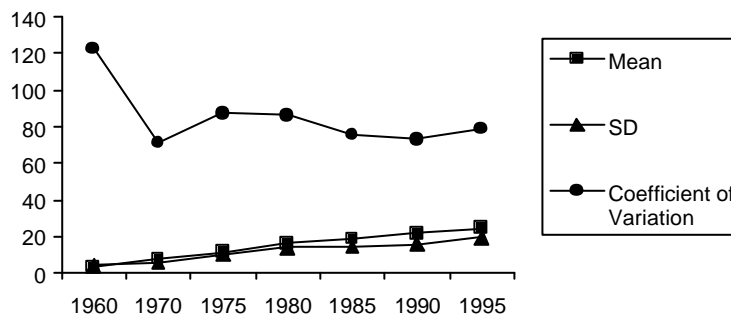
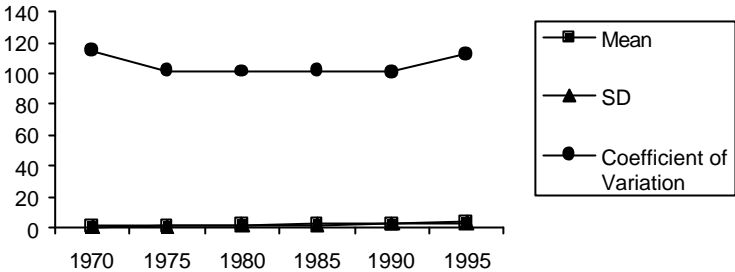


Diagram 2c: Tertiary Education: Mean, Standard Deviation and Coefficient of Variation



Further analysis reveals that the average annual growth rates in school enrollment vary widely among different groups of African countries. The average annual growth 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 percent in 1985 to 1990, to 0.1 percent in 1990 to 1996 (See Diagram 3a). Moreover, it was only these two groups that experienced a decline in the average annual growth rates in secondary education. As Diagram 3b shows, the middle-income oil importers saw average annual growth rates in secondary education decline from 7.2 percent in 1985 to 1990, to 5.2 percent in 1990 to 1996. However, all of these countries experienced sharp falls in the average annual growth rates of tertiary education. For example, in the low-income, semi arid countries such as Kenya and Burkina Faso, average annual growth rates in tertiary education were halved in the post 1990 period, from 6.5 percent in 1985 to 1990 to a mere 3.5 percent in 1990 to 1996 (See Diagram 3c).

Diagram 3a: Average Annual Growth Rates (%) in Primary Education

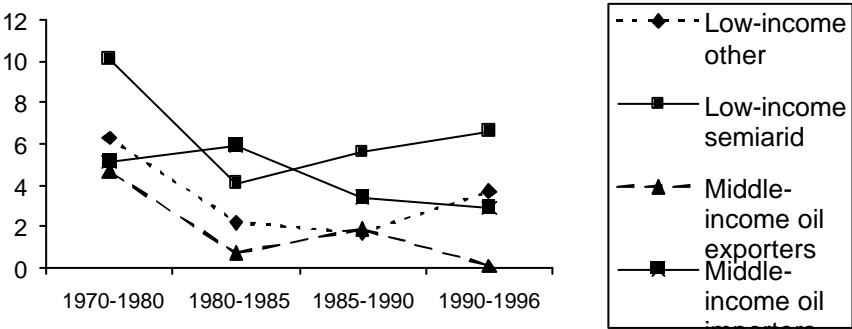


Diagram 3b: Average Annual Growth Rate (%) in Secondary Education

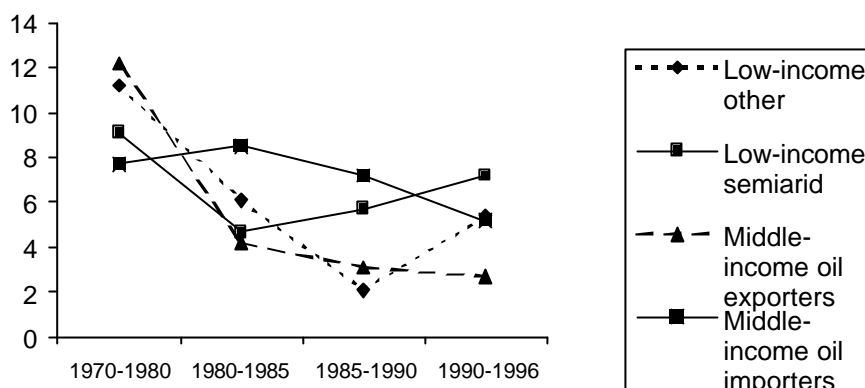
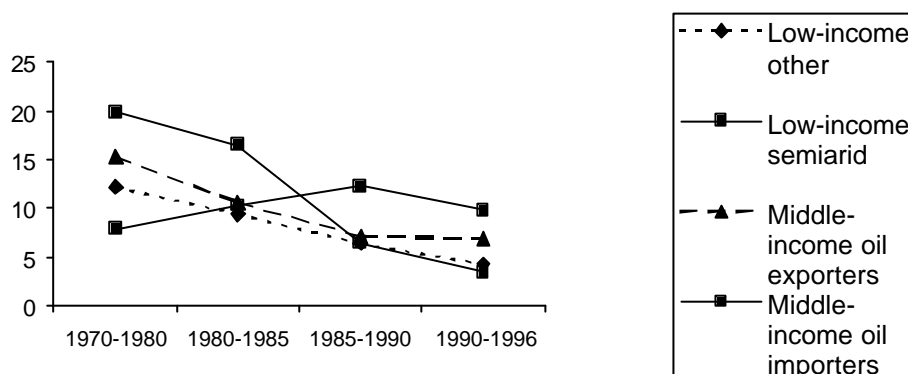


Diagram 3c: Average Annual Growth Rate (%) in Tertiary Education



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

Notes:

Low-income, other include 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, Mali, Mauritania, Niger, Somalia.

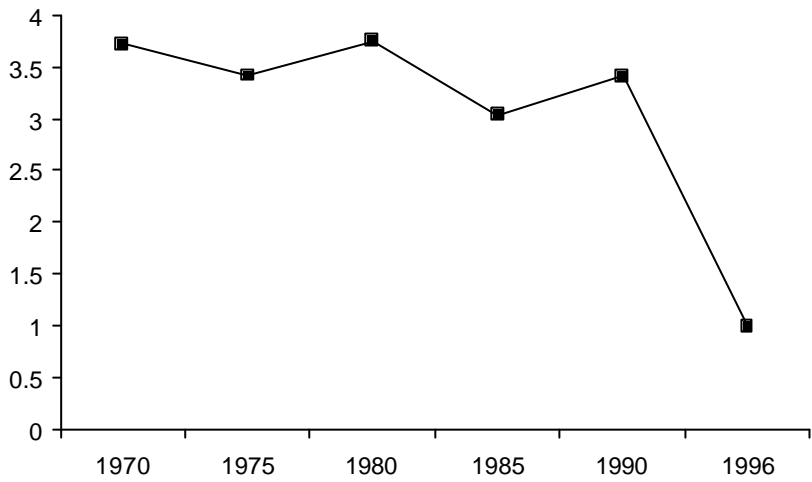
Middle-income oil exporters include: Angola, Cameroon, Congo, Gabon.

Middle-income oil importers include Botswana, Cape Verde, Cote d'Ivoire, Djibouti, Mauritius, Namibia, Senegal, Seychelles, South Africa, Swaziland, Zimbabwe.

This period also saw 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 Diagram 4a). Further analysis of the data on public education expenditure

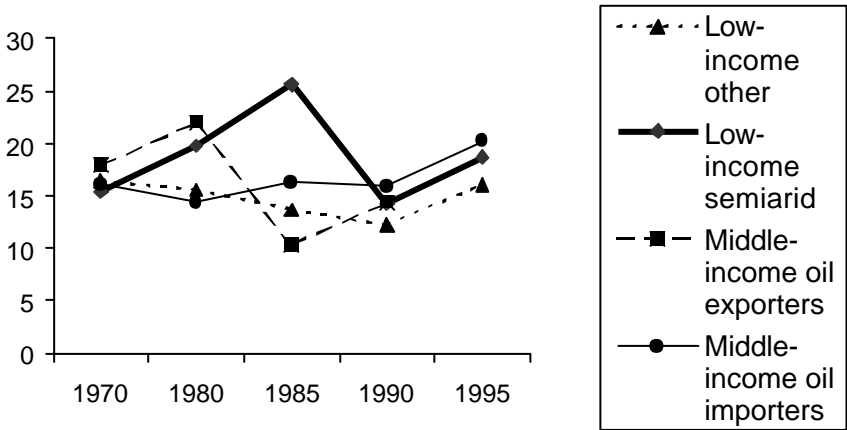
reveals wide variations among African countries. For example, low-income countries such as Benin, Ghana and Kenya, experienced the greatest decline in public expenditure on education: government expenditure on education as a proportion of total expenditure precipitously fell in two decades from 16 percent in 1970 to 12 percent in 1990. It was only in 1995 that government spending on education was restored to 1970 levels (See Diagram 4b). 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 (See Diagram 4b).

Diagram 4a: Public Expenditure on Education as a percentage of GDP, 1970 to 1996



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

Diagram 4b: Public Expenditure on Education (as a percentage of total government expenditure)



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

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. However, public spending on education is subjected to a number of conditions within a given context. Indeed, Colclough et al. (2000) noted that trend data on public expenditure on education alone, is of limited explanatory value. They suggest that other variables need to be considered. These include the proportion of the population of school age, the proportion of GNP spent by households on primary schooling, the proportion of GNP spent by government on primary schooling, and the unit costs per child in school as a proportion of GNP per capita. The last two show the widest variations, and wider still are the overall spending as a proportion of GNP on education. In other words, averages hide substantial inter-country differences and this would lead to differential behavior of Gross Enrolment Ratios (GERs) across African countries. For instance, while some countries spend relatively lower proportion of GNP on education as a result of low teachers' salaries, this does not automatically translate to high GERs because these are ordinarily very poor countries.²⁴

Nonetheless, the severe economic decline experienced in Africa in the 1980s adversely affected government spending on education. The interaction between this 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. The situation was also compounded by declining household income and a possible reduction in the demand for education by some households (World Bank 1988; Colclough and Al-Samarrai 2000).

Interestingly enough, while African governments have recorded substantial progress in educational attainment, 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 policy makers had very little influence over the development of their education systems. He argues that the education system that evolved in post-colonial Africa, was largely influenced by foreign donor agencies and other international institutions operating in the continent. The donor/client dependency relationship that emerged hindered the capacity of Africans to develop educational policies that were socially relevant and financially feasible (King, 1991).²⁵ It seems that the

²⁴ The countries include Sierra Leone, Uganda, Zaire, Malawi, Chad and Tanzania. On the other hand, moderate unit cost and strong commitment to education in countries such as Namibia, Lesotho, Swaziland, Botswana, Zimbabwe, Togo and Mauritius have led to the achievement of universal primary education (UPE).

²⁵ For example at the Addis Ababa conference of 1961, which was one of the first conferences that sought to address the education system in Africa, King notes that the African voice appears to have been "indistinct". This seems to have been the case for subsequent conferences such as the UNESCO/ECLA of 1962, and research reports, such as the Faure Report of 1972, which

combination of the colonial legacy and the lack of significant African involvement in education policy formulation has resulted in an education system, which still remains elitist in ethos and does not cater for the employment and skill needs of the continent.

Indeed, the education system, specifically at tertiary level, produces an inappropriate mix of skills. African institutions of higher education presently enroll 60 percent of students in the arts and humanities, and 40 percent in science and engineering. Enrollment in technical subjects presently lags behind that of other regions. While in 1995, only 0.04 percent of persons as a percentage of the population were enrolled in technical subjects such as engineering and mathematics, the figure for four Asian Tigers was 1.34 percent (Lall, 2001). In a set of technical enrolment index constructed by Harbison_Myers²⁶, 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 percent of the Norwegian figure) with most SSA ranged from 1 to 5. The colonial legacy of a limited emphasis on technical enrollment may have been appropriate in the early independence period when most African countries were faced with a paucity of administrative staff. 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; Delano et al. 2000).

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” (Clarke 2000: 82). Indeed, 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 (See Diagram 5a-b). 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. This has made the financing of education recurrent costs more difficult (World Bank 1988). As Diagram 6a-c shows, the expenditure per student at all levels has declined drastically since 1970. This decline is more severe for

were all influential in shaping educational policies in Africa. See King (1991: 73-90). In addition, it is interesting to note that it was only in the late 1980s that the World Bank began to make a conscious attempt to include African nationals in analytical work for their various education sector studies. Prior to this, the Bank used its own staff or those of UNESCO for such work. See World Bank (2001: 64-65).

secondary and tertiary education, with most low-income countries experiencing the most severe declines. Indeed, in countries such as Chad, Gambia and Niger, government expenditure per secondary student fell from US\$ 536 in 1970 to a mere US\$ 90 in 1995. Expenditure on tertiary education fared no better: spending per student dropped from US\$ 5,054 in 1980 to US\$ 1,185 in 1990.

Diagram 5a: Student/Teacher Ratios in Primary Schools in Africa, 1980-1996

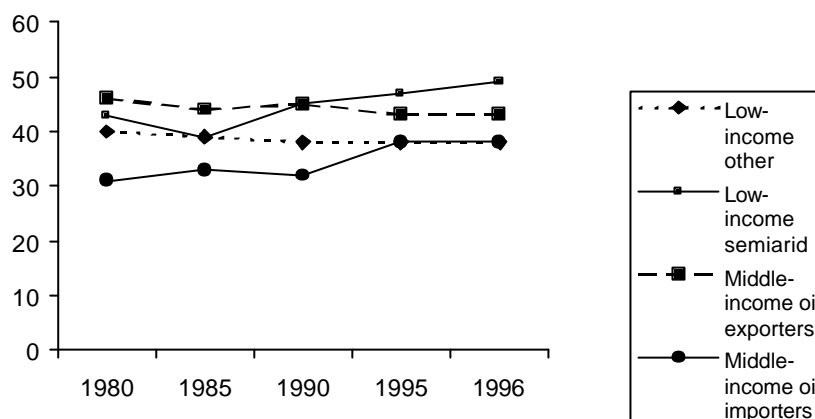
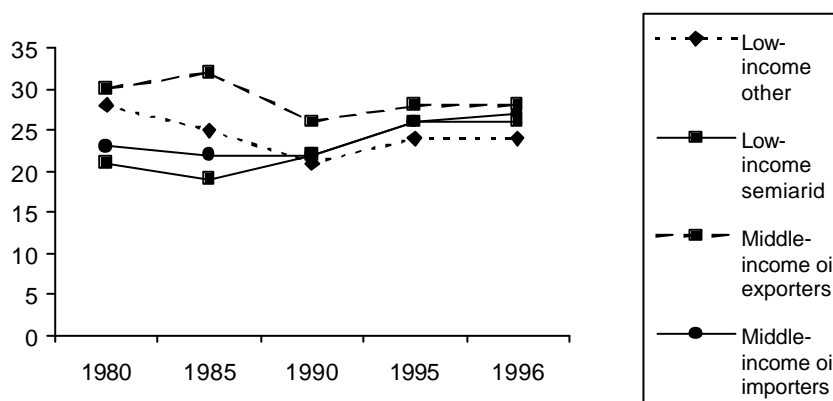


Diagram 5b: Student/Teacher Ratios in Secondary Education in Africa, 1980-1996



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

²⁶ See Lall (2001). Technical enrolment index is tertiary enrolment (times 1000) plus tertiary enrolment in technical subjects (times 5000), both as percentage of population.

Diagram 6a: Government Expenditure on Primary Education per student (constant 1990 US\$)

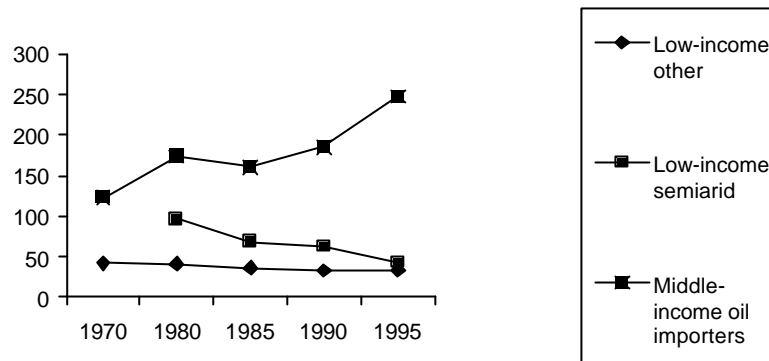


Diagram 6b: Government Expenditure on Secondary Education per student (cost in constant 1990 US\$)

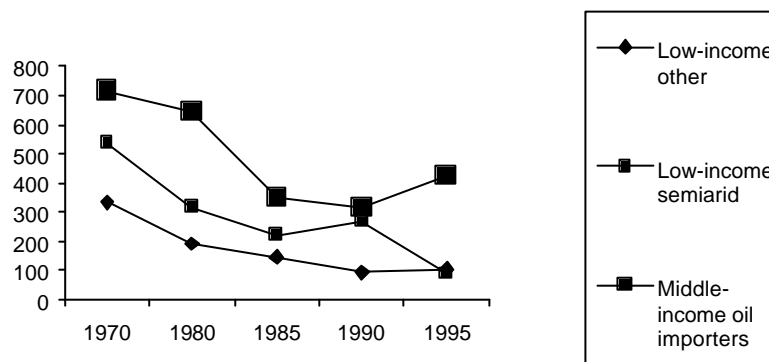
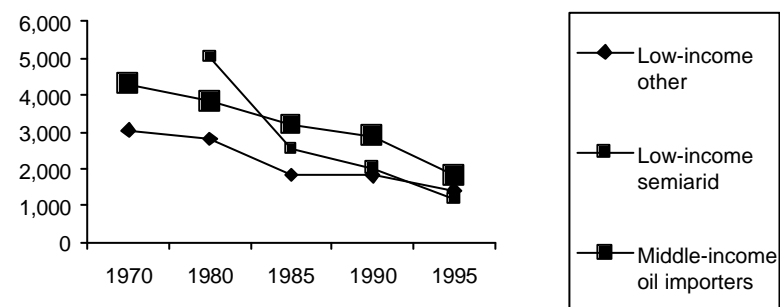


Diagram 6c: Government Expenditure on Tertiary Education per student (constant 1990US\$)



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

Moreover, firm-level training, which complements the education system, is weak in Africa. Enterprises, with the exception of the major multinationals, invest very little in training. Moreover, 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). It is noteworthy that several countries have attempted to by pass the formal education system by establishing non-formal training activities, which are largely funded by Non-Governmental Organizations (NGOs). They involve activities such as literacy, agricultural extension and vocational skills. However, it appears that the activities offered by the informal system are vulnerable to disincentives and are of poor quality (Clark 2000).

The economic conditions in most African countries, together with declining employment prospects in the public sector, which historically has been the largest employer, have resulted in growing levels of unemployment and underemployment of graduates. Indeed, a recent study conducted in Nigeria places the level of unemployment among tertiary graduates as high as 22 percent (Delano et al. 2000). Further, studies point to the under utilization of graduate skills. Indeed, it is a paradox that in a region, which suffers from a shortage of graduates with relevant skills, there seems to be unemployed engineers or technically qualified personnel operating in non-technical operations (Lall 1992; Fabayo 1996). Underemployment of skills within firms persists as a result of slow growth of capita income, a result of low and stagnating growth of key productive sectors.

4.0 AN EMPIRICAL ANALYSIS OF SYSTEMS OF INNOVATION AND HUMAN CAPITAL

In this section, we carry out statistical tests of human capital and system of innovation using the variables identified in the study as being particularly strong predictors of national economic development. We have related the ways in which institutions act as carriers of history, the persistence of initial political, institutional factors as they influence the process of development. Figure 1 provides a simple diagrammatic representation for the test. While we employ enrollment rates, we are aware of their limitations in explaining growth of per capita income.²⁷ 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.

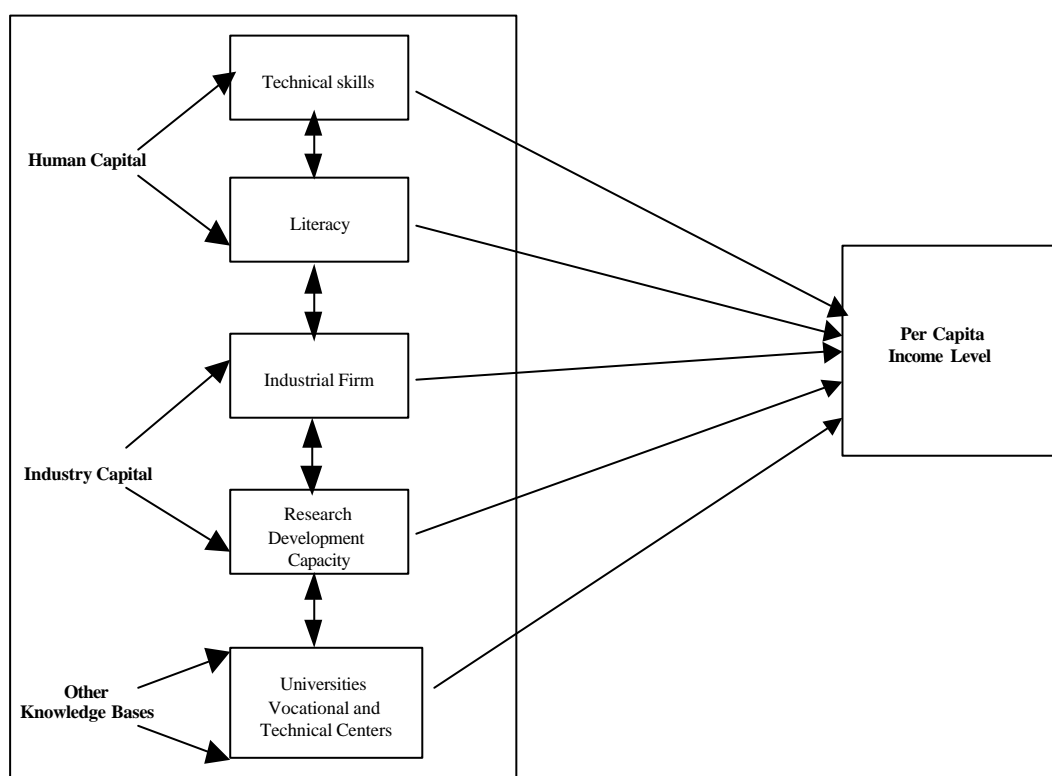


Figure 1: Human Capital Variables in the System of Innovation

²⁷ 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 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.

4.1 Statistical Analysis of the Variables

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

$$\text{LOG of PER CAPITA INCOME (LOGPCAP)} = f(\text{PRI70+SEC70+TERT70+AGL90+ILA90+TECHSUB+RD96}).$$

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 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 medium income countries. These differences are reflected in the graphs of per capita income and the various variables, figures 2 to 6 done within a univariate framework. High levels of percentage of labour force working in agriculture tend to be associated with low per capita income, while MVA values show an almost no association, implying little contribution to wealth contribution except for a few countries notably South Africa and Mauritius. Confirming our hypothesis, enrolment in primary education thirty years earlier is correlated with per capita income, figure 2, so is technical subjects enrolment as a percentage of population. Further tests are carried out employing Ordinary Least Squares (OLS).

We assume a log function of per capita income to eliminate non-linearity as a result of the wide variation in per capita income. All variables were included in the first model, and two additional models were tested. The correlation matrix is presented in Table 3 and Table 4 is a pooled regression of the education enrollments while Table 5 includes the other variables. There is high correlation among the variables, as shown in Tables 3. From the Table PRI70, ILA90 display significant positive correlation with the dependent variable at 1 percent and 5 percent levels of significance. SEC70, , and TERT display negative but non-significant correlation while AGL90 shows negative and significant correlation.

Table 1: Descriptive Statistics

| | Mean | Standard Deviation |
|----------------|-----------|--------------------|
| <i>LOGPCAP</i> | 6.3970 | .9851 |
| PRI70 | 57.2818 | 32.0868 |
| SEC70 | 7.5182 | 4.6089 |
| TERT70 | .4364 | .2976 |
| AGL90 | 65.4545 | 23.0927 |
| ILA90 | 11.0000 | 8.6487 |
| TECHSUB | 5.373E-02 | 4.675E-02 |
| RD96 | .2622 | .4406 |

PRI70: Primary Education gross enrollment ratio in 1970.

SEC70: Secondary Education gross enrollment ratio in 1970.

TERT70: Tertiary Education gross enrollment ratio in 1970.

AGL90: Percentage of labor force working in agriculture.

ILA90: Percentage of labor force working in industry.

TECHSUB: Technical subjects enrolments as a percentage of population in 1996.

RD96: Total Research and Development (R&D) personnel per million in 1996.

Table 2: Mean Values of Variables in the "Low" and "Medium" Income SSA Countries

| Variable | Mean (all) | Mean (Low) | Mean (Medium) | T-value | DF | F-statistic | Significance Level |
|---------------|----------------|----------------|-----------------|---------|----|-------------|--------------------|
| Percapita2000 | 688.42(972.15) | 218.95(64.54) | 1157.90(1213.8) | 3.3672 | 36 | 11.3383 | .0018 |
| AGL90 | 70.432(19.292) | 80.32(11.82) | 60.00(20.40) | 3.7325 | 35 | 13.9318 | 0.0007 |
| ILA90 | 9.108(8.306) | 5.26(3.33) | 13.17(10.02) | 3.2559 | 35 | 10.6015 | 0.0025 |
| PRI70 | 53.464(33.214) | 44.64(24.49) | 62.29(38.81) | 1.6316 | 34 | 2.6622 | 0.1120 |
| SEC70 | 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 |
| TERT70 | 0.7541(0.8557) | 0.5797(0.4179) | 0.9290(1.132) | 1.0821 | 26 | 1.1709 | 0.2892 |

Standard Deviation in bracket

Figure 2: Primary Enrolment and wealth

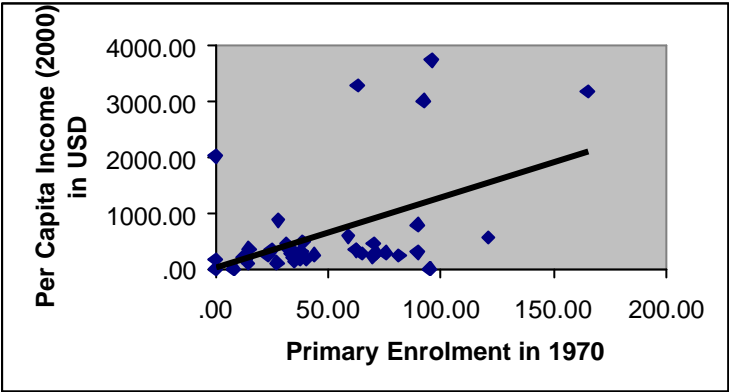


Figure 3: Secondary Enrolment and Wealth

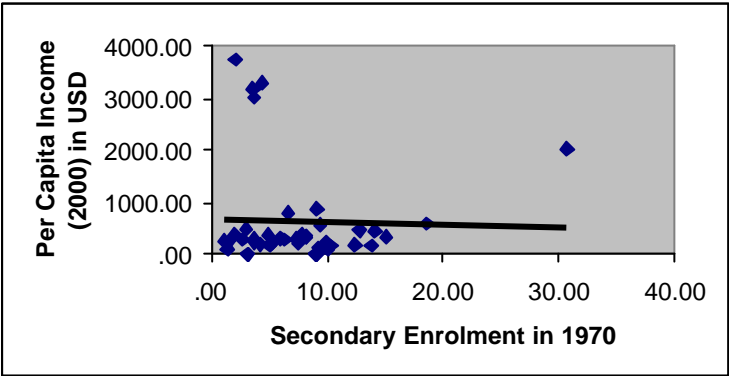


Figure 4: Tertiary Enrolment and Wealth

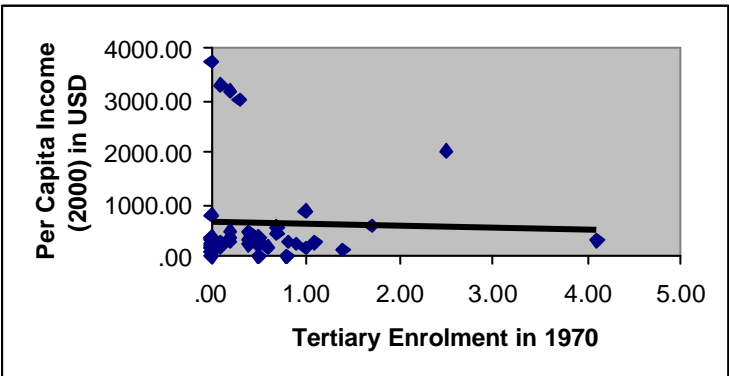


Figure 5: Percent labour Force in Agriculture

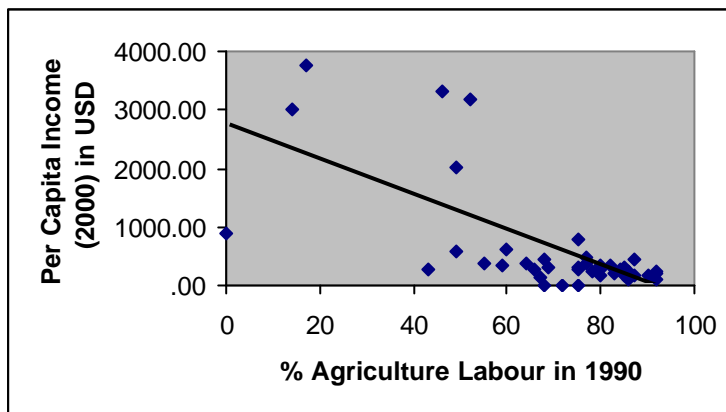
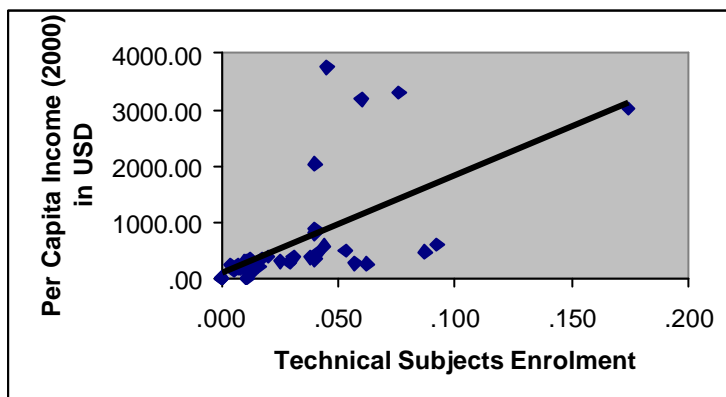


Figure 6: Technical Subjects Enrolment and Wealth



4.2 Correlation of the three Levels of Enrollment

Correlation coefficients indicate tendencies rather than causation. In this exercise we examine the relationship of the three levels of enrollments. Additional enrollment variables eliminated by the model were used in the correlation. As Table 3 demonstrates, correlation coefficients are as high as 0.873 between SEC85 and TER90, and also between PRI60 and SEC75, SEC85, and also between the like variables. One way of interpreting this might be that the higher the primary enrollment, the greater the demand for and provision of secondary education and as the latter increases, the pressure on tertiary enrollment increases. The reverse tendency may be said to hold, that is, the lower the primary enrollment rates, the less the tendency for secondary education provision and less so the pressure for university education. This findings implies that: *a low initial schools enrollment, 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 is likely to have widespread impact throughout the system of innovation, thereby leading to the non-dynamic SI 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 enrollment data since the data is both time series and cross sectional. Tables 4 and 5 show the separate regression outputs.

The re-estimation resulted in models 2 to 3. Table 4 shows the pooled regression output with the three level enrollments as independent variables and per capita income, our indicator for economic development, as the dependent variable. Parameters of the models assume that enrolments 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 show, these variables are highly correlated and cannot be used in a single model as explanatory variables.

This finding is consistent with (Mironov 1990; Sandberg 1982) that economic development is significantly correlated with society's human capital in a time lag of 20 to 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 enrollment is also significant. They all appear in the pooled regression models.

Table 5 shows the OLS regression output without the enrollment 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 labor force in industrial but non-significance with agriculture labor 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.

Table 3: Correlation of the Three Levels of Enrollment

| | Variables | PRI60 | PRI70 | PRI75 | PRI85 | SEC60 | SEC70 | SEC85 | TER75 | TER85 | TER95 |
|----------------|-----------|--------------|--------------|--------------|--------------|-------------|-------------|--------------|--------------|--------------|-------------|
| Spearman's rho | PRI60 | 1.000 36 | | | | | | | | | |
| | PRI70 | .872** 35 | 1.000 38 | | | | | | | | |
| | PRI75 | .835** 35 | .916** 37 | 1.000 38 | | | | | | | |
| | PRI85 | .734** 32 | .859** 35 | .867** 34 | 1.000 35 | | | | | | |
| | SEC60 | .117 36 | .149 38 | .106 38 | .150 35 | 1.000 41 | | | | | |
| | SEC70 | -.020 36 | -.223 38 | -.163 38 | -.210 35 | .371* 41 | 1.000 41 | | | | |
| | SEC85 | .620** 32 | .670** 35 | .709** 34 | .745** 34 | .123 35 | -.116 35 | 1.000 35 | | | |
| | TER75 | .595** 31 | .551** 33 | .499** 33 | .420* 32 | .242 35 | .216 35 | .715** 32 | 1.000 35 | | |
| | TER85 | .422* 29 | .424* 31 | .387* 30 | .421* 30 | .112 32 | .169 32 | .736** 30 | .872** 31 | 1.000 32 | |
| | TER95 | .578** 23 | .593** 25 | .449* 25 | .515* 23 | .039 27 | -.184 27 | .759** 23 | .745** 24 | .798** 23 | 1.000 27 |

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

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

Table 4 :Result of Pooled Regression of the Three Levels of Enrollment

| Source | SS | Df | MS | | | |
|----------------------|-------------|-----------|------------|---|-------------------------|----------|
| I.1 Tertiary | | | | | | |
| Model | 8.79785787 | 1 | 8.79785787 | Number of obs = 61 F (1,59) = 10.81 Prob>F = 0.0017 R-squared = 0.1548 Adj R-squared = 0.1405 Root MSE = .90227 | | |
| Residual | 48.0313897 | 59 | .81409135 | | | |
| Total | 56.8292475 | 60 | .947154126 | | | |
| Logcap | Coefficient | Std. Err. | t | P>/t/ | 95% confidence Interval | |
| Tertiary | .1980261 | .060238 | 3.287 | 0.002 | 0.774901 | 0.318562 |
| constant | 5.512774 | .1746936 | 31.557 | 0.000 | 5.163212 | 5.862335 |
| I.2 Primary | | | | | | |
| Model | 18.3359971 | 1 | 18.3359971 | Number of obs = 72 F (1,70) = 31.60 Prob>F = 0.0000 R-squared = 0.3110 Adj R-Squared = 0.3012 Root MSE = .76172 | | |
| Residual | 40.6152439 | 70 | .58021777 | | | |
| Total | 58.951241 | 71 | .830299169 | | | |
| Logcap | Coefficient | Std. Err. | t | P>/t/ | 95% Confidence interval | |
| Primary | .0045066 | .0008017 | 5.622 | 0.000 | .0029077 | .0061054 |
| constant | 5.109552 | .1745699 | 29.269 | 0.000 | 4.761383 | 5.457721 |
| I.3 Secondary | | | | | | |
| Model | 12.8812523 | 1 | 12.8812523 | Number of obs = 72 F (1,70) = 19.57 Prob>F = 0.0000 R-squared = 0.2185 Adj R-squared = 0.2073 Root SME = .81126 | | |
| residual | 46.0699887 | 70 | .658142696 | | | |
| Total | 58.951241 | 71 | .830299169 | | | |
| Logcap | Coefficient | Std. Err. | t | P>/t/ | 95% Confidence Interval | |
| Secondary | .15553 | .0035156 | 4.424 | 0.000 | .0085414 | 0.225645 |
| constant | 5.492399 | .1410547 | 38.938 | 0.000 | 5.211075 | 5.773724 |

I.1 = tertiary

I.2 = primary

I.3 = secondary

Table 5: Regression of Per Capita Income and Human Capital

| | Equations | | |
|-------------------|------------------------|-----------------------|-----------------------|
| | 1 | 2 | 3 |
| Constant | 6.048* (6.275) | 5.069* (19.115) | 5.187* (22.504) |
| Pri70 | 9.389E-03* (3.009) | 1.060E-02* (3.637) | 9.694E-02* (3.637) |
| Sec70 | 4.020E-02 (1.224) | 2.834E-02 (.914) | |
| Tert70 | -.569 (-1.692) | -.542 (-1.609) | -.338 (-1.346) |
| AGL90 | -1.164E-02 (-1.056) | | |
| TECHNSUB | 5.342 (1.133) | 8.970** (2.769) | 10.110* (3.399) |
| PCUSE | .103** (2.633) | .114* (2.996) | .107* (.000) |
| R square | .864 | .853 | .845 |
| Adjusted R Square | .806 | .804 | .806 |

T values are shown, while levels of significance are indicated as: *1%; ** 5%; ***10% levels

Table 6: Regression of Per Income and Human Capital

| | Models | |
|----------|------------------------|------------------------|
| | 1 | 2 |
| Constant | 4.817* (25.642) | 4.838* (27.134) |
| ILA90 | 4.528E-02** (2.122) | 4.047E-02** (2.185) |
| TECHSUB | 10.757*** (1.980) | 11.509** (2.261) |
| SEC95 | 1.687E-02 (1.064) | 2.045E-02** (1.926) |
| TER85 | 4.580E-02 (.870) | |

*Significant at 1%; **sig. at 5%; ***sig

at 10%

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 hypothesize that poor human capital formation could explain the lack of dynamism of the region's systems of innovation (SI), institutions that underlie the adoption, diffusion and adaptation of innovation. Secondly, institutions possess path-dependent characteristics influencing the growth rate of per capita incomes, our proxy for development. Third, we conjecture that these path-dependent variables, codified loosely into the concept of systems of innovation, have institutional origins that have persistently impacted the evolution of African development. These variables include among others, human capital, R&D system and industrial capacity. Fourth, 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 enrollment 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 enrollment 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, the school enrollment at the three levels over the last 35 years (1960 to 2000), as well technical enrolment, labour force in agriculture and industry, and R&D as percent 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 enrollment and as such, its impact on the national system thenceforth. We also confirm the correlation of enrollment with per capita income (1960, 1970 and 1995 respectively) with a periodicity of some 25 to 35 years, consistent with the findings in the literature with regions starting from low levels of technological development. This means that investment in education impact 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.

However, considerable work remains to be done 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 the system of innovation 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 at a wider socio-economic level. For instance, how do we intensify interactions of economic actors and make them more effective? Third, 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 SSA. 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 fulfill 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 policy makers need take a long-term view. Getting the institutions right is certainly more crucial than getting the prices right.*

Table A1: Data Sources of Descriptive Statistics

| Variables | Source of Data |
|------------------|---|
| <u>LOGPCAP</u> | UNDP, <i>Human Development Report</i> , various issues |
| PRI60 | UNESCO, <i>Statistical Yearbook</i> , various issues |
| PRI70 | Ditto |
| PRI75 | Ditto |
| SEC60 | Ditto |
| SEC70 | Ditto |
| TERT70 | Ditto |
| TELCAP96 | UNDP, <i>Human Development Report</i> , various issues and World Bank 2001, <i>African Development Indicators</i> |
| ELCETCAP | Ditto |
| ROADS96 | Ditto |
| MVA99 | Ditto |
| AGL90 | Ditto |
| ILA90 | Ditto |
| TECHSUB | UNESCO, <i>Statistical Yearbook 1999</i> , estimates |
| RD96 | Gale Research Group (1998); UNESCO, <i>Statistical Yearbook 1999</i> ; UNESCO, <i>World Science Report 1998</i> . |

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