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SYSTEMS OF INNOVATION AND UNDERDEVELOPMENT: AN INSTITUTIONAL PERSPECTIVE

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Abstract

Based on recent field survey data collected in three African countries, this study examines inter-firm and inter-organizational collaboration in African industry. Three sets of interactions were analyzed namely: firm-firm linkages, including user-supplier and subcontracting relationships; firm-university linkages; and firm-industrial association linkages. Employing univariate and multivariate analysis, we examined the channels and institutions for collaboration and tested three hypotheses. Collaboration with universities was expected to promote greater firm-level technical innovation resulting in greater output and product quality but little incidence of such collaboration was recorded. However, collaboration among suppliers of inputs, subcontractors and firms was found to have contributed to significantly better performance.

Keywords: Network, collaboration, Africa, industry, innovation

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1. INTRODUCTION[1]

The relationship between institutions and development has become a subject of considerable academic interest. Cross-sectional studies have established that “institutions matter” and that they have a direct impact on economic growth (Rodrik et al., 2002). In addition, a plethora of institutional case studies has emerged, although many of these deal with legal and political institutions for conflict resolution and the reduction of transaction costs in production in Africa and other developing regions.[2] This paper addresses the impact of technological and organizational innovation on the process of development. While there has been a preponderance of theoretical and empirical scholarship on institutions promoting technical innovation in advanced industrialized countries, corresponding studies in developing countries are notable by their absence (Edquist, 1997; Mokyr, 2002; Rosenberg, 1976; Sampat and Nelson, 2002). Studies on institutions often employ evolutionary theory together with an analysis of systems of innovation (SIs) (Lundvall, 1988; 1992; Nelson, 1993), a conceptual framework that places innovation, learning and interaction at the centre of its analysis. This paper takes these concepts as its point of departure.

I follow the definition of an institution proposed by North (1996) as “The rules of the game of a society or more formally the humanly devised constraints that structure human interaction. They consist of formal rules (statute law, common law and regulations); and informal constraints (social norms, habits, routines and practices) and the enforcement characteristics of both.”

The national SI is defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987, p.1). Lundvall's concept of the national SI emphasizes the diffusion of "economically useful knowledge" (Lundvall, 1992, p.12). There is a wide variety of definitions (Metcalfe, 1994; Nelson and Rosenberg, 1993), but there is also a fairly good convergence of the key ideas at the heart of the SI framework. One of these ideas is the persistent but uneven distribution of the capabilities of firms to innovate across sectors, countries and regions. This skewed effect of innovation performance is a function of specific national or sectoral factors and as such the competitive advantage of sectors and nations depends greatly on how advanced the SI is, and how well it has generated coherence and interactions.

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[1] I am grateful to Andy Hall and two anonymous reviewers for reading an earlier version of this paper and making useful suggestions for revision. The usual disclaimer applies, however.

[2] See Aron (2000) and Brautigham (1997).

This paper advances three propositions on the relationship between institutions and innovation. First, it argues that orthodox science and technology policy, which focuses exclusively on the supply and use of scientific and technical human resources, has failed to stimulate the desired endogenous technological dynamism, largely because the policy-making process assumes away the role of institutions. Second, the capacity building efforts administered through international technology transfer processes have been equally flawed, because they focus largely on the purchase of equipment and the imitation of external organizational forms for R&D, with little consideration for the underlying institutional forms and practices in which they are embedded. Third, because the path of development is highly dependent on past decisions and actions, institutions of science and technology (S&T) in Africa are trapped in the sub-optimal system configurations that have taken root over the past four decades. To the extent that institutions determine the efficiency of knowledge creation and exchange, the artificial separation of technology from the institutional structures in which it is created has been a major conceptual and policy mistake.

Innovation has long been recognized as a social process shaped by the institutional structures in which it is embedded. Although the increases in workers' productivity in industrial countries have been driven largely by technological advance, investment in physical capital and the growth of human capital, these factors are profoundly shaped by institutions. The institutions that support technological advance are thus extremely important for long-term economic growth, since technology mediates the introduction of new products and processes into the economy. In an industrially dynamic context, changes in machinery and equipment will be accompanied by new institutions: "The institutionalization of…new social technologies may require new law, new organizational forms, new sets of expectations" (Nelson and Sampat, 2001, p.49). The corollary is that, in a situation of economic backwardness, changes to institutions are rare, just as technological innovation itself may be equally rare, even non-existent.[3] Institutional changes become even more crucial at a time of humanly engineered or induced change in economic conditions. Indeed, programmes such as the Structural Adjustment Programme (SAP) of the International Monetary Fund (IMF) are inevitably accompanied by profound structural shifts, not just in economies but also in the laws governing social behaviour and the social norms and habits of people.

While the effects of institutional innovation may be difficult to measure, aggregate structural changes in the economy, as revealed by indicators such as the composition of gross domestic product (GDP) or the distribution of trade and labour, are underpinned by and reflect the long-

[3] Nelson and Sampat (2001) cite North's (1990) re-articulation of the "institutional obstructionist" notion of economic backwardness as being responsible for the failure of poorly performing economies to adopt productive technologies.

run outcome of institutional and technological change. However, outcomes are often difficult to trace from their causes and the direction of causality is typically difficult to establish. For instance, do countries possess efficient scientific institutions because their individual scientists are of high quality, or vice versa? In other words, do scientists exhibit good research habits and practices because they are placed in efficient institutions or is the emergence of these institutions the result of inherently good practices in science?

In studies of technological change, institutions may be conceptualized narrowly or broadly,[4] but in both cases they take on a wide range of functions. These include managing uncertainty, providing information, managing conflicts and promoting trust among groups (Edquist, 1997; North, 1989).[5] Institutions in these areas are necessary for innovation for two reasons. First, the innovation process is characterized by considerable uncertainty. Institutions provide stability by, for example, regulating the actions of individuals and enforcing contractual obligations. Second, the creation, validation and distribution of learning and knowledge, which are prerequisites of economic change, are mediated by institutions. These institutions operate in such areas as R&D, finance and investment, intellectual property rights, patent laws and so on.

This paper examines institutions and their role in supporting technological advance, and asks how these institutions shape the SI. It explores the *functions* that need to be met in order to generate technical dynamism in the SIs of developing countries. It introduces the idea of a *System of Learning Innovation in Development (SLID).* This idea emphasizes the competence-building functions of individual skills development and organizational learning. I will use the example of Africa in much of the discussion, but the concepts will apply to many if not most developing countries in other regions. The paper is structured as follows**:** the next section addresses the role of institutions in development, while Section 3 discusses the institutional roots of innovation systems and identifies the differences between a “Pure” or Advanced

[4] In a narrow sense, institutions are seen merely as organizations such as universities and technological service organizations, whereas more broadly the concept includes the political and social context and the rules regulating innovation.

[5] Coriat and Dosi (1998) refer to the broad meaning of institutions as having three components, which are: (i) formal organizations (ranging from firms to technical societies, trade unions, universities and state agencies); (ii) patterns of behaviour that are collectively shared (from routines to social conventions to ethical codes); and (iii) negative norms and constraints (from moral prescriptions to formal laws).

System of Innovation (ASI), and two kinds of SLID. Section 4 highlights the various functions and domains found in SIs, illustrated through the issue of infrastructure. The final section provides a summary and suggests directions for future research.

2. INSTITUTIONS, DEVELOPMENT AND UNDERDEVELOPMENT

As Mokyr (2002) notes, different institutional structures produce different outcomes, while certain distinct factors define the trajectories of national and local institutions.[6] According to North (1990, p.6), institutions are humanly devised constraints that structure political, economic and social interactions. They consist of informal institutions—such as sanctions, taboos, customs and codes of conduct—and formal institutions, such as laws, regulations, property rights and constitutions. In other words, institutions assume regulatory functions as well as mediating ethical and behavioural norms. These "rules of the game" shape the incentives of the actors (individuals and organizations) involved in development.

In the context of development, institutions are viewed largely in terms of their role in enhancing or retarding economic growth (Rodrik, 1998; 1999; Aron, 2000). The role of the State, so often weak in formulating and enforcing the rules, has received plenty of theoretical treatment, forming the basis for economic reforms proposed in the main by the IMF and the World Bank during the 1980s (Stein, 1994).[7] What is missing in these analyses is a systemic focus on the micro- and meta-level organizations and institutions that drive production and innovation.[8] The solutions proposed for generating endogenous technical dynamism are almost always purely technical, with scant consideration for the institutions and the social environment that also condition technological development.[9] Consequently, and more seriously, the underlying connections between the political, economic and technological factors that affect development were seldom reflected in the reform agenda.

From the point of view of path-dependent development, the role of institutions in African societies is considerable.[10] At the macro level, three broad institutional factors have been

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[6] Mainstream economics explains the need for institutions in terms of market imperfections. At the micro-economic level, the twin concepts of property rights and transaction costs account for the role of firms (Coase, 1937; North, 1990). North subsequently broadened the scope of his concept of institutions, while other authors, notably Nelson and Winter (1982), rejected the notion of rational choice in favour of evolutionary theory. Several authors in Edquist (1997) elaborated the meaning of institutions and organizations from an SI perspective.

[7] See Akyüz and Gore (2001) for a theoretical and empirical treatment of the African situation.

[8] The focus of institutional analysis has been largely on macro-economic, fiscal and monetary crises that prompted recommendations on expenditure cuts and reductions in the size of the civil service.

[9] See Vitta (1990)

[10] The examples of institutional explanations of underdevelopment cited in this paper derive from studies carried out in the framework of the New Institutional Economics (NIE). There are four broad sets of explanations, which can be encapsulated as: (i) "Colonial heritage": this applies to countries that have inherited weak institutions from their former colonial masters; (ii)

identified as accounting for the observed underdevelopment of SIs in Africa. First is educational structures, with the level and pattern of postcolonial education enrolment—a proxy of human capital—emerging as a strong determinant of national technological capacity. Second is the financial and other institutions associated with factor endowment, which has been the starting point for wealth creation in other regions but may well be an obstacle to development in Africa.[11] Factor endowments have strongly determined the course of investments and subsequently the path of endogenous technical change. Third is the provenance of institutional models: in an increasingly interdependent global context, institutions may not necessarily be endogenous to regions and societies; they may be, and often are, imported.[12] In any event, much of the economic prosperity of latecomer countries is ascribed to technologies and institutional forms borrowed from the West (Amsden, 1989). For this reason the institutional orientation of latecomers is different from that of the West: institutions in these countries are largely dedicated to the search for, and adoption of, technologies transferred from advanced industrial countries.

While some analysts at least recognize and agree on the role of institutions, our knowledge of the origins of institutions in Africa is limited. The literature identifies three distinct institutional forms, which are said to have created three kinds of "society": enclave societies, industrializing "Western" societies (including Japan) and colonial societies (Engerman, 2000). In enclave societies, the evolution of institutions is chiefly influenced by factor endowments, often leading to high income inequalities and skewed levels of human capital, which tend to favour certain ethnic or elite groups. Enclave economies are strongly associated with a combination of local political interest and foreign investment in agriculture, and mineral resources with a strong export orientation. These sectors are characterized by "extensive scale economies", requiring exacting technological capabilities in investment and production.[13]

Enclave-driven institutional structures are found in the mineral-producing countries of Africa, such as Ghana, Nigeria, South Africa and Zambia, and in many developing countries producing only one or a few agricultural commodities for export. The resource profile of enclave economies exhibits broadly similar characteristics, consisting of plentiful land to support plantations (tea, coffee, banana and sugar), or from which minerals (copper, gold, diamond, iron

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"Colonial heritage plus": countries whose natural resources were captured using exploitative institutions established during the colonial era; (iii) "Political conflict": countries with little political control over their territory or borders that allowed their elites to exploit them; and finally (iv) "Beliefs and norms": countries with beliefs and norms that are hostile to the processes of industrialization and innovation (see Shirley, 2004).

[11] The term "resource curse" has been used to describe the lack of growth associated with natural resources in developing countries (see Aunty, 1993 and Mikesell, 1997).

[12] For instance, the system of organized R&D within laboratories is an invention of the West (see Rosenberg and Birdzell, 1986).

[13] This necessary conjunction of domestic and international partnerships is referred to as "disproportionate political influence" by Engerman and Sokoloff (1997).

ore, bauxite) can be extracted. Capital and technology intensiveness are normally high in mineral processing complexes, as also are skill requirements. As specialization grows, the imperative to stimulate manufacturing through alternative industrial organizations such as small and medium-sized enterprises (SMEs) is reduced. The institutions designed to support an enclave production system often get locked into that system, with the result that they start to have strong exclusionary effects. For example, single-commodity research institutes or boards may become dominated by a few families who have both farmed and researched the commodity in question, who then install their relatives or associates in key positions—to such an extent that bringing "new blood" into the institution becomes extremely difficult**.** Alternative modes of industrial organization have by this time been foreclosed and the dominant institution starts to exhibit self-reinforcing attributes.

The second type of society is well known. Rosenberg and Birdzell (1986) trace the evolution of Western science- and technology-driven societies—an evolution that has culminated in the pattern of SI seen in many of the advanced industrial economies today. This evolutionary path is being pursued to a greater or lesser extent by many developing countries. Some Asian countries, notably Japan, have advanced very far down the path.

Following the earlier path-breaking work of Edquist (1997), Freeman (1987), Lundvall (1992) and Nelson (1987), attempts have recently been made to apply the SI concept to the situations of developing countries (Arocena and Sutz, 1999; Cimoli, 2000; Gu, 1999; Intarakumnerd et al., 2002). Lundvall et al. (2002) and Muche et al. (2003) suggested that such an application should consider not only the considerable differences between the advanced industrial countries and the developing countries as a bloc, but also, within this bloc, the marked differences between individual countries. The SIs in underdeveloped and industrialized countries differ in several respects and markedly so in three attributes. First, advanced economies tend to be highly science- and technology-intensive, with relatively high levels of domestic investment in R&D. Second, industry and the service sector are becoming more and more knowledge-based and innovation-driven in these countries. Third, and complementary to the first two, these economies have high levels of skilled manpower, whose importance is accentuated by intensifying global competition.

To place the foregoing historical and resource-based factors shaping institutional systems in context, I draw specifically on a modified version of Carlsson's (1997) treatment of technological systems, defined as networks of agents interacting in particular fields to generate, diffuse and utilize technology. He identified four elements that are important to the functioning of SIs: the initial conditions and nature of technology spillovers; receiver competence or national absorptive capacity; linkage capacity of the system (connectivity); and, lastly, the variety-creating mechanisms. The effect of path-dependence on each of these elements in the evolution of SIs in two different environments is summarized in Table 1. In this approach, I take institutions to be "products of their environment" as well as the carriers of the history that helped to form and shape them. Historical precedent thus assumes an important place in the analysis, in addition to the basic assumption that industrialization is an evolutionary process. As David (1994, p.215) observes: "Institutions typically evolve new functions and because these are added sequentially they are shaped by internal precedents."

For ease of analysis, I define two main types of SI. The first is a dynamic and rapidly learning system, termed *Dynamic System of Learning Innovation in Development (SLID1)*, while the second is a non-dynamic system that is slow to learn, termed *Non-Dynamic System of Learning Innovation in Development (SLID2)*. For instance, East Asian countries that have achieved rapid economic progress by learning how to industrialize and compete in the global economy are a case of SLID1, whereas many African countries fall into the SLID2 category. There are several measures that differentiate developed from underdeveloped countries or areas.[14] Complementary indicators of SLID1 and SLID2 are levels of investment in R&D, the presence and condition of infrastructure (both hi-tech and basic), the proportion of technical and scientific manpower, and cohesion in the SI, which is based on interaction intensity and ease of information exchange and flows. The different SLIDs also reflect the importance of competence building, which in turn should stress both individual skills development and organizational learning.

The concept of the SLID also draws attention to the weakness of the techniques currently employed to measure the effectiveness of institutions. These techniques tend to be static, with no sense of path-dependence, and to assume contents and outcomes from the form of the institution alone, rather than its provenance and history. For instance, if a country in Africa replicates an R&D laboratory originally established in the USA, it is assumed to be developing an institution capable of the same level of research effectiveness.

[14] Notably, GDP per capita (high-income countries had GDP per capita above US$9,266 in 2000), high literacy levels (100% adult literacy) and low mortality rate (typically less than 10 per 1000). See World Bank Annual reports and UNDP Human Development Reports.

Table 1. Institutional characteristics of SLID1 and SLID2 countries

Elements of innovation system	**Dynamic Systems of Innovation (SLID1)**	**Non-dynamic Systems of Innovation (SLID2)**
1. Initial conditions and nature of production system	Pre-existence and continued existence of large local entrepreneurship. Knowledge bases quickly developed through imitation of advanced industrial countries. Beneficial interactions with foreign and domestic suppliers.	No pre-existing entrepreneurship; largely traditional craft-based or artisanal industries. Systems of subsistence trade but no factory-type system at the onset of efforts to industrialize. Importation and import substitution characterize initial technology learning efforts, which are largely unsuccessful.
2. National technological capabilities	Build up strengths in mechanical engineering and electro-mechanical fields, rapidly acquire telecommunications, information and computer technology.	Weak capabilities in mechanical and engineering industries. Trade-based commodity economies. Few users of new technologies.
3. Linkages and networking capacities	High to average degree of: • Links between buyers and suppliers (global and domestic) • Community-based technical networks. Building of institutions occurs through policy measures and spontaneously. Buyer and supplier competence in public and private domains, resulting in institutional clusters. Integration of academic and industrial institutions and with international actors, leading to 'excellent observation post' status.	Very weak in: • Links between buyers and suppliers (global and domestic) • Technical problem solving (local networks largely absent and almost entirely reliant on foreign technical services). • Informal networks and enterprises. Institutions are weak or absent. Low competence among buyers and suppliers. Hardly any institutional clustering. R&D and universities only marginally important to production.
4. Education and human capital	High levels of literacy and great emphasis on human capital, even at early stages of development. Formal education translates into high skills levels in industry and R&D organizations.	Inherited enrolments in education that were highly skewed. Education was selective and limited to a few. Low educational attainment persists despite 40 years of investment in education.
5. Institutional capital (formal and informal)	Pre-existing institutions for generating and protecting innovations. Co-evolution with technological system and with formal and non-formal types of behaviour and rules of the game.	No pre-existing institutions to generate modern innovations. Policy-derived institutions are inadequately linked with traditional production, much of which has been destroyed by colonial policies encouraging "extractive" institutions.

3. INSTITUTIONS AND DIFFERENCES IN SYSTEMS OF INNOVATION

Observed differences in national economic performance can be traced in large part to differences in their institutions (North, 1996).[15] The comparative empirical work of Nelson (1993) on national SIs showed that countries have developed different knowledge bases in both R&D and the capacity for innovation. For instance, Nelson noted the differences that size makes in SIs: "The differences in the innovation systems reflect differences in economic and political circumstances and priorities {while} size and the degree of influence matter a lot" (Nelson, 1993, p.507). By implication, Nelson's definition acknowledges the role of forces outside the domain of R&D and the institutions associated with it. But how then do SIs differ? There are four broad dimensions that help to answer this question.

First, in developing countries, the amount of R&D[16] (an important source of learning for innovation) carried out in universities and firms is significantly lower than is found in advanced industrial countries. This is equally the case for both SLID1 and SLID2 countries**.** In addition, many of the innovative activities in firms are imitative and product-related rather than process-centred. Again, the functions of the production systems are different. For instance, industrial production in the USA is more specialized in R&D-intensive hi-tech products—far more so than in the EU; and public-sector research, for example at universities, is more closely linked to industry, performing R&D functions that private-sector firms fulfil in Japan, for instance (Edquist and Texier, 1996).

Second, the competence building capacity of organizations such as universities and training centres, many of which were set up expressly to produce manpower, is smaller and in most African countries has failed to meet the challenges of the new, more competitive global economy (Oyelaran-Oyeyinka and Barclay, 2003).

Third, the function of information exchange is usually very weakly coordinated or not coordinated at all in SLID2s. In SLID1s, the situation is better, although often still imperfect. In the SIs of advanced economies, the flow of information is much greater and access to it is

[15] Edquist (2001) identifies nine broad similarities, namely: all SI approaches place innovation at the centre of activities; innovation processes are evolutionary in nature; they all reject the concept of optimality and emphasize diversity and variety; they take innovation as an interactive learning process; they stress the interdependence between organizational actors; and they affirm that innovation generally occurs within an institutional context.

[16] R&D, however it is defined, is not only an avenue for economic and social diversification (new products and processes) but also helps build scientific and technical competencies.

generally easier, even for non-specialists, although a significant proportion of R&D information is withheld from the public domain because it consists of trade secrets.

Fourth the regulatory functions of SIs differ, even among advanced countries, but these differences are more pronounced still between SLID1s and SLID2s. Some SLID2 countries have almost no regulatory institutions for dealing with imported new technologies. For example, most African countries are at very early stages of developing biosafety systems to regulate the introduction and release of genetically modified (GM) organisms.

In sum, the SI framework, with its roots in evolutionary economics as well as its Neo-Schumpetarian variant (Dosi et al., 1988), exhibits considerable heterogeneity.

Having outlined the differences in SIs in terms of technological change, I now turn to the links between SIs and the origins and development of institutions. I summarize these links as five broad hypotheses, which I will state without further elaboration.

First, institutional change constitutes a strong selection mechanism for innovation. This has both market and non-market origins, with the latter providing the leverage for policy intervention at different levels of the economy (Metcalfe, 1997).

Second, learning processes are key determinants of innovative activities and institutions are the carriers of knowledge, representing the cumulative learning of groups and societies (North, 1996). This is particularly so for tacit, non-codified knowledge. The speed of economic change is a function of the *rate of learning*, but the direction of that change is a function of the expected payoffs to the acquisition of different kinds of knowledge (North, 1996, p.346) (italics mine).

Third, path-dependence is a central concept of institutional change and it too underpins learning and innovating activities that are essentially heuristic and possess strong feedback loops (Edquist, 1997).

Fourth, as Sampat and Nelson (2002) observe, technological innovation relies strongly on institutional innovation, the absence of which has been responsible for many of the policy failures in developing countries' efforts to acquire technology.

Fifth, considerable diversity is generated through learning, in much the same way that economic change is brought about by market and non-market selection mechanisms that create diversity (Edquist, 1997, p.7).

4. SYSTEM FUNCTIONS AND DOMAINS

My hypothesis is that, if a SLID2 performs sub-optimally, this is because of systemic and institutional failure. In order to analyse the sources of failure, I introduce the notion of functions, defined as the purposes to be served by the SI. However, it is not enough to specify the broad character of institutional functions, for three reasons.

First, a system's formal description and explicit functions are not necessarily the same as its content. In other words, formal specifications of rules do not always represent the reality of a system's capacity, nor the values and the interpretation given to it by individual and organizational actors. For instance, the rules governing competition and the organizations set up to enforce the rules of the game tell us little about the real intentions of players in the system, nor the power that they wield.

Second, functions change with time and actors play different roles at different times, so no functions remain static. In other words, the notion of function can only be realistic if applied in specific historical and institutional contexts.

Third, as learning takes place among interacting players, functions cannot be analysed in isolation. The context, legitimacy and performance of an SI derive significantly from its institutional environment. However, defining the functions of a system is important for several reasons.[17] To start with, it helps to define the boundaries of the system and establish its domain more specifically. It identifies the extant capacity of the system and points in the direction of ameliorating policy measures. Again, it provides us with a picture of how a particular function has been served in the past and thus the sort of performance one can expect from the system in the future. Lastly, the disaggregation of functions and their domain from organizational actors can help in the design of cross-country and cross-systems comparisons.

Several authors have highlighted the notion and relevance of functions, notably Edquist (2004), Edquist and Johnson (1997), Johnson and Lundvall (2003) and Liu and White (2001). In their earlier formulation, Edquist and Johnson identified four functions, which are: reduction of uncertainty among institutions; the management of conflicts and engendering of cooperation among actors; the provision of incentives to engage in learning and participate in innovation; and the channelling of resources to innovative activities (for instance through government subsidies and use of tax rules to allocate funding to universities).

[17] See Johnson and Lundvall (2003).

There are two points to note in the way various authors treat this subject. First, contrary to the orthodox notion, system function is not only technical but also institutional and organizational. Second, a specific institutional context will consist of a number of functions that are associated with a recognizable system. For these reasons, system functions could be defined in a more generic and much broader sense.

The following seven system functions are identified in the literature, together with how they differ in the developed and developing world context:[18]

1. Knowledge generation, including R&D
2. Competence building: formal and non-formal training in educational institutions and training of technical manpower in firms and organizations
3. Supply of inputs, particularly finance for production and innovation and for the development of scientific, technical and managerial manpower; flow of Foreign Direct Investment (FDIs), venture capital and loans
4. Provision of regulatory frameworks and measures, standards and quality functions (such as product quality tests) and provision of incentives to develop new products and services
5. Facilitation of the exchange and dissemination of knowledge and information
6. Stimulation of demand and creation of markets
7. Reduction of uncertainties and resolution of conflicts through appropriate institutions, such as industrial arbitration.

In the context of underdevelopment, empirical analysis of system functions would need to take into account three issues. The first is the structure of production, which may consist of low-cost, low-wage production in addition to high-cost, technology-intensive industrial production. This is the well-known production dualism, which I choose to label here *structural heterogeneity*, as in fact economic agents vary greatly both within and across countries. The diversity of firms and organizations no longer permits a simplistic bipolar structure. Second, the system of knowledge accumulation should be seen as including the role of formal institutions and their products and how these enable a society to make the transition from structures with individuals who have only the most basic literacy to structures with high levels of skilled and well informed labour. Third, while the ideal locus of industrial production is the private enterprise in a developed market, the role of the state in underdeveloped areas, contrary to the developmental focus of

[18] Modified from Edquist (2004), in Fagerberg et al. (2004).

dynamic SIs, has been largely unsuccessful, yet this role remains crucial.[19] Policy and political coordination, rather than markets, have been the dominant focus of institutional intervention in underdeveloped areas.

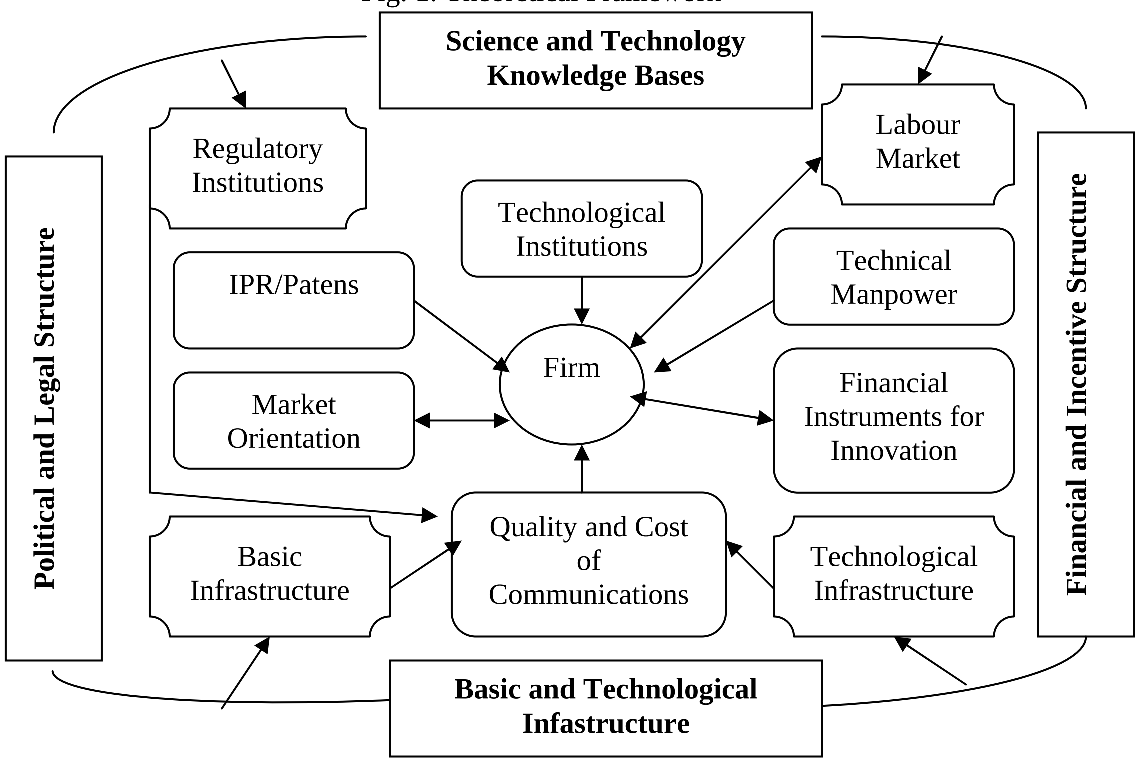
In sum, the seven functions may be collapsed into four sets of institutional structures, namely:

1. Political and legal structures, such as patents and intellectual property regimes (IPRs), tax regimes, and copyright laws
2. Resources and incentive provision structures
3. Basic and technological infrastructure
4. Scientific and technological knowledge bases.

Figure 1 is a diagrammatic representation of the broader SI.

Figure 1. The system of innovations and its functions: the example of infrastructure

Fig. 1: Theoretical Framework



[19] Edquist (2001) rightly observed the imperative not to neglect education and the role of the State in the SI literature. The pervasive role of the State and the poor market co-ordination functions associated with it make these issues extremely important.

I will now illustrate what functions mean in SIs by using infrastructure as an example. Infrastructure relates to two broad domains. The first is knowledge infrastructure, which comprises the “bricks and mortar” aspects of knowledge organizations, such as universities, public research institutes (PRIs), libraries and so on. The second is physical infrastructure, which is made up of energy supply, water supply, telecommunications, and transport systems (roads, railways, airfreight, etc). Both domains are embedded in the institutional context of the national SI. In other words, infrastructure “failure”, for instance, would be interpreted in part as an institutional failure.

Infrastructure possesses technical and economic characteristics that profoundly affect SIs. The technical characteristics include scale, indivisibility, multiple use and generic functions that separate infrastructure from other forms of capital.[20]

Indivisibility confers a systemic attribute on infrastructure by allowing it to serve the entire industrial and non-industrial sectors, with considerable flexibility for multiple extensions. The latitude for multiple use of infrastructure by both urban and rural consumers extends its economy-of-scale characteristic. As infrastructure is fundamental to all production activities, it has traditionally been supplied by monopolies or at least by bodies within the public domain. The required scale of investment is often beyond the financial capacity of private investors, especially in developing countries. Infrastructure provision affects three broad groups of users: individual firms, whole industries and individual consumers.

The absence of necessary utilities in such fields as electrical power, water supply or telecommunications compels firms to make alternative provision. This raises production costs and hence the price of goods and services, thereby depressing demand. By the same token, drastic reductions in the price at which infrastructure is supplied may be productivity enhancing.

In the second instance, the impact is industry-wide and has direct effects on the market. Cheap but high-quality infrastructure encourages the entry of a greater number of firms into an industry. The resulting competition raises industrial output. Importantly also, the presence of infrastructure encourages the establishment of key industrial facilities and the diffusion of key technologies. Examples include the role of industrial estates, science parks and technology incubators, all of which act to attract firms to specific locations. Clustering is now well known to provide firms with benefits that lead to productivity growth. Geographic concentration leads to “collective efficiency”, whether the clusters evolve organically or are promoted by public policy. The provision of public utilities, such as transportation and communication, has strong externalities and a direct impact on factor prices.

[20] See Smith (1997), in Edquist and Johnson (1997), for an excellent treatment.

The third and last impact of infrastructure is on consumer behaviour, and this is the result of its positive impact on the prices of goods and services. Again, telecommunications and electrical power are prominent examples. For instance, the introduction of mobile telephony in Africa has greatly improved teledensity in many countries. Improved communication leads to lower information access costs, in much the same way that cheap transport and good roads lower transaction costs.

Efficient infrastructure is therefore vital to enterprises for two main reasons. First, its absence compels private acquisition, which places added financial and material burdens on firms. Firms regard the cost of alternative utilities as a major impediment to new investments, as extra financial provision is usually required for major plant installations as well as minor plant additions. Secondly, inadequate national infrastructure makes networking among firms extremely difficult. For example, transaction costs are high where communication is hindered either by poor telecommunications or frequent power outages. In some cases, linking production with markets is not only made difficult but becomes impossible. In most African countries, both agricultural and industrial production are constrained by inadequate linkages to input and output markets. This may be due to poor road networks, lack of information, and inadequate storage facilities.[21]

Frequent power outages force firms to acquire standby electricity generating equipment. Firms that are unable to acquire private facilities either cut down on production or, in rare cases, share power with nearby firms that have generators. Individual entrepreneurs may be tempted to steal power, using do-it-yourself systems that are often dangerous as well as unreliable**.** Unplanned power cuts can damage sensitive machinery. The perennially poor state of infrastructure leaves manufacturers with little confidence in the future ability of public utilities to meet their supply obligations.

The effect of poor infrastructure on routine production activities can be highly significant. To the extent that there is greater propensity for technical change in a regime of continuous production, the availability of infrastructure is critical to achieving competitive advantage. Without it, planning becomes difficult and coordination among economic agents in the national and global economy highly problematic. The spontaneous inter-organizational linkages made possible by all-purpose infrastructure are a prerequisite for “networking”—that complex of backward and forward linkages that is taken for granted in dynamic industrial economies.

In effect, when infrastructure is poor, firms are penalized for what is essentially a failure of public policy. Whether or not firms invest in alternative supplies to compensate for missing utilities, innovation investments tend to be the first casualty. In sum, issues relating to infrastructure provision in sub-Saharan Africa should be central to discussions on innovation in the region, since infrastructure profoundly influences both the pace and quality of innovation. It would be misleading to consider infrastructure as a fixed factor of technical change.

To illustrate the empirical relationship between SIs and formal institutions, I assume that a dynamic SI is essentially a wealth-creating one that employs advanced infrastructure such as the Internet more intensely than a weak or non-dynamic SI. I therefore use "Internet intensity" (ratio of Internet users to total population) in a correlation matrix against other institutional variables, namely education (% of tertiary education enrolment), personal computer ownership (PC), telephone use per capita or teledensity (TELEDEN), GDP per capita, Internet hosts per capita, and Internet use.

The effectiveness of the Internet depends on the quality of telecommunications infrastructure in a country, in addition to the other factors listed in the preceding paragraph. The literature is replete with evidence on the role of physical and knowledge infrastructure in creating economic wealth (represented by GDP in this paper). In turn, a country's level of wealth will influence the type and quality of infrastructure investment. In other words, countries with a higher per capita income can be expected to have higher Internet diffusion rates.

Again, information and communication technologies (ICTs) are rightly regarded as knowledge-intensive technologies and several studies (Doms et al., 1997) have found that firms employing more skilled workers are more likely to take advantage of ICTs. Investment in telecommunications infrastructure (ITI) becomes an important variable. Linked to this is the connectivity of computers as the backbone of electronic networks.[22] There is considerable empirical evidence (Hargittai, 1999; Kiiski and Pohjola, 2002; Lal and Shampa, 2004) on the importance of "last mile" connectivity in the diffusion of the Internet. While the Internet can be accessed though systems other than PCs, institutional access to the Internet is usually through local area networks (LANs) employing a combination of PCs (intelligent terminals) and dumb terminals. For this reason, PCs are a vital node in the network for a functioning Internet-based SI.

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[21] On a 1998 mission to one of Ethiopia's agricultural research stations by road, the journey, which on a good road should have taken no more than one hour, took three hours. The station had no functioning telephone.

[22] Connectivity is central to all types of electronic networks, that is, local area networks (LANs), wide area networks (WANs), Intranet and Internet.

Drawing on the above, the relationships below explain the variability in the diffusion of the Internet in African countries[23]:

IU	= f (IH, PCDEN)	diffusion of internet
IH	= f (TELEDEN, ITI [-1], EDU)	infrastructure equation
TELEDEN	= f (IU, GDP)	communication network equation

Where,

IU→ internet users per 10,000 persons
IH→ internet hosts per 10,000 persons
PCDEN→ personal computers per 1,000 persons
TELEDEN→telephone lines per 1, 000 persons
ITI→ per capita investment in telecommunications infrastructure in USD
EDU→ percentage of enrolment in tertiary education
GDP→ per capita gross domestic product in USD (constant 1995 prices)

Given these relationships, I can demonstrate the linkage between the variables as proxies of institutional infrastructure.

Starting with the basics, Table 2 shows how an Internet user index (IUI) is related to a number of technological infrastructure variables. The table demonstrates the strong correlations among the various forms of infrastructural investment, although the direction of causality is not always easy to establish.

The variables were analysed by classifying a sample of African countries on the basis of density of Internet use. The two groups of countries were categorized on the basis of whether they were above or below the median value of Internet use, that is, 19 per 10,000 inhabitants. The table also presents descriptive statistics of the variables, along with the significance of group mean differences.

[23] Details of a similar exercise (with the methodology explained in more detail) can be found in Oyelaran-Oyeyinka and Lal (2005).

Table 2. Distribution of mean value of variables according to intensity of Internet use (2000)

Variables	Intensity of Internet use		F-statistics	Level of significance
	Low	High		
EDU	2.604 (2.33)	4.23 (4.33)	2.11	0.155
GDP	381.61 (334.57)	1452.2 (1642.9)	8.14	0.007
IH	0.18 (0.22)	6.51 (12.35)	5.28	0.028
ITI	0.02 (0.34)	6.36 (10.40)	5.98	0.020
IU	10.71 (6.48)	130.83 (199.67)	7.64	0.009
PCDEN	2.94 (2.39)	21.01 (26.72)	8.19	0.007
TELEDEN	5.44 (3.07)	46.06 (66.79)	6.29	0.018

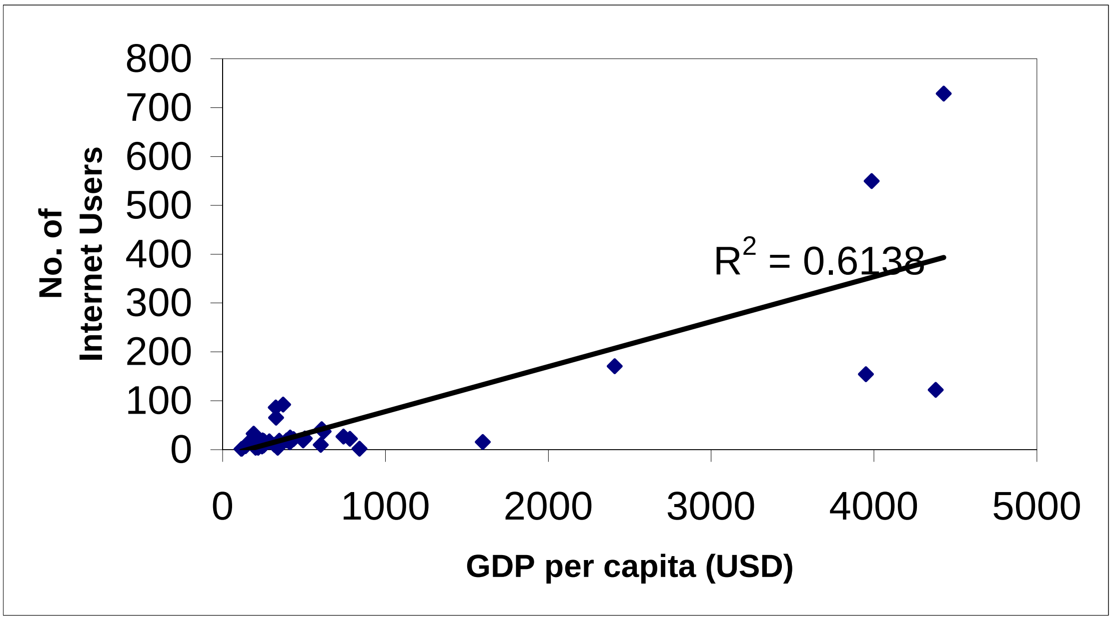
Notes: Figures in parentheses are standard deviations. Database: World Bank (2001), World Development Indicators. The variables are: tertiary education enrolment % (EDU), gross domestic product per capita (GDP), Internet host (IH), investment in telecommunications infrastructure (ITI), Internet use (IU), personal computer density (PCDEN) and telephone density (TELEDEN).

The table shows that the ratio of enrolment in tertiary education differs significantly between the two groups. There is also a high significance level for many of the other variables. For instance, PC density and GDP differ significantly (1%). The significance level of the remaining variables—IH, ITI and TELEDEN—is at the 5% level, although one should be careful in drawing conclusions because the data are for one year only and the results are based on univariate tests that exclude the interaction of other variables.

I will now explore the relationship between Internet use and the most significant variables in the univariate analysis. The trends are presented in Figures 2, 3 and 4.

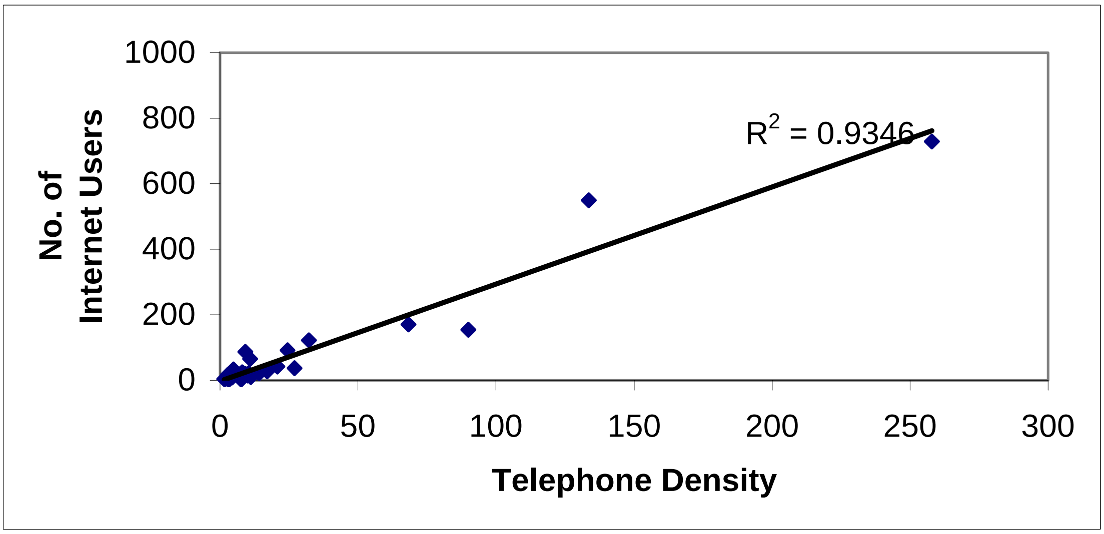
Figure 2 presents the relationship between density of Internet use and economic wealth. The figure shows that GDP per capita is an important determinant of diffusion of the Internet. The R-square of a trend line between Internet use and GDP is 0.62, indicating that 62% of the variance is explained by GDP per capita. This confirms my hypothesis that infrastructure plays a crucial role.

Figure 2. Internet use and GDP per capita in USD (2000)



Similarly, Figure 3 presents the relationship between use of the Internet and last mile connectivity. The value of the R-square of the trend line between these variables is 0.93, which is very high. In other words, 93% of the variance is explained by telephone density.

Figure 3. Internet use and telephone density (2000)

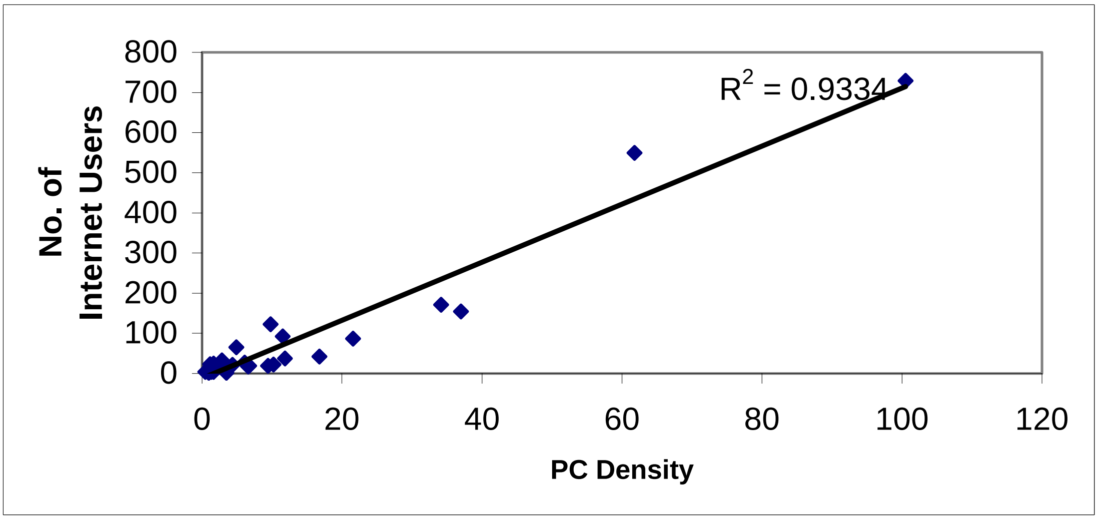


I conclude from Figure 3 that telephone density is even more important than GDP in explaining the variation of Internet diffusion in the sample countries, when the results are analysed separately in a single-equation framework. However, the relative importance of these two variables might change in a multivariate model (Oyelaran-Oyeyinka and Lal, 2005).[24]

[24] See Oyeyinka and Lal, Telecommunication Policy (forthcoming 2005).

The mean values of PC density also emerged as significantly different in low and high Internet-using countries. The relationship between these variables is depicted in Figure 4. The very high R-square (0.93) of the trend line between these variables suggests that the explanatory power of PC density is also very high.

Figure 4. Internet use and PC density (2000)



Note: The graphs shown in Figures 2, 3 and 4 are based on data for the year 2000. The trends depicted in these figures may not remain the same once the data are analysed to include other years.

5. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This paper calls attention to the persistent differences in three kinds of SIs and submits that SIs differ because the institutions supporting them exhibit marked differences in structural and historical attributes. Since economic structures, even in relatively advanced industrial economies, continue to exhibit different paths of development, SIs should logically also exhibit significant differences in their evolutionary paths. One way to conduct a realistic comparison between SIs is to examine the functions they perform and to see how well these functions are delivered. However, because SIs in developing countries will undergo continuous structural change, functions are not static and the rate of change in learning is a strong determinant of system performance. How well an SI learns will manifest in the speed at which it accumulates knowledge and as such development and knowledge acquisition are merely two sides of the same coin.

I emphasize the notion of learning in the SI following the insights from recent work on SIs that suggest a broadening of the approach (Edquist, 2004; Johnson and Lundvall, 2003). While SIs have broad similarities irrespective of their geographic or sectoral environments, they also vary greatly across countries and sectors. The differences in the effects of the SI on development have been highlighted by calling attention to a pure form of "Advanced" SI and to two other forms common in post-colonial developing countries, SLID1 and SLID2. For SLID2 in particular, a widening of the domain of research is imperative, in order to include the role and functions of competence building, ranging from individual to organizational learning.

In order to understand the influence of institutional factors, I chose one of the four composite variables, namely infrastructure, from the analytical framework shown in Figure 1. I examined the impact of GDP per capita, telecommunications investment, PC density, telephone density, educational enrolment and other variables on Internet diffusion in 41 sub-Saharan African countries for the period 1995 to 2000. The findings suggest that the density of Internet hosts, the number of PC owners, level of investment in telecommunications infrastructure, existing telephone density and economic wealth (GDP per capita) significantly influence Internet diffusion. Education, in particular, is a major factor in development and, as my findings show, the Internet is more widely diffused where there are more educated people.

The lessons for policy makers in developing countries are at once complex yet simple. The role of formal institutions emerges strongly from the examples cited in the paper**,** but the context is as different as the past century is from the present one. What has worked during the past 50 years may not be applicable now, and what has worked in Europe may not be suitable for

Africa. What seem important are the underlying principles: the role of institutions and their path-dependence, and the importance of investment in human capital at all levels, from formal schooling to industry. More work is needed to understand the influence of informal institutions and I hope this area of study will be taken up in future by others.

The paper highlights the institutional basis of SIs and suggests that a fruitful direction for future research will be an engagement in more case studies at the national and sectoral levels. Complementary to this approach will be comparative institutional studies of SIs across countries that employ common methodology in order to detect underlying similarities and differences. This could be combined with cross-country statistical studies to identify truly significant institutional variables.

REFERENCES

Akyüz, Y. and Gore, C. 2001. "African Development in a Comparative Perspective," *Cambridge Journal of Economics*, 25:3, pp 265–288.

Amsden, A.H. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. New York and Oxford: Oxford University Press.

Arocena, R. and Sutz, J. 1999. "Looking at National Systems of Innovation From the South," *Industry and Innovation*, 7:1, pp.55–75.

Aron, Janine. 2000. "Growth and Institutions: A Review of the Evidence," *The World Bank Research Observer*, 15:1, pp. 99-135..

Aunty, R.M. 1993. *Sustaining Development in Mineral Economies: The Resource Curse Thesis*. London: Routledge.

Brautigam, D. 1997. "Substituting for the State: Institutions and Industrial Development in Eastern Nigeria," *World Development*, 25:7, pp. 1063–1080.

Carlsson, B. 1997. "On and Off the Beaten Path: The Evolution of Four Technological Systems in Sweden," *International Journal of Industrial Organization*, 1:5, pp. 775–799.

Cimoli, M. 2000. *Developing Innovation Systems: Mexico in a Global Context*. London and New York: Continuum 2000.

Coase, R.H. 1937. "The Theory of the Firm," *Economica*, 4, pp. 386–405.

Coriat, B. and Dosi, G. 1998. "The Institutional Embeddedness of Economic Change: An Appraisal of 'Evolutionary' and 'Regulationist' Research Programmes," in: Nielsen, K. and Johnson, B. (eds), *Institutions and Economic Change: New Perspectives on Markets, Firms and Technology*. Cheltenham: Edward Elgar Publishing, pp. 3–31.

David, P.A. 1994. "Why are Institutions the 'Carriers of History'?: Path Dependence and the Evolution of Conventions, Organisations and Institutions," *Structural Change and Economic Dynamics*, 5:2, pp. 205–220.

Doms, M., T. Dunne, and K. Troske. 1997. "Workers, Wages and Technology," *Quarterly Journal of Economics*, 112: pp. 253-290.

Dosi, G., Freeman, C., Nelson, R, Silverberg, G. and Soete, L. 1988. *Technical Change and Economic Theory*. New York and London: Columbia University Press.

Edquist, C. 1997. *Systems of Innovation Technologies, Institutions and Organizations*. London and Washington: W.W. Norton.

____ 2001. "Innovation policy: A Systemic Approach," in: Archibugi, D. and Lundvall, B-Å. (eds), *The Globalizing Learning Economy*. Oxford: Oxford University Press, pp. 219–237.

____ 2004. "Systems of Innovation: Perspectives and Challenges," in: Fagerberg, J., Mowery, D. and Nelson, R. R. (eds), *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, pp. 1-28.

Edquist, C. and Johnson, B. 1997. "Institutions and Organizations in Systems of Innovation," in: Edquist, C. (ed) *Systems of Innovation Technologies, Institutions and Organizations.* London: Pinter Publishers, pp. 41–63.

Edquist, C. and Texier, F. 1996. "The Growth Pattern of Swedish Industry," in: Kuusi, O. (ed), *Innovation Systems and Competitiveness.* Helsinki: Francois Taloustieto Oy in collaboration with ETLA (The Research Institute of the Finnish Economy) and VATT (The Government Institute for Economic Research), pp. 1975–1991.

Engerman, S.L. 2000. "Institutions, Factor Endowments and Paths of Development in the New World," *Journal of Economic Perspectives,* 3: pp. 217–232.

Engerman, S.L. and Sokoloff, K.L. 1997. "Factor Endowments, Institutions and Differential Paths of Growth Among New World Economies," in: Haber, S.H. (ed) *How Latin America Fell Behind.* Stanford: Stanford University Press, pp. 260–304.

Fagerberg, J., Mowery, D. and Nelson, R.R. 2004. *The Oxford Handbook of Innovation.* Oxford: Oxford University Press.

Freeman, C. 1987. *Technology Policy and Economic Performance: Lessons from Japan*. London: Frances Printer (Publisher).

Gu, S. 1999. *Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development.* Maastricht: UNU-INTECH Discussion Paper 9903, http://www.intech.unu.edu/publications/discussion-papers/9903.pdf.

Hargittai, E. 1999. "Weaving the Western Web: Explaining Differences in Internet Connectivity Among OECD Countries," *Telecommunication Policy,* 23: pp.701–718.

Intarakumnerd, P., Chairatana, P. and Tangchitpiboon, T. 2002. National Innovation Systems in Less Successful Developing Countries: The Case Study of Thailand. *Research Policy,* 31: 8–9, pp. 1445–1457.

Johnson, B. and Lundvall, B-Å. 2003. "National Systems of Innovation and Development," in: Muchie, M., Gammeltoft, P. and Lundvall, B-Å. (eds), *Putting Africa First.* Aalborg: Aalborg University Press.

Kiiski, S. and Pohjola, M. 2002. "Cross Country Diffusion of the Internet," *Information Economics and Policy*, 14:2, pp. 297–310.

Lal, K. and Paul Shampa. 2004. "Digital Divide and International Orientation:Evidence From Asia-Pacific Countries," *The ICFAI Journal of Applied Economics,* 3:2, pp. 31-41.

Liu, X. and White, S. 2001. "An Exploration into Regional Variation of Innovative Activity in China," *International Journal of Technology Management*, 21 (1–2): pp. 114–129.

Lundvall, B-Å. 1988. "Innovations as An Interactive Process: From User–Producer Interaction to the National System of Innovation," in: Dosi, G. (ed) *Technical Change and Economic Theory*. London: Pinter Publishers, pp. 349-369.

____ 1992. *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning*. London: Frances Printer (Publishers).

Lundvall, B-Å., Johnson, B., Andersen, E.S. and Dalum, B. 2002. "National Systems of Production, Innovation and Competence Building," *Research Policy*, 31:2, pp. 213–231.

Metcalfe, J.S. 1994. "Evolutionary Economics and Technology Policy," *The Economic Journal*, 104 (425): pp. 931–944.

____ 1997. "On Diffusion and the Process of Technological Change," in: Antonelli, G. and de Liso, N. (eds), *Economics of Structural and Technological Change.* London: Routledge, pp. 123-146.

Mikesell, R.F. 1997. "Explaining the Resource Curse, With Special Reference to Mineral-Exporting Countries," *Research Policy*, 23:4, pp.191–199.

Mokyr, J. 2002. *The Gift of Athena: Historical Origins of the Knowledge Economy*. Princeton: Princeton University Press.

Muchie, M., Gammeltoft, P. and Lundvall, B-Å. 2003. *Putting Africa First: The Making of African Innovation Systems*. Aalborg: Aalborg University Press.

Nelson, R. 1993. *National Innovation Systems a Comparative Analysis*. New York and Oxford: Oxford University Press.

Nelson, R. and Winter, S. 1982. *An Evolutionary Theory of Economic Change*. Cambridge: Belknap Press.

Nelson, R.R. 1987. *Understanding Technical Change as an Evolutionary Process*. Amsterdam: North Holland.

Nelson, R.R. and Rosenberg, N. 1993. "Technical Innovation and National Systems," in: Nelson, R.R. (ed), *National Systems of Innovation. A Comparative Analysis.* Oxford: Oxford University Press, pp. 3–21.

Nelson, R.R. and Sampat, B. 2001. "Making Sense of Institutions as a Factor Shaping Economic Performance," *Journal of Economic Behavior and Organization*, 44: pp. 31–54.

North, D.C. 1989. "Institutional Change and Economic History," *Journal of International and Theoretical Economies*, 145: pp. 238–245.

____ (ed). 1996. *Economic Performance through Time*. Cambridge: Cambridge University Press..
North, D.P. 1990. *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.

Oyelaran-Oyeyinka, B. and Barclay, L.A. 2003. Human Capital and Systems of Innovation in African Development, in: Muchie, M., Gammeltoft, P. and Lundvall, B-Å. (eds), *Putting Africa First: The Making of African Innovation System.* Aalborg: Aalborg University Press, pp. 93–108.

Oyelaran-Oyeyinka, B. and Lal, K. 2005. "Internet Diffusion in sub-Saharan Africa: A Cross-Country Analysis. *Telecommunications Policy*, (Forthcoming).

Rodrik, D. 1998. "Trade Policy and Economic Performance in sub-Saharan Africa," NBER Working Papers, http://www.nber.org/papers/W6562.

Rodrik, D. 1999. "Institutions for High Quality Growth: What that are and how to acquire them," Paper prepared for an IMF conference on Second Generation Reforms, http://www.imf.org/external/pubs/ft/seminar/1999/reforms/rodrik.htm

Rodrik, D., Arvind Subramanian, and Francesco Trebbi. 2002. "Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development," CID Working Paper No. 97.

Rosenberg, N. 1976. *Perspectives on Technology*. Cambridge: Cambridge University Press.

Rosenberg, N. and Birdzell, L.E. 1986. *How the West Grew Rich: The Economic Transformation of the Industrial World*. London: L.B. Tauris & Co.

Sampat, B. and Nelson, R.R. 2002. "The Emergence and Standardization of University Technology Transfer Offices: A Case Study of Institutional Change. *The New Institutionalism in Strategic Management*, 19.

Shirley, M.M. 2004. What does institutional economics tell us about development. Paper presented at ISNIE, 2003, Budapest. [http://www.coase.org]

Smith, K. 1997. "Economic Infrastructures and Innovation Systems," in: Edquist, C. *Systems of Innovation Technologies, Institutions and Organizations*. London and Washington: W.W. Norton, pp. 86-103.

Stein, H. 1994. “Theories of Institutions and Economic Reform in Africa,” *World Development*, 22:12, pp. 1833–1849.

Vitta, P.B. 1990. “Technology Policy in sub-Saharan Africa: Why the Dream Remains Unfulfilled,” *World Development*, 18 (11): 1471–1480.

World Bank, 2001. World Development Indicators.

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