African context for technological futures for digital learning and the endogenous growth of a knowledge economy

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The Southern African countries, embodied as the Southern African Development Community (SADC) region, face sustainable development problems and low global competitiveness. Innovation in the education sector presents a promissory note that can stimulate an endogenous growth of the knowledge economy and reduction of poverty. Technological futures in digital learning are largely influenced by complexity, simulation and modeling, and decision-making capabilities. The paper is purposed to develop an endogenous growth model for a knowledge economy for SADC countries where digital learning is the engine for sustainable growth with its associated technological futures and complexity. The learners in ubiquitous learning environments are able to access the various contents on the Web, search the electronic databases, interactively communicate with instructors and other learners and obtain knowledge anytime and anywhere through wireless technologies. The diffusion discourse and the social embedded innovation can achieve a desirable impact in development, mainly through ICTs for development (ICT4D). Social media is one area that has introduced complexity in the digital learning environment. Chaos Theory is used to seek understanding of the aperiodic behaviour in deterministic, non-linear dynamical systems in a digital learning environment and the design thereof. The Lorenz attractor for such a learning environment is innovation that brings solutions and relevancy to the developmental agenda, with Lyapunov exponents expressed by divergent trajectories of ICT4D. The Jacobian matrix grows exponentially with each technology that goes through diffusion and adoption. The Neo-classic theory of growth is about technical progress premised on exogenous factors and driven by labour, capital and technology. Technology diffusion in SADC is not exogenous. The endogenous growth theory is a model of long-run economic growth that emphasizes that technological change is influenced by economic incentives and a great diversity of resources in an African environment, which largely supports innovation, an embodiment of knowledge in capital and learning by doing. The mixed method methodology is used in this research, which is a research study of the SADC region countries. Mixed methods often combine nomothetic and idiographic approaches in an attempt to serve the dual purposes of generalisation and in-depth understanding—to gain an overview of social regularities from a larger sample while understanding the other through detailed study of a smaller sample. The methodology used was largely qualitative on human capital development and technology diffusion, and quantitative on GDP and Infodensity covering 18 countries in East and Southern Africa. The 18 countries covered by the qualitative study are South Africa, Angola, Botswana, Burundi, D.R. Congo, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. An endogenous model for sustainable economic growth is developed through panel data analysis. Panel Data is a data set that contains repeated observations over time, i.e., observations on multiple phenomena observed over multiple time periods for the same firms, individuals, households, enterprises, countries, or any set of entities that remain stable through time. An endogenous model for a knowledge economy for SADC countries is proposed.

Keywords: Knowledge economy, sustainable development, ICT4D, digital learning environment, Chaos Theory, endogenous growth model, technological future
BACKGROUND

Innovation has enormous implications and extensive applications in the African context. The application of knowledge as a key source for growth, mainly through education and training, is of paramount importance in sustainable development. Innovation encompasses both technological diffusion and adoption, and non-technological aspects. The innovation system of any country often includes the institutions, policies, legal framework, practices and procedures on the creation, dissemination, preservation and application of knowledge. In all these initiatives, excellence, innovation and leadership are the critical success factors. A Knowledge Economy requires a scientific and technological literacy, critical thinking about sustainable economies, global competence, diverse cross-cultural leadership skills, and students who can learn how to learn and adapt to rapid change.

The four pillars for a knowledge economy are (Kabanda, 2012b):

1) **Human capital** - an educated and skilled population to create, share, and use knowledge well;
2) **ICTs** - a dynamic information infrastructure to facilitate the effective communication, dissemination, and processing of information;
3) **Institutions** – an efficient innovation system comprising academia, firms, consultants, SMEs, etc.;
4) **An enabling policy and legal framework** - an enabling environment with supportive economic and institutional mechanisms.

Technology is about the application of scientific knowledge for practical purposes, and is often associated with machinery, equipment and intangibles developed from such scientific knowledge. The term “Technology” in this paper is loosely associated with the Objects (machinery or physical hardware), Knowledge used in technological innovation, Activities conducted with the technology, the Process that yields the solution, and the Socio-technical system for the manufacturing and use of the objects. The basic definitions used in this paper are shown on Appendix 1.

The specific future technologies and innovations are grouped into the following broad areas: (http://www.bis.gov.uk/assets/foresight/docs/general-publications/10-1252-technology-and-innovation-futures)

1. **Materials and Nanotechnologies**
2. **Biotech and Pharmaceuticals**
3. **Energy and low-carbon technologies**
4. **Digital and Networks:**
   - Biometrics
   - Cloud Computing
   - Complexity
   - Simulation and Modelling
   - Searching and Decision-Making
   - Intelligent Sensor Networks and Ubiquitous Computing
   - New Computing Technologies
   - Next Generation Networks
   - Photonics
   - Service and Swarm Robotics
   - Secure Communication
   - Supercomputing
   - Surveillance

The focus on education and sustainable endogenous growth of the knowledge economy requires us to place much emphasis on Complexity, Simulation and Modelling, and Searching and Decision-Making. The critical elements for ICT for Development (ICT4D) in Africa are:

- Access to ICTs;
- Ability to use ICTs;
- Actual use of ICTs; and
- The impact of using ICTs in economic growth.

The problem

The major problem facing Southern African countries, specifically the SADC Region is a sustainable development problem, with the following elements:

1) **Main Problem**
   - The SADC region faces a sustainable development problem and low global competitiveness.

2) **Sub-problems**
   a) Endogenous growth of a knowledge economy is far from reality on the ground and in predicting the future.
   b) Poverty reduction is not yet correlated to the sustainable solution that increases production capacity at individual, institutional, community and national levels.
   c) The education sector is yet to manage the complexity, re-imagine the technological futures in digital learning and amply demonstrate innovation.
   d) The Government policies, donor interest and community development needs are totally divergent.

Sustainable development challenges in SADC region

The Southern African Development Community (SADC) consists of 15 member states in Southern Africa, has a population of 220 million people and occupies 9.3 million km², as shown on Figure 1 below (http://www.sadc.int/). The SADC region is characterized by the following features:
Figure 1. The SADC region

Figure 2. Annual cereals yield production 2008-2010

The cereals yield production levels of most of the SADC member states are below 2000 kg/ha, except Mauritius with an average of 8000 kg/ha and South Africa with 4000 kg/ha.

- Around 40% of the SADC country population are under 15, i.e. school age children. There is high demand for schooling at every level, whose demand cannot be met by the conventional institutions, hence the need for open and distance learning (ODL).
- Poverty and food insecurity are widespread. The SADC Regional annual gross domestic growth rate averages only 5.5%.
- About 76%-80% of the people in the SADC Region live in the rural areas.
- 60-80% of the SADC population depend on agriculture, largely subsistence, whose yield production per hectare is one of the lowest regions in the world.

The major sustainable development problem of the SADC is observed in the following 3 areas:

**Low cereals yield production**

The annual cereals yield production for the countries in East and Southern African countries are shown in Figure 2 Above, using data obtained from the World Bank. (http://data.worldbank.org/indicator/AG.YLD.CREL.KG).
Low competitiveness

The Global Competitiveness Index (GCI) ranks factors that drive productivity in various countries throughout the world, and the lower the index the more competitive a country is perceived to be. The main parameters used in the computation of GCI are mainly institutions, infrastructure, macroeconomic position, health and primary education, marketing efficiency, technology readiness and innovation. The competitiveness of the SADC, according to the World Bank study on competitiveness of 2007 (Africa Competitiveness Report 2007), is not very good for most of the SADC countries, except Mauritius, South Africa and Namibia with respective indices of 27, 35 and 43, respectively. Zimbabwe, Angola and DRC are rated the worst with indices of 152, 167 and 178, respectively. These are shown in Figure 3 Above.

The emergence and convergence of information and communication technologies (ICTs) has remained at the centre of global socio-economic transformations. ICTs include a wide range of services, applications and technologies, using various types of equipment and software, often running over telecommunications networks. ICTs impact on all the Millennium Development Goals (MDGs) in different ways. The fast track to the achievement of MDGs lies greatly in the ability to effectively manage the diffusion and adoption of ICTs for development (Kabanda, 2012a).

Education sector with little innovation and relevancy

According to the SARUA survey conducted on the higher education section of the SADC region in 2010, South Africa has the highest of universities and private colleges, followed by Tanzania, as shown on the table, Table 1, below.

About 47% of the students studying at SADC universities are studying Humanities. The SADC region appears to be training more politicians and social scientists than engineers and scientists who may provide innovative solutions to the development challenges facing the African countries. However, the research output is very low, with South Africa alone producing about 72.1% of the research output for the entire SADC Region, as evidenced by the table, Table 2, below from the survey conducted by SARUA.

Purpose and Objectives

The major objectives of the research paper are to

1. Develop an endogenous model for sustainable economic growth through panel data analysis
2. Establish sustainable capacity building for the adoption and diffusion of ICTs in education
Table 1. Overview of the SADC Region Higher Education sector

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Angola</td>
<td>1</td>
<td></td>
<td></td>
<td>47,373</td>
<td>16,403</td>
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<tr>
<td>Botswana</td>
<td>1</td>
<td>12</td>
<td>5</td>
<td>15,710</td>
<td>1,702</td>
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<tr>
<td>DRC</td>
<td>4</td>
<td></td>
<td>21</td>
<td>31,478</td>
<td>61,532</td>
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<td>Lesotho</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>8,508</td>
<td>2,447</td>
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<tr>
<td>Madagascar</td>
<td>6</td>
<td>2</td>
<td>21</td>
<td>41,691</td>
<td>2,447</td>
</tr>
<tr>
<td>Malawi</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>7,869</td>
<td>12,758</td>
</tr>
<tr>
<td>Mauritius</td>
<td>2</td>
<td>7</td>
<td>30</td>
<td>9,720</td>
<td>1,253</td>
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<tr>
<td>Mozambique</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>46,865</td>
<td>19,886</td>
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<tr>
<td>Namibia</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>8,378</td>
<td>1,991</td>
</tr>
<tr>
<td>South Africa</td>
<td>23</td>
<td></td>
<td>80</td>
<td>746,538</td>
<td>47,391</td>
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<tr>
<td>Swaziland</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>5,785</td>
<td>1,146</td>
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<tr>
<td>Tanzania</td>
<td>5</td>
<td>18</td>
<td></td>
<td>33,420</td>
<td>38,524</td>
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<tr>
<td>Zambia</td>
<td>3</td>
<td>43</td>
<td>6</td>
<td>14,395</td>
<td>11,700</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>52,453</td>
<td>12,233</td>
</tr>
<tr>
<td>SADC Total</td>
<td>77</td>
<td>119</td>
<td>168</td>
<td>1,070,183</td>
<td>246,833</td>
</tr>
</tbody>
</table>

Source: SARUA Higher education survey

Table 2. SADC Higher Education Research Output

<table>
<thead>
<tr>
<th>Major field of study</th>
<th>Internationally accredited Journals</th>
<th>Locally accredited Journals</th>
<th>Books</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science, Engineering and Technology</td>
<td>2,215</td>
<td></td>
<td></td>
<td>1,931</td>
<td>5,359</td>
</tr>
<tr>
<td>Business Management and Law</td>
<td>314</td>
<td>7211,134</td>
<td>902</td>
<td>423</td>
<td>2,359</td>
</tr>
<tr>
<td>Humanities and Social Sciences</td>
<td>609</td>
<td>1,193</td>
<td>346</td>
<td>826</td>
<td>2,973</td>
</tr>
<tr>
<td>Health Sciences</td>
<td>937</td>
<td>491</td>
<td>23</td>
<td>489</td>
<td>1,940</td>
</tr>
<tr>
<td>Others</td>
<td>533</td>
<td>166</td>
<td>83</td>
<td>196</td>
<td>979</td>
</tr>
<tr>
<td>Total (all countries)</td>
<td>4,608</td>
<td>3,704</td>
<td>1,433</td>
<td>3,866</td>
<td>13,609</td>
</tr>
<tr>
<td>Total (excluding SA)</td>
<td>1,045</td>
<td>685</td>
<td>965</td>
<td>1,182</td>
<td>3,709</td>
</tr>
</tbody>
</table>

Source: Universities, questionnaire responses

thereby creating a sustainable knowledge economy.

3. Investigate on the appropriate model to manage complexity in education that promotes access and diffusion of ICTs (digital learning) within the selected African countries.

4. Assess the impact of research and innovation to sustainable capacity building.

Research questions

The main research questions are as follows

1. How do we establish the endogenous growth for a sustainable knowledge economy in African countries?
2. What is the digital future in and Africanisation of education?
3. How can we accelerate the adoption, diffusion and impact of ICTs in development?
4. How do we manage the complexity in digital learning?
5. What is the impact of research and innovation to sustainable capacity building?

Critical context

Literature on information systems discourses

An Information System (IS) can be defined technically as a set of interrelated components that collect or retrieve, process, store and distribute information to support
decision making, coordination, control, analysis, and visualization in an organization (Laudon and Laudon, 2007). This definition clearly shows the importance of IS for highly successful, adaptive and modern organizations. Avgerou (2008) has conducted extensive research on discourses on innovation and development in Information Systems (IS) in developing countries. Discourses are research approaches emanating from assumptions on the context and consequences of IS innovation in developing countries.

Information systems (IS) implementation comprises technology development and organizational change. A discourse arises from a combination of assumptions on the nature of IS innovation processes in developing countries and relevant conceptual constructs in the study of these processes. Developments in information systems for developing countries (ISDC) are severely challenged by financial resources, technology and skills in most developing countries (Avgerou, 2008). The transfer and diffusion discourse can be explained by the theories of diffusion and technology acceptance (Davis, 1989; Rogers, 1995). Avgerou (2008) presents three discernible discourses with respect to research in IS in developing countries (ISDC):

a) IS innovation in terms of transferring of ICT and organizational practices from advanced economies and adapting them in the context of developing countries;

b) IS innovation as a process embedded in local conditions in developing countries; and

c) IS innovation as a transformative intervention and associates it the aspirations and policies for socio-economic development.

Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas (Rogers, 2003: 5). Innovations diffuse through a social system explained by the diffusion of innovation theory (Rogers, 2003). Diffusion of innovation is a theory that analyzes, as well as explain, the adaptation of a new innovation. The purpose of this theory to the research is to provide a conceptual paradigm for understanding the process of diffusion and social change associated with ICTs. African countries are largely end consumers of technology and fall among the late majority (34%) and laggards (16%) with respect to ICT innovations (Kabanda, 2011). Innovations that are perceived by individuals as having greater relative advantage, compatibility, trialability, observability, and less complexity will be adopted more rapidly than other innovations (Rogers, 1995).

However, Avgerou (2008) challenged the feasibility of transferring generic technical know-how into developing countries organizations with the expectation that it will result in the same organizational practices and outcomes as in their context of origin, and yet they retain the general assumptions on the validity of purpose of the attempted innovation as well as the validity of the underlying objectives and rationality of the transferred methods in their new context of practice. One should also consider ICT innovation and organizational change as socially embedded action, studied through social constructionist and situated research perspectives. The social embeddedness discourse view IS innovation as a locally socially constructed course of action. Innovation is studied as a locally constituted process of technology construction and organizational change. Its purpose arises from local problematizations and its course is determined by the way local actors make sense of it and accommodate it in their lives (Avgerou, 2008). The transformative ISDC discourse associates IS innovation with processes of change of the social, economic, and political conditions in developing countries. Specifically, it addresses the development struggle in which IS innovation is implicated (Avgerou, 2008). Transformative research is often based on the same theoretical underpinnings regarding social context as the social embeddedness discourse. However, while socially embedded analyses tend to take social, economic, and political relations in a developing country community or the world at large as given, the transformative discourse is explicitly concerned with the way ICT is implicated in the dynamics of their change. According to Avgerou (2008), the distinctiveness of the ISDC research lies in its attention to the developing countries’ context of IS innovation and problematization of the developmental role of IS innovation.

The essence of the significant contribution by Avgerou (2008)’s three discourses are summarized below:

i. The diffusion discourse assumes that the material/cognitive entities that comprise ICT and associated best practices of organizing are adequately independent from the social circumstances that give rise to them to be transferable, more or less intact, into any other society. Consequently, subject to suitable adaptation, these entities can make a desirable impact.

ii. The social embedded innovation discourse finds this assumption about the nature of IS oversimplifying and misleading. It has developed more elaborate ontologies of IS innovation as socially constructed entities, and therefore contingent in their perceived significance and their interplay with human actors and their social institutions (Avgerou, 2008). The focus should be on the process of innovation in situ, thus tracing the cognitive, emotional, and political capacities that individuals nurtured in their local social institutions bring to bear on unfolding innovation attempts. Through this approach the socially embedded innovation discourse sheds light on what, regarding an attempted innovation, is locally meaningful, desirable, or controversial, and therefore how innovation emerges (or is retarded) from the local social dynamics.

iii. The third discourse, the transformative IS
innovation intervention, introduces new elements in the IS research field by expanding the domain of IS research beyond the organization or inter-organizational links and addresses questions related with institutions of broader social collectivities.

In order to estimate how difficult or unattractive could be for the private sector to invest in areas where infrastructures are chronically missing, we will refer to the INEXSK. The Infrastructure, Experience, Skills, Knowledge approach: a measurement technique that aims to provide insight into how infrastructure, experience and skills may contribute to knowledge-based economic growth and development framework developed by Mansell and Wehn (1998) and shown on Figure 4. The approach would assess the gaps in the ICT infrastructures and skills development between developing and industrialized countries. The INEXSK approach is used to map and compare strengths and weaknesses of developing countries.

Footprints analysis made from the INEXSK approach would bring in evidence the tiny infrastructure basis of most of African countries to be combined with scarce production capabilities. In fact, considering the above framework, it appears clear that either the production nor the consumption of ICT could be ensured by the only efforts that African universities are making to promote and diffuse ICT knowledge (skills) and technologies (start up or projects implementation) in the continent. Cooperation or partnership on ICT infrastructure construction, including fixed, mobile and satellite networks as well as Internet should be strengthened. This could be done by promoting and facilitating the development of social enterprises in the sector. In addition to market, skills, infrastructures, the private sector needs appropriate regulations for the development of ICT activities in all related sectors.

At a national level among the African countries there is a great need to measure both infodensity and info-use, which are illustrated in Figure 5. Where there is a reasonable infodensity,
emphasize is placed a lot more on the info-use aspects

Panel data analysis

Panel Data is a data set that contains repeated observations over time, i.e., observations on multiple phenomena observed over multiple time periods for the same firms, individuals, households, enterprises, countries, or any set of entities that remain stable through time. Two important models are the fixed effects model and the random effects model. The fixed effects model is denoted as

\[ y_{it} = \alpha + \beta' X_{it} + u_{it} \]

where \( u_{it} = \mu_i + \nu_{it} \).

The random effects model assumes in addition that

\[ \mu_i \sim \text{i.i.d.} N(0, \sigma^2) \]

and

\[ \nu_{it} \sim \text{i.i.d.} N(0, \sigma^2) \]

that is, the two error components are independent from each other.

The can be written as shown below. The characterization of the \( \alpha \) component will be seen to be crucially important in what follows. In that case the \( \alpha \) term may be dropped and pooled OLS may be used to fit the model, treating all the observations for all of the time periods as a single sample.

\[ Y_{it} = \beta X_{it} + \alpha + \delta t + \epsilon_{it} \]

Panel data sets have several advantages over cross-section data sets:

- One can overcome the problem of bias caused by unobserved heterogeneity
- It is possible to investigate dynamics without relying on retrospective questions that may yield data subject to measurement error. In such a situation, one can develop a full and reliable life history, e.g. family formation, employment patterns, etc.
- They are often very large. If there are \( n \) units and \( T \) time periods, the potential number of observations is \( nT \).
- The study changers may be known, i.e. how many of them, what are they like, what caused change, etc.

This paper uses panel data analysis approach to analyze the economic variables, such as GDP per capital, of the African countries in order to develop an econometric model for a knowledge economy. However, the panel data drawbacks are as follows:

- Data analysis can be complex, with some methods that are advanced or still developing
- Data management tends to complexity, and so training would be required
- Data set access varies by topics and so may face disclosure risks
- Attrition (dropout of cases from recontacts)
- Long duration, e.g. reliance on politics for funding.

Economic growth and R and D

The Exogenous (Solow) Growth Model explains growth rates in real GDP per capita over the long-run. According to the endogenous model of growth, government policy can help increase the accumulation of knowledge capital through protecting intellectual property with patents and copyrights, subsidizing research and development, and subsidizing education. Therefore, economic growth depends on savings rate, education and research and development (R and D) guided by the appropriate knowledge frontiers of a nation.

Sadraoui and Chokri (2010, page 279) adopted a new econometric approach using a dynamic panel data studies to analyse if public investment in research and development are complement or substitute for private investment in R and D. The activity of R and D represents a significant source of development of new knowledge and technological innovation. Expenditure on research and development especially constitute a principal source of growth of productivity for innovating countries. Sadraoui and Chokri (2010) suggested that government should make a favourable environment for innovation and support of the companies to be incentivized to be innovated because the company itself constitutes a significant factor of innovation, and the resources of the latter are varied as the R and D or the acquisition of technology. Several legislative measures are taken to support the effort of investment, tax treatment, and the expenditure on R and D. The policies of innovation encourage the accumulation of a qualified labour on the one hand, and to help the companies achieve better markets’ prospect on the other hand (Sadraoui and Chokri, 2010). What has been the quantitative effect on productivity growth of information and communication technology (ICT) in SADC? A comparison is made between two countries, Israel a Zimbabwe, where Israel has made extensive investment in R and D, as shown on the table below, Table 3.

Economic growth is often measured by the rate of change of real GDP. Although this has many deficiencies, it omits output that is not bought/sold, e.g. leisure, pollution, congestion, etc. It also neglects income distribution, and so higher GDP per capita does not necessarily mean greater happiness, but it helps. An exogenous change is one that comes from outside the model and is unexplained by the model. It is the opposite of endogenous, something generated from within the system. Generally, these can help us to understand how
SADC can achieve sustainable growth and development in tangible economic ways, from the context of capital, skilled labour and technology.

**Neoclassic growth theory (Solow)**

The Neo-classic theory of growth is about technical progress premised on exogenous factors. This is an economic theory that outlines how a steady economic growth rate will be accomplished with the proper amounts of the three driving forces: labour, capital and technology. The theory states that by varying the amounts of labour and capital in the production function, an equilibrium state can be accomplished. When a new technology becomes available, the labour and capital need to be adjusted to maintain growth equilibrium.

The centerpiece of Solow’s neoclassical model is the production function: \( Y = AF(K, L) \), where \( Y \) is output, \( K \) is capital, \( L \) is labour, and \( A \) is a productivity parameter. Assuming constant returns to scale (CRS), we can rewrite the production function as: \( y = Af(k) \), (Kabanda, 2008), where

- \( y = Y/L \) (output per unit of labour), \( k = K/L \) (capital per unit of labour), and \( f(k) = F(k, 1) \)

Output per capita \( y \) increases because of increases in capacity \( k \) and improvements in technology \( A \).

The neoclassical model emphasizes growth through capital accumulation: \( \dot{K} = I - \delta K \)

where \( I \) is investment, \( \delta \) is the rate of capital depreciation.

Expressing in units of labour and assuming that \( I = sY \) we have

\[
    k = sAf(k) - (n + \delta)k
\]

where \( s \) is the saving rate, \( n \) is the rate of population growth, and all parameters are exogenous.

In the Solow model without technological progress (shown on Figure 6), saving rate and population growth are determinants of per capita income. An increase in saving rate or a decrease in population growth causes a period of growth (but eventually the growth ceases as the new steady state is reached) and increases the long run (steady-state) per capita income.

In the Solow model with technological progress, the growth rate of per capita income is determined solely by the exogenous rate of technological change. In this case, convergence exists, but it’s conditional. A change in the saving rate or in the population growth rate has a level...
effect but not a growth effect. In the Solow model only changes in the rate of technological progress have growth effects; all other changes have only level effects. To augment the Solow model one has to consider also human capital, geography, government policies and the role of institutions in the country. The problem with Solow’s model is that it takes productivity as given, wherein Solow’s model also predicted that growth rates among nations would tend to converge, along with profit and wage rates. Wages and prices on a global scale should converge. In theory, countries tend to specialize in producing those commodities in which they have a comparative advantage.

The neoclassical growth model seemed unable to answer some burning questions about economic growth: Is technological change exogenous from an economic point of view? Technology is probably not exogenous. Technology depends on economic factors such as the amount of capital available to workers, the capital/labour ratio, etc.

Endogenous growth theory

The endogenous theory of growth recommends the relaxation of certain neo-classic assumptions and incorporates the failures of the market (Sadraoui and Chokri, 2010). Endogenous growth theory is “an equilibrium model of endogenous technological change in which long-run growth is driven primarily by the accumulation of knowledge by forward-looking, profit-maximizing agents.” – Romer (1990). The endogenous growth model is a model of long-run economic growth that emphasizes that technological change is influenced by economic incentives and so is determined by the working of the market system. According to the endogenous model of growth, government policy can help increase the accumulation of knowledge capital in three ways:

- Protecting intellectual property with patents and copyrights;
- Subsidizing research and development; and
- Subsidizing education.

The endogenous models of growth are characterized by a great diversity of the resources selected including the investment in physical capital, in human capital, public capital, and labour division, learning by doing, research and the technological innovation (Sadraoui and Chokri, 2010). The endogenous theory of growth recommends that technical progress rises from the R and D carried out by companies with lucrative goals. However, research and development constitute a significant factor of production process. Indeed, if long-term growth is directed by factors of production based on the knowledge which belongs to the normal structure of costs of the company, then, by changing the cost of these factors by direct subsidies of tax incentives or of marketing policies, the public administrations can influence the long-term growth (Sadraou and Chokri, 2010).

The production function shows the maximum output that can be produced using specified quantities of inputs, given existing technical knowledge. The output is a function of capital, labour, land, raw materials, and technology. The motivation for the new growth theory and the Romer (1990) model can be represented by the following Cobb-Douglas production functions (Kabanda G., 2008):

\[
Y_t = AK_t^\alpha L_t^{1-\alpha} K_t^\beta \\
Y = AK^{\alpha+\beta} L^{1-\alpha} \\
g - n = \frac{\beta}{[1-\alpha + \beta]}
\]

Sometimes market failures lead to a need for public policy intervention. We observe that income of people and revenues of government depends on economic growth. Knowledge and innovation are perceived as the main elements supporting competitiveness in a nation. Differences in wage rates and profit rates result from differences in growth rates. Differences in growth rates result from differences in education. Human capital increases proportionate to increases in the capital stock. Firms engage in R and D, which increases the knowledge base having external benefits. Therefore, growth depends on savings rate, education and R and D, as guided by developments in the knowledge frontiers of a nation.

In these models discussed, growth is associated with:
- A short term increase in employment and income levels;
- As an increase in individual well-being; and
- As an increase in real productive capacity of a country.

There has to be a distinction between the quantity and quality of labour. Education, by increasing labour productivity, increases also efficiency and growth. However, the state of technical knowledge changes through time because of:

- Inventions;
- Embodiment of knowledge in capital; and
- Learning by doing.

Chaos Theory

Design of a digital learning environment is often very complex, especially when one considers the ubiquitous context where learners seem to be everywhere at the same time and using different access devices and technologies (The Free Dictionary, 2008). The learners in ubiquitous learning environments are able to access the various contents on the Web, search the electronic
databases, interactively communicate with instructors and other learners and obtain knowledge anytime and anywhere through wireless technologies (Chang and Sheu, 2002). According to Yang (2006), the main purpose of ubiquitous learning is to provide intuitive ways for identifying learning collaborators, learning contents and learning services in the right place at the right time. The paper applied Chaos Theory to design and understand a digital learning environment with fully functional interactive e-learning facilities, typical of a modern digital learning environment used in various e-learning environments, e.g. Moodle. The Zimbabwe Open University (ZOU) Moodle-based e-learning platform is used in this case to create an analogy using Chaos Theory.

Chaos theory is the qualitative study of unstable, aperiodic behaviour in deterministic, non-linear, dynamical systems. It often seeks to understand the behaviour of a system by reconstructing its attractor, and knowing this attractor gives us qualitative understanding. This includes theoretical hypotheses that assert relationships of qualitative similarity between its abstract models and the actual systems it studies. Dynamics is used more as a source of qualitative insight than for making quantitative predictions. Dynamics of a fluid is described by its velocity field \( \mathbf{V} \). Vorticity is defined as the curl of velocity \( \mathbf{W} = \nabla \times \mathbf{V} \). At low velocities vortices are generally observed when a fluid is subject to rotation, the most common example being the kitchen sink vortex, while at high velocities, rotation is inherent in the fluid. They are known to occur in various forms such as lines, rings, etc. (Murugesh and Lakshmanan, 2005).

A learner is often overwhelmed with massive volumes and different kinds of Information to learn from, e.g. from social media. These sources of Information or learning objects are characterised by vortices acquired from different subjects and courses, as shown in Figure 7 Above, especially in a ubiquitous setup.

**Figure 7. Learning vortices (objects) in a Chaotic Learning Environment**

**Chaotic Systems**

The behaviour of a disordered system could be due to random noise or low-dimensional deterministic but chaotic dynamics. The Lorenz system gives an approximation to the Navier-Stokes equation for a convection system, one of the first sets of differential equations found to show a chaotic behaviour. The system consists of three non-linear first-order ordinary differential equations:

\[
\begin{align*}
x &= \sigma(y - x) \\
y &= \rho x - y - xz \\
z &= -\beta z + xy
\end{align*}
\]

There are three degrees of freedom for the Lorenz system, showing that the system evolution takes place on a well-defined subset of three-dimensional space (an "attractor") (Gershenfeld, 1988). An attractor is a set of points or states in state space to which trajectories within some volume of state space converge asymptotically over time (Kauffman, 1993). However, it is important to distinguish between random noise and deterministic chaos. Deterministic chaos occurs in a low-dimensional space, while random noise does not.

**Time Delay and analyzing the Dynamics**

Information theory can be used to quantify the relation between the time delay and the amount of information available from a measurement, as is the case in message communication in signalling systems. Historically, information theory was developed by Claude E. Shannon to find fundamental limits on compressing and reliably storing and communicating data. The information entropy of a system that has a meter to indicate \( n \) different values \( v_1, v_2, \ldots, v_n \) with observed probabilities \( P(v_1), P(v_2), \ldots, P(v_n) \), is defined by:

\[
I = - \sum P(v_i) \log_2 P(v_i)
\]

The function defined above is continuous in the probabilities and, if all the probabilities are equal, it is a monotonically increasing function of \( n \). If a choice can be broken down into successive sub-choices, then \( I \) should be a weighted sum of the entropies of the sub-choices. I provide a measure of the amount of information that is gained by a measurement of \( v \). If a measurement has a probability of either one or zero then \( I \) equals zero, and the entropy is maximized by the greatest uncertainty (\( P = \frac{1}{2} \)).
The entropy can be naturally defined for continuous quantities:

\[ I = -\int P(s) \log_2 P(s) \, ds. \]

Our goal is to be able to predict information or knowledge about the next measurement in the next time delay or interval, for the purposes of disseminating knowledge to the learner. Multisource information theory deals with information transmission in a network. Such a network includes information sources (one or many), the destinations (one or many) where information should be delivered, and channels that are used for transmission; some (or all) channels may have limited capacity (Shen, 2006).

A manifold is a generalised notion of a surface that allows it to be described without reference to an external coordinate system. A simple two-dimensional manifold can be obviously embedded into a two dimensional real space. A hydrodynamic system has infinitely many degrees of freedom, yet just beyond the onset of convection it can act as a very low dimensional system. The Center Manifold theorem guarantees that the linearization of a dynamical system accurately reflects the full non-linear dynamics. In the local linearization there will be stable, unstable, and neutrally stable degrees of freedom. Ultimately, the unstable degrees of freedom will diverge until they reach a bound, the table degrees will exponentially vanish, and so the dynamics will collapse down onto the neutral and stable degrees of freedom (“center manifold”). The center manifold, if it exists, will frequently have fewer dimensions than the full system, and so the system will behave as if it had only this reduced number of degrees of freedom. A more complicated possibility is for the stable and unstable manifolds to cross; a situation related which is related to chaos.

The Lorenz attractor comes from a three-dimensional system, yet its correlation dimension of 2.05 is distinctly less than three. This difference suggests that a full three-dimensional plot of the evolution of the Lorenz system, contains redundant information about the flow. The Poincare section is a standard technique, generally applied to near-periodic systems, that is used to dissect the flow and produce a more lucid representation. This section is formed by taking a surface transverse to the flow, and then plotting the intersections of the flow with the surface. The Poincare section replaces the continuous time dynamical system with a map. This map may have a much simpler structure than was obvious from the original system, and serve as a useful step and guide for further analysis.

**Lyapunov Exponents**

The divergence of nearby trajectories underlies the sensitive dependence on initial conditions in a strange attractor. Whereas fractals quantify the geometry of strange attractors, Lyapunov exponents quantify the sensitivity to initial conditions. The Lyapunov exponents quantify the relationship between nearby trajectories, and provide another indicator of the presence of chaos. The Lyapunov exponent or Lyapunov characteristic exponent of a dynamical system is a quantity that characterizes the rate of separation of infinitesimally close trajectories (http://en.wikipedia.org/wiki/Lyapunov_exponent).

Quantitatively, two trajectories in phase space with initial separation \( \delta Z_0 \) diverge

\[ |\delta Z(t)| \approx e^{\lambda t} |\delta Z_0|, \]

where \( \lambda \) is the Lyapunov exponent.

Lyapunov exponents measure the rate of divergence of trajectories on an attractor or nearby trajectories in a dynamical system. The rate of separation can be different for different orientations of initial separation vector. They characterize the dynamical system as a whole and do not depend on any specific orbit. Lyapunov exponents also reveal how infinitesimal perturbations will behave over long time periods rather than short ones. Generally, Lyapunov exponents measure how random a system is or its stochasticity. A positive value for the Lyapunov exponent usually indicates that nearby trajectories will diverge and that the flow is chaotic (Anderson and Born, 2003). An analysis of the Lyapunov exponents will allow us to determine whether two nearby orbits will converge toward each other or diverge from each other. This will lead us to a way of quantifying the sensitive dependence on initial conditions which we observed numerically in the Lorenz equations. Similar to the design of digital learning environments being pursued on the ZOU Online platform, the local Lyapunov exponents can be used to indicate where it would be most important to reduce the magnitude of navigation uncertainties (Anderson and Born, 2003). However, there are several technical difficulties associated with the predictive power of the Lyapunov exponents, as was shown on the study on epilepsy, which include the difficulty in computing the Lyapunov exponents from time series, complexity of the dynamical systems concerned and the fundamental relationship between fractal dimension and Lyapunov spectrum (Lai et al., 2001).

Consider the growth of an arbitrary perturbation \( dx \) about a point \( x \). The growth rate of this perturbation will be exponential, with the rates locally given by the eigenvalues of the Jacobian matrix:

\[ \frac{dx}{dt} = f(x) \]

\[ \frac{d(x + \delta x)}{dt} = f(x + \delta x) \]

\[ df/dt + (d/dt) \delta x = f(x) + (Df) \delta x \]

Each of the eigenvectors of the Jacobian matrix \( Df \) will locally grow at a rate \( e^{\lambda_i t} \), where the \( \lambda_i \)'s are the eigenvalues of the matrix. Taking the flow to be \( u_t \), the growth of \( dx \) is given by the Jacobian, \( T_x \) of the flow:

\[ \delta x(t) = T_x \delta x(0) = (D_x u_t) \delta x(0) \]

The Lyapunov exponents are given by the asymptotic growth rate of the eigenvalue of \( T_x \):
The Chaos Theory nomenclature equivalent to the ZOU E-learning platform components is summarized in the table above, shown as Table 4, illustrating the correlation between the two areas, where the ZOU Moodle-based e-learning platform is used in this research:

**Social media and its complexity in learning**

Social media are the various forms of user generated content and the collection of websites and applications that enable people to interact and share information online. Social media can be used in a digital learning environment, although this precipitates chaos to the learning process or a high degree of complexity. Serious social jokes and events often dominate such platforms and so the teacher is not in full control of the content and its ramifications to the learning process, although some innovation is often exhibited. For educational purposes, the most popular social media used include Facebook, YouTube, Blogs, MySpace, etc. The commonly used social media include the following, which present...
### Table 5. The difference between social and industrial media

<table>
<thead>
<tr>
<th>Area of difference</th>
<th>Specific Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach</td>
<td>Both industrial and social media technologies provide scale and are capable of reaching a global audience. Industrial media, however, typically use a centralized framework for organization, production, and dissemination. Social media are by their very nature more decentralized, less hierarchical, and distinguished by multiple points of production and utility.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>The means of production for industrial media are typically government and/or corporate (privately-owned); Social media tools are generally available to the public at little or no cost.</td>
</tr>
<tr>
<td>Permanence</td>
<td>Industrial media, once created, cannot be altered (once a magazine article is printed and distributed changes cannot be made to that same article) whereas social media can be altered almost instantaneously by comments or editing.</td>
</tr>
<tr>
<td>Usability</td>
<td>Industrial media production typically requires specialized skills and training. Conversely, most social media production requires only modest reinterpretation of existing skills; in theory, anyone with access can operate the means of social media production.</td>
</tr>
<tr>
<td>Immediacy</td>
<td>The time lag between communications produced by industrial media can be long (days, weeks, or even months) compared to social media (which can be capable of virtually instantaneous responses). However, as industrial media begins adopting aspects of production normally associated with social media tools, this feature may not prove distinctive over time.</td>
</tr>
<tr>
<td>Community media</td>
<td>Constitute a hybrid of industrial and social media. Though community-owned, some community radio, TV and newspapers are run by professionals and some by amateurs. They use both social and industrial media frameworks.</td>
</tr>
</tbody>
</table>

Complexity and forms of chaos in the digital learning environment:
- Social networking sites (*Facebook, Twitter, Myspace*)
- Blogs (*Wordpress*)
- Video sharing sites (*YouTube*)
- Photo sharing sites (*Flickr*)
- Crowdsourcing (*Wikipedia*)
- User reviews (*Amazon, Yelp*)
- Streaming sites (*Ustream*)
- Social bookmarking (*Digg, del.icio.us*)

The difference between social media and industrial media are summarized as follows: Table 5

**RESEARCH METHODOLOGY**

- The Mixed Methods methodology was used. Mixed methods often combine *nomothetic* and *idiographic* approaches in an attempt to serve the dual purposes of generalisation and in-depth understanding—to gain an overview of social regularities from a larger sample while understanding the other through detailed study of a smaller sample.
- The methodology used a critical review literature on the panel data models, the ICT innovation discourses, Chaos Theory and the Endogenous growth model for the knowledge economy.
- The methodology used was largely qualitative on human capital development and digital learning
- Technology diffusion
- Quantitative on GDP and Infodensity covering 18 countries in East and Southern Africa.
- The 18 countries covered by the qualitative study are South Africa, Angola, Bostwana, Burundi, D.R. Congo, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.
- Data on GDP was collected from the IMF and World Bank, and data on infodensity was obtained from the International Telecommunications Union (ITU).

**Analysis of Results**

**GDP per capita**

The nominal GDP per capita for the Eastern and Southern African countries covered by the study are illustrated by the chart below on Figure 8 below.

**ICT4D and Infodensity**

The ICT developments in the SADC countries are summarized as follows:
Information and communication technologies (ICTs) have great promise to reduce poverty, increase productivity, boost economic growth, and improve accountability and governance.

ICTs help reduce poverty directly and indirectly by addressing all the millennium development goals (MDGs). ICTs provide information to all communities, thereby reducing the digital divide especially in rural areas, including contributing to pro-poor market developments such as microfinance and mobile money.

In spite of its recognized benefits, the availability of ICTs in Africa has remained inadequate in comparison with other parts of the world. Despite the benefits above referred, the gap between “Developed Countries” and “Africa” is wide and limits Africa’s ability to develop competitiveness and to effectively participate in the global economy.

Telecommunications Services are now considered to be a basic necessity of all African countries have revamped regulations, opened their telecommunication markets to competition, and privatized telephone operators in order to realize the full potential of ICTs. This has attracted great amounts of private investment and radically expanded access. Governments have also used a number of IT applications to transform back-end finance and public administration functions.

Promotion of ICT entails the availability of telecommunications and broadcasting infrastructure at National and Continental level. It is envisaged that ICTs will transform services and strengthen accountability and governance, improve public services, and enable more inclusive private delivery of services.

Use of social media has grown at phenomenal rates, especially Facebook, Twitter, LinkedIn, YouTube, etc. The near ubiquity of mobile technology and the proliferation of social networks and geospatial tools create new ways for citizens to express demands and take initiatives in support of development.

Innovation in advancing ICTs is critical for development, especially ICT4D. Innovation, mainly led by the private sector and at the grassroots level, relies on creativity’s ability to blossom, which may not operate in phase with government bureaucracy. Rather than direct
intervention, governments are encouraged to focus on the key enablers of ICT innovation: developing a skilled workforce, implementing ICT innovation policies, promoting ICT entrepreneurship, and facilitating a bottom-up approach to innovation. The number of internet users per country, as at end of 2012, are shown below in Figure 9 Above.

Figure 10 shows the internet penetration rates from 2000 to 2010. The mobile density levels for the period 2000 to 2010 are shown in Figure 11 Above. Like other African countries, Zimbabwe witnessed one of the fastest growth rates in mobile density as shown in Figure 12 below.
The logical framework for education for sustainable development, a more accurate measure of human capital development, for Zimbabwe is as shown below in Figure 13. The logical framework for sustainable development requires the policy framework, human capital development, centres of excellence, and infrastructure and facilities (Kabanda, 2012b).

The key challenges facing human capital development in the SADC were identified as the following:

1. Improve access, equity and retention
2. Improve quality assurance
3. Increase flexibility and responsiveness to meet market demand and the priorities of the national development agenda
4. Increase diversity in programmes and forms of delivery
5. Increase efficiency and effectiveness by rationalizing existing resources, improving management systems, and diversifying sources of finance.
6. Corporate Governance, e.g. regulatory mechanisms for policy implementation, facilitating regional integration and international cooperation, etc.
7. National level Institutional challenges:
   - Inadequate funding and inappropriate funding mechanisms
   - Maintenance of infrastructure, equipment, ICTs and facilities
   - Leadership development and planning capacity
8. General National Human Capital Challenges identified
9. Brain drain or human capital flight is an emigration of trained and talented individuals (“human capital”) to other nations or jurisdictions, due to conflicts, lack of opportunity, health hazards where they are living or other reasons. The push factors include pay, working conditions and broader management and governance factors that encourage professionals to exit their own systems and leave their country.
10. Conditions of service and Innovation in public sector
11. Addressing gender and societal imbalances
12. Enhancing science, technology and enterprise (SMEs) development
13. Transformational Leadership among our corporate leaders

However, pull factors at work in the SADC region are those factors that encourage professionals to move to other countries, including shortages and active recruitment from high income countries. These pull factors include:

- Higher wages and income
- Higher standard of living
- Better working conditions; job and career opportunities and professional development
- Substantial funds for research, advanced technology, modern facilities; availability of

Figure 13. Logical framework for education for sustainable development for Zimbabwe
experienced support staff

Political stability

Modern educational system; prestige of ‘foreign training’

Meritocracy, transparency

Intellectual freedom

In conclusion, the following are the recommended the critical human capital development strategies:

- Increase the numbers and improve the retention of teachers/lecturers/administrators /technologists in schools and tertiary institutions
- Establish emphasis on exploration of innovative ways of retaining skilled manpower
- Empower indigenous people and reduce dependency on expatriates
- Embark on private-public partnerships
- Promote facilities for open and distance learning throughout the country
- Establish connection with science and technology, annual expositions and intellectual fairs
- Periodically review curricula to keep abreast of developments that are responsive to national challenges

However, the education sector is advised to address the following problems:

- Quality of teaching and lack of teachers
- Equitable access, including girls/women
- Lack of materials
- Local languages as medium of instruction
- Pertinence of curriculum
- Reform implementation
- Overemphasis on basic education (vs. secondary/higher, lifelong learning, non-formal, TVET, etc.)
- HIV/AIDS
- Financing/management

From the survey conducted of selected higher education institutions, 60% agreed with a scenario outlining more change:

- By 2020, higher education will be quite different from the way it is today. There will be mass adoption of teleconferencing and distance learning to leverage expert resources. Significant numbers of learning activities will move to individualized, just-in-time learning approaches. There will be a transition to "hybrid” classes that combine online learning components with less-frequent on-campus, in-person class meetings. Most universities’ assessment of learning will take into account more individually-oriented outcomes and capacities that are relevant to subject mastery. Requirements for graduation will be significantly shifted to customized outcomes.
- Capacity building is critical to education of SADC member states, and this can be achieved through mainly ODL to cover:

  - Teaching in ODL

  - Online teaching, including E-learning and ODeL
  - ODL pedagogical and Andragogical skills
  - Use of OER materials and Open access
  - Quality Assurance
  - Innovation Schools and Globalisation
  - Next Generation Learning Models
  - Professional development
  - Research skills
  - Inquiry Based Science Education
  - Scholarship of ODL in Africa

CONCLUSION

The Southern African countries, embodied as the Southern African Development Community (SADC) region, face sustainable development problems and low global competitiveness. Innovation in the education sector presents a promissory note that can stimulate an endogenous growth of the knowledge economy and reduction of poverty. The paper was purposed to develop an endogenous growth model for a knowledge economy for SADC countries where digital learning is the engine for sustainable growth with its associated technological futures and complexity. The diffusion discourse and the social embedded innovation can achieve a desirable impact in development, mainly through ICTs for development (ICT4D). Social media is one area that has introduced complexity in the digital learning environment. Technology diffusion in SADC is not exogenous. The endogenous growth theory is a model of long-run economic growth that emphasizes that technological change is influenced by economic incentives and a great diversity of resources in an African environment, which largely supports innovation, embodiment of knowledge in capital and learning by doing.

Avgerou (2008) has conducted extensive research on discourses on innovation and development in Information Systems (IS) in developing countries. Discourses are research approaches emanating from assumptions on the context and consequences of IS innovation in developing countries. Innovations diffuse through a social system explained by the diffusion of innovation theory (Rogers, 2003). One should also consider ICT innovation and organizational change as socially embedded action, studied through social constructionist and situated research perspectives. Innovation is studied as a locally constituted process of technology construction and organizational change.

The Exogenous (Solow) Growth Model explains growth rates in real GDP per capita over the long-run. According to the endogenous model of growth, government policy can help increase the accumulation of knowledge capital through protecting intellectual property with patents and copyrights, subsidizing research and development, and subsidizing education. Therefore, economic growth depends on savings rate, education and research and
development (R and D) guided by the appropriate knowledge frontiers. The activity of R and D represents a significant source of development of new knowledge and technological innovation. Expenditure on research and development especially constitute a principal source of growth of productivity for innovating countries.

Economic growth depends on savings rate, education and R and D, as guided by developments in the knowledge frontiers of a nation. Endogenous growth theory is “an equilibrium model of endogenous technological change in which long-run growth is driven primarily by the accumulation of knowledge by forward-looking, profit-maximizing agents.” The endogenous growth theory recognizes that there may be significant externalities to capital. The endogenous growth model is a model of long-run economic growth that emphasizes that technological change is influenced by economic incentives and so is determined by the working of the market system. According to the endogenous model of growth, government policy can help increase the accumulation of knowledge capital. The endogenous models of growth are characterized by a great diversity of the resources selected including the investment in physical capital, in human capital, public capital, and labour division, learning by doing, research and the technological innovation (Sadraoui and Chokri, 2010).

The paper applied Chaos Theory to design and understand a digital learning environment with fully functional interactive e-learning facilities, typical of a modern digital learning environment used in various e-learning environments, e.g. Moodle. Multisource information theory deals with information transmission in a network. The Poincare section replaces the continuous time dynamical system with a map. The Lyapunov exponent or Lyapunov characteristic exponent of a dynamical system is a quantity that characterizes the rate of separation of infinitesimally close trajectories. Lyapunov exponents measure the rate of divergence of trajectories on an attractor or nearby trajectories in a dynamical system. Generally, Lyapunov exponents measure how random a system is. This theoretical framework is applicable to a digital learning environment. Social media can be used in a digital learning environment, although this precipitates chaos to the learning process or a high degree of complexity.

The methodology used was a mixed methodology which was largely qualitative on human capital development and technology diffusion, and quantitative on GDP and Infodensity covering 18 countries in East and Southern Africa. An endogenous model for sustainable economic growth was developed through panel data analysis.

Information and communication technologies (ICTs) have great promise to reduce poverty, increase productivity, boost economic growth, and improve accountability and governance.

Innovation in advancing ICTs is critical for development especially ICT4D. Rather than direct intervention, governments are encouraged to focus on the key enablers of ICT innovation: developing a skilled workforce, implementing ICT innovation policies, promoting ICT entrepreneurship, and facilitating a bottom-up approach to innovation. Like other African countries, Zimbabwe witnessed one of the fastest growth rates in mobile density as shown in Figure 12 Above. The logical framework for sustainable development requires the policy framework, human capital development, centres of excellence, and infrastructure and facilities.

The way forward for sustainable development in the SADC countries includes the following fundamental steps:

- Promotion of technology development, transfer and diffusion to Africa and further develop technology and knowledge available in African centres of excellence;
- Supporting African efforts to develop affordable transport systems and infrastructure that promote sustainable development and connectivity in Africa;
- Leadership development and planning capacity;
- Enhancing science, technology and enterprise (SMEs) development;
- Harmonisation and development of Private Public Partnerships (PPPs), and
- Effective utilisation of Human Capital.

REFERENCES


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Appendix 1: Definitions

Sustainable development

World Commission on Environment and Development (WCED). Our Common Future. Oxford. Oxford University Press, 1987, page 43. is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Human capital

Is about “the knowledge, skills and competences and other attributes embodied in individuals that are relevant to economic activity” (OECD, 1998).

The Exogenous (Solow) Growth Model

Explains growth rates in real GDP per capita over the long-run with measurable labour productivity expressed as a quantity of goods and services that can be produced by one worker in one hour of work.

The Endogenous growth model

Is a model of long-run economic growth that emphasizes that technological change is influenced by economic incentives and so is determined by the working of the market system. Government policy can help increase the accumulation of knowledge capital through protecting intellectual property with patents and copyrights, subsidizing research and development, and subsidizing education.

Open and distance learning (ODL)

Refers to a philosophy of learning that uses an array of educational methods and is based on the principle of flexibility to increase access to and equity in openness with a specific role to achieve a development function, social justice/access, and social mandate aimed at developing human capital.