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UNRAVELING THE IMPACT OF INVESTMENTS IN ICT, EDUCATION AND HEALTH ON DEVELOPMENT: AN ANALYSIS OF ARCHIVAL DATA OF FIVE WEST AFRICAN COUNTRIES USING REGRESSION SPLINES

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ABSTRACT

For more than a decade African nations have been investing in Information and Communication Technologies (ICTs) as a strategy for fostering development. Under the auspices of international development agencies such as the United Nations (UN), and World Bank these nations have been constituting and implementing technology strategies that aim to bring 'digital opportunities' to all constituents—especially those who are impoverished and living in remote communities. These strategies have put new demands on national governments to invest both human and financial resources into the expansion of telecommunications infrastructure and the training of new users. Such investments, however, have received some scrutiny as some claim that developing nations should focus their limited financial resources on the improvement of education or healthcare. Others argue that these ICT investments are vital for development, but should be synergized with others such as education and healthcare. In this study we will employ Multivariate Adaptive Regression Splines (MARS) to explore the interaction amongst investments in ICT, education and healthcare. We further analyze how each class of investments impacts human development measures in five West African nations: Benin, Cameroon, Senegal, Ivory Coast and Niger. With such an analysis we illustrate the interdependencies amongst the three classes of investments and conclude that investments in ICTs alone are not enough to significantly impact human development. Complementary investments in education and healthcare must be given equal consideration.

1. INTRODUCTION

The view that communication technologies can act as conduits of development has been pervasive in discourse emerging from international organizations such as the UN, International Telecommunications Union (ITU), and the World Bank (Gilhooly and Ocampo, 2005; Hicks and Streeten, 1979; ITU, 2003a, 2003b, 2003c; UNRISD, 2001a). The general consensus is that these technologies can provide novel opportunities for constituents in developing nations to access information. Constituents can then use this information to educate themselves, increase their productive capacity and improve their health. Put simply, information provides opportunities for personal empowerment, which thereafter leads to development at an aggregate level. Based on these assumptions that ICTs foster development, there has been a collaborative effort among national governments and international organizations to constitute and implement information communication technology for development (ICT4D) strategies. These strategies have put new demands on national governments to invest both human and financial resources for the expansion of telecommunications infrastructure and the training of new users.

It is important to note that investments can be generally classified into two categories. The first-order investments address the immediate needs of impoverished individuals (Servon, 2002). Resources in this class are allocated towards the provision of food, clothing, and housing as well as the improvement of healthcare or education (primary and secondary level) (Servon, 2002). The second-order investments are meant to create opportunities for people to escape conditions of poverty and marginalization. They include investments in communication technologies, post-secondary education, or economic literacy.

Many have argued that governments of developing nations should allocate their limited financial resources to the first-order class of investments. They assert that developing nations have a greater need for schools, basic healthcare, and clean water rather than telecommunications infrastructure (Sunden and Wicander, 2002). Others argue that ICT investments will only have positive impacts when synergized with first-order investments (Ngwenyama et al., 2006). For example, using stepwise OLS regression, Ngwenyama et al. showed that complementary investments in ICTs, healthcare and education could have significant impacts on human development measures (Ngwenyama et al., 2006). The study also demonstrated that each class of investments had a threshold—a point at which it no longer affected HDI measures. This means that increasing investments do not always positively affect the HDI. Although this study acknowledged a relationship between the three types of investments, it was not able to explicate the interaction between them. Understanding this interaction is a primary goal of this research.

In this study we will employ Multivariate Adaptive Regression Splines (MARS) to: (1) examine the interaction amongst investments in ICT, education and healthcare; (2) delineate how each class of investments affects human development measures; (3) investigate how these investments can be synergized to more effectively impact human development. This paper will focus on five West African nations—Benin, Cameroon, Senegal, Ivory Coast and Niger—and use data extrapolated from the UN and ITU databases. It will proceed as follows: section 2.0 will provide a definition of development; section 3.0 will introduce the context of investigation, providing an overview of the five African nations; section 4.0 will discuss the methodological approach; finally, section 5.0 will present the results of our data analysis and make suggestions for future research.

2. DEFINING HUMAN DEVELOPMENT

Before going into the discussion of ICT and development it is important for us to establish some understanding of what is meant by development. For many years, discussions about development focused on the expansion of national economies or measures of per capita income. However, during the late 1980s the concept of development has been extended to include measures of social welfare. As economist David Fielding explained: “A nation’s progress with respect to its material wealth is not independent of its progress in other spheres…economic growth promotes democratic development; education is good for health; and health is good for education” (Fielding, 2002). From this perspective development is not purely a measure of the output. It also includes measures of social improvement that mutually enforce the economic success of a nation.

In 1990 the United Nations Development Program (UNDP) introduced their notion of human development, which provides a more encompassing measure of progress (UNDP, 2006). According to this perspective development is not simply about the rise or fall of incomes. Instead, it is about expanding the choices of people so that they can live the type of lives that they value. The objective of human development practitioners is thus to find

innovative ways to expand these choices and to create an environment in which individuals can develop their full potential. In the same report the UNDP introduced the human development index (HDI), which measures a nation's average achievements in three basic aspects of human development: longevity (life expectancy at birth), knowledge (literacy rates and school enrollment ratios) and standard of living (GDP per capita). Based on a nation's performance in these three areas, they are given a score and then ranked accordingly to the scores of other nations.

The concept of human development is central to this study. The HDI is used to contextualize the nations under investigation and explicate their level of development. Furthermore, the components of the HDI are used as variables in this analysis. This will allow us to gauge how investments can affect levels of human development. To date there are few empirical studies examining this link between investments—particularly ICT—and human development. The empirical research conducted thus far has found a correlation between ICT investments and economic growth (Colecchia and Schreyer, 2002; Helpman, 1998; Smith, 2001). This research, however, has been primarily focused on developed nations and does not explicate how such investments translate to social improvement. There are numerous reasons why the relationship between ICT permeation and human development has been under-investigated. Until the constitution of the HDI, there has been not been a standardized measure of human development. As such, a comparative analysis between nations was difficult. Furthermore, attempting to simply correlate technology investments to human development measures would lead to inadequate conclusions as there are numerous other factors that may impact human development measures. Hence, a sophisticated approach—which considers these factors—is needed to appropriately study this correlation. Such an approach will be introduced in this study.

3. THE CONTEXT OF INVESTIGATION

We started this study with the intention of systematically analyzing the impact of investments in ICT on development in several African countries over the last decade. However, as our work progressed we encountered difficulties in data collection which forced us to limit our study to five French speaking countries in West Africa: Benin, Cameroon, the Ivory Coast, Senegal and Niger. These countries were chosen primarily because we were able to obtain data which was needed for this analysis. They were also chosen because they are similar in numerous ways. They share a common French colonial history and have recently been granted independence after three centuries of French colonial rule. Four of them Benin, Ivory Coast, Niger and Senegal were French colonies. Cameroon was a German colony until the end of World War I. It was thereafter governed jointly by Britain and France.

All five of these African countries placed close to the bottom of HDI ranking in 2006 (see table 1). Niger not only ranked at the bottom of the five nations, but also on the HDI as a whole. There is some variation in measures such as literacy rates in our sample. The lowest rate is that of Niger in which only 26% of the population is literate. The most literate nation was Cameroon with 75% of the population being literate—an anomaly in the context of our sample. This high literacy rate can explain why the country is ranked the highest in the HDI. Furthermore, the majority of these nations are battling with the HIV/AIDS pandemic with as many as 7% of the population infected in countries such as Cameroon and the Ivory Coast (CIA, 2006). These rates can explain why these nations ranked relatively low in measures such as average life expectancy, which ranged from 45 to 52 in this sample. Also, the majority of these countries depend heavily on the agricultural sector for the generation of GDP. Senegal and Benin, for example, generate over a third of their GDP and employ nearly

half of their constituents in this sector (CIA, 2006). Finally, with the exception of Niger, the nations in our sample had close to half of their populations living in urban areas. Given the similarities between these five nations we found that they were appropriate for this comparative analysis.

Countries	Population (Millions)	% Living in urban Area	Land area (Sq km)	Life Expectancy Years	GPD per Capita Constant US$	Literacy Rate %	HDI	HDI Ranking 2006[1]
Cameroon	16.4	51	465400	48	653	75	0.499	144
Senegal	10.5	50	192530	52	503	39	0.43	156
Benin	6.89	45	110620	53	393	56	0.411	163
Ivory Coast	17.1	45	318000	45	596	60	0.396	164
Niger	12.1	22	1266700	46	179	26	0.292	177

Source: UN Database and CIA Factbook

Table 1: Demographic Background of the Countries

4. METHODOLOGICAL APPROACH

In this paper we use a regression splines (RS) analysis method called Multivariate Adaptive Regression Splines (MARS) (Abraham and Steinberg, 2001; Friedman, 1991; Hastie et al., 1994). While ordinary regression methods (such OLS) attempt to model the relationship between dependent and predictor variables using a single function, the RS method models the relationship between dependent and independent variables as a piecewise polynomial function $f(x)$ (called basis functions, BF) (Abraham and Steinberg, 2001; Hastie et al., 1994). The result is a model comprising a linear combination of BF joined together by knots instead of a smooth curve or straight line. The coefficient of each BF is estimated by minimizing the sum of square errors for each region. Both regression and regression splines methods can identify the order of importance of the independent variables in a predictive model, and estimate the value of the coefficient for each independent variable. However, if the impact of an independent variable on the dependent variable is conditional, then regression splines can identify such conditions while regression cannot. Thus, regression splines provide the means for exploring our research questions in greater depth than would have been possible using traditional regression methods.

The MARS software used in this research is a computer assisted approach to regression splines analysis. The MARS software builds the RS model in a two-phase process, using a forward stepwise regression selection and backwards-stepwise deletion strategy. In the forward phase, an overfitted model is built by adding basis functions. Starting with the resulting model of the forward phase, and using a residual sum of squares criteria MARS eliminates the BF which hurts the model the least. The end result of this deletion procedure, as will be discussed in greater detail later, is a unique sequence of candidate models. A complexity penalty measure is used to induce parsimony into the final model. The researcher can specify that the MARS model[2] be generated with no interaction between the input variables, or to permit interactions between two or more variables. In MARS analysis interactions between independent and dependent variables have a hierarchical, tree-like structure, with parent and child relationships between basis functions. In the following

[1] Out of 177 nations.

[2] The MARS model is optimized based on the Generalized Cross Validation measure (Hastie et al., 2001). A MARS model that does not involve interaction between the variables (or factors) can be expressed as a linear combination of non-linear functions (i.e., BF_{jk}) of the independent variables such that $y = b_0 + \Sigma_j f_j(x_j)$.

section we will discuss the data analysis and each of the models resulting from the MARS analysis process. This will help us to delineate the relationships among the variables for the five African countries.

4.1 Data Analysis

The data for our study was drawn from the archives datasets of the UNDP, and the ITU. The data covers the period 1993-1999 inclusively. This period marks the beginning of intensive ICT investments, not only in the aforementioned African nations, but also developing nations in general. The independent variables for our MARS analysis were investment in healthcare, education, and ICT. The dependent variables were chosen to conform to those used by the HDI: GDP per capita, literacy rates, and life expectancy. Our interest in conducting this analysis was to understand the relative importance of investments in ICT, education and healthcare on three key components of the HDI. We also wanted to investigate how first-order investments, such as education and healthcare, could interact with second-order investments, such as ICT, to impact human development measures. We focused our investigation on the following questions:

1. How are investments in ICT, education and healthcare impacting GDP per capita?
2. How are investments in ICT, education and healthcare impacting literacy rates?
3. How are investments in ICT, education and healthcare impacting life expectancy?

We use the Translog production function and MARS to investigate the impact of investments in ICT on components of the HDI. We further examine the interactions amongst investments in ICT and the input variables: investments in ICT (T), investments in education (D), and investments in healthcare (H). The output variables include: GDP per capita, literacy rates, and life expectancy. We model the impact and interactions of the input variables on each output variable separately. In our translog production function we will use the generic variable V for the output variable (e.g. Value Added, V), the relevant Translog function that applies to our production function using these input variables can be estimated as the following form:

$$\log_e V = \beta_0 + \beta_D \log_e D + \beta_H \log_e H + \beta_T \log_e T + 1/2\beta_{DD}(\log_e D)^2 + 1/2\beta_{HH}(\log_e H)^2 +$$

$$1/2\beta_{TT}(\log_e T)^2 + \beta_{DH}\log_e D)(\log_e H) + \beta_{DT}(\log_e D)(\log_e T) + \beta_{TH}(\log_e T)(\log_e H) + \varepsilon$$

We present the resulting MARS models from this analysis in Appendix A for those readers who are interested in the technical details or validating our findings. Table 4.0 presents statistics of our dataset; the minimum and maximum are log values of the variables. In the following we explain our findings for a general audience, minimizing the technical details.

Variable	Minimum	Maximum
$\log_e T$	-2.659	0.284
$\log_e D$	1.808	3.541
$\log_e H$	-0.357	1.030
$\log_e GDP$	5.144	6.562
$\log_e LitRate$	2.539	4.248
$\log_e LifeExp$	3.759	3.991

Table 4.0: Sample Statistics from MARS Model Generation

4.1.2 Findings of Impact on GDP

Our MARS analysis shows that all three variables—investments in ICT, education and healthcare (represented as T, D and H respectively in Table 4.1)—are important predictors of GDP growth. However, investment in ICT has much higher level of importance than the others as a predictor GDP growth. Table 4.1 shows that ICT investment (T) is the most important (of the variables we investigated) to predicting GDP growth. The cost to omit this variable from the model would be .239, a significant reduction in GDP. This is not surprising since ICT currently generates a large percentage of the revenues for the economies of these countries than we would have been conjectured. These finding are of high statistical significance as the R-Squared or this regression spline model is 0.959. Thus the model explains 95.9 per cent of the variance of GDP.

Variable	Cost of Omission	Importance
$\log_e T$	0.239	100.000
$\log_e D$	0.203	88.186
$\log_e H$	0.134	59.470

Table 4.1: Relative Impacts on GDP

The relationships among the independent variables and their collective impact on GDP are quite complicated as the regression spline model shows (see Appendix 1, Table 1.A for a summary). For example, when investment in ICT ($-\infty$ > logeT < -1.566) and investments in education are beyond a certain threshold (logeD > 2.98), the direction of the rate of impact of investments of ICT on GDP is positive. However, when the amount invested in ICT is in the range (-1.566 > logeT < 1.313), the direction of the rate of impact of investment in ICT on GDP depends on whether the amount invested in healthcare exceeds a certain threshold that is itself dependent on the amount invested in education. This means that for countries with higher levels of investment in education the direction of impact of ICT investments will be positive only if the amount invested in healthcare is also relatively high. When the amount invested in healthcare is the threshold (logeH < 1.761) the direction and rate of impact of investments in ICT on GDP is always negative. When investments in healthcare are in the range (1.761 > logeH < 2.739), investments in ICT have no impact on GDP. The direction of the rate of impact of investments of ICT on GDP is positive only if the amount invested in healthcare exceeds a certain threshold (logeH > 2.739). This result suggests that when the amount invested in ICT is relatively high, the impact on GDP will be positive only if the investment in healthcare is also relatively high.

4.1.3 Findings of Impact on Literacy Rate

Once again the three variables—investments in ICT, education and healthcare—were found to be important predictors of literacy rates. Surprisingly, however, the most important predictor of literacy rates is investment in healthcare not education as we would have conjectured. Any amount invested in healthcare has positive impact on literacy rates. These findings are significant R-Squared of 0.894; they explain 89.4 percent of the variance in the literacy rates. Table 4.2 provides the order of relative importance of variables from regression spline model. The relationships between the independent variables and literacy rates are complex as the regression spline model has several important segments. Appendix 2, Table A.2 summarizes the different segments and specific impact on the dependent variable that each represents. The results of an analysis of these segments suggest the following: When investments in ICT are at the lowest levels (logeT $\in$ ($-\infty$, - 1.313]), the direction of the rate of impact of investments is ICT on literacy rates is positive only when a country's investment in education is low (logeD < 3.11). If the country's investment in education is higher, this same low level of ICT investment will be counterproductive. When investment in education

is beyond a certain threshold (logeD < 3.11), then if the amount invested in ICT is in the range (-1.313 > logeT < -0.868) these ICT investments will have a negative impact on literacy rates. Further, apart from the lowest levels (logeT $\in$ (-∝, - 1.313]), the amount invested in ICT has to surpass a threshold (logeT > -0.868) before it can have a positive impact on literacy rates.

Variable	Cost of Omission	Importance
$\log_e H$	0.231	100.000
$\log_e T$	0.205	89.229
$\log_e D$	0.115	32.393

Table 4.2: Relative Impacts on Literacy Rate

4.1.4 Findings of Impact on Life Expectancy

All three variables were also found to be predictors of life expectancy. However, there are two puzzles in the results: (1) Investments in ICT is the most important predictor of life expectancy with investment in healthcare in second place. (2) While the model explains 92 per cent of the variance in (R-Squared is .920) the cost of omission of the variables is relatively low. Both these features suggest that there are some important variables missing and some important interactions amongst these variables.

Variable	Cost of Omission	Importance
$\log_e T$	0.007	100.000
$\log_e H$	0.005	80.406
$\log_e D$	0.004	64.627

Table 4.3: Relative Impacts on Life Expectancy

The regression spline model describes the complex relationships among investments ICT, education and healthcare and their impact on life expectancy (See Appendix 3 for a summary). For example, when the amount invested in ICT is in the range (-∝ > logeT < -2.695) the rate of impact of these investments on life expectancy increases when the amount invested in education increases. However, when the amounted in ICT is in the range (-2.659 > logeT < -1.168) the rate of impact of this investment on life expectancy is dependent on the level of investment in healthcare and education. When the amounted investment in ICT is in the range (-1.168 > logeT < -.868) these investments have a positive affect on life expectancy if investments in health are beyond the threshold (logeH >-0.713) and negative if below this threshold. However, when the amount invested in ICT is beyond the threshold (logeT > -.868) and investment in healthcare is beyond the threshold (logeH > 0.359), the rate of impact of investments in ICT of life expectancy is positive.

5. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

In this paper we present a MARS-based analysis to explore the impact of investments in ICT on human development measures in five African countries. The result of the analysis provided numerous significant findings. Firstly, investments in ICT, education and healthcare all had an impact on measures of GDP. ICT investments, however, were found to be the most important predictors to GDP growth. It was also discovered that these investments impacted GDP measures only when investments in education and healthcare were relatively high. Secondly, investments in ICT, education and healthcare all had positive impacts on literacy rates. However, the most important predictor variable was investments in healthcare and not education. The numerous reasons for such a result are outside the scope of this analysis. What can be gauged from such a finding is the interdependency of these two variables. We can thus

concur with Fielding's statement that education is indeed good for health, while health is good for education. Finally, investments in all three areas positively impacted life expectancy measures. We were surprised to find that investments in ICTs were the most important predictors of life expectancy, with healthcare in second place. This led us to deduce that some important variables were missing from our analysis.

What is the importance of these findings? How can they inform future ICT4D investment strategies? The most important conclusion of this work is that investments in ICTs are not enough to impact human development. Investments in education and healthcare must be given equal consideration. The interactions amongst these variables and the ways in which they can mutually enforce measures of development must also be investigated. Furthermore, the analysis elucidated that second-order investments also have an impact on measures of human development. That being the case, national policymakers should not undermine the importance of investments in areas such as ICT. Another vital finding is that there are some significant variables missing from our analysis. Perhaps future research can examine how investment in other areas—such as civil infrastructure—may also impact measures of human development.

It is also important to gauge that this analysis only considered the aggregate amount invested in the three areas. What this type of investigation cannot explicate is the effectiveness of the various strategies that were constituted as a result of these investments. As such, we cannot identify how each of these strategies has impacted human development, or how long it takes before positive affects are materialized in HDI measures. Future research can examine the effectiveness of different strategies to show policymakers how to synergize their investment strategies to avoid the misallocation of resources. The reader should also note that although this research provides advice on how actual investments can be synergized, it does not discuss how ICT policies can be aligned with those of education or healthcare to positively impact human development. For example, how can computers be integrated into schools to most effectively foster learning? What are the numerous ways in which information systems can be used to improve the national healthcare system? How can mobile phones be used to increase per capital GDP levels? These questions can only be answered by a thorough investigation of recent initiatives to use ICTs for purposes of development.

Furthermore, although this research provides an analysis of the correlation between investments and human development measures at an aggregate level it cannot make adequate conclusions as to which segment of the population is gaining from such investments. As was previously mentioned, the majority of our sample countries had close to half of the population living in rural areas. This leads us to question whether or not the benefits of communication technologies are spilling over to remote areas which are often the most impoverished. It also leads us to wonder if individuals if these areas are using these technologies for purposes of 'development' as asserted by the international development community. These types of questions can only be answered by fieldwork analysis which identifies the numerous users as well as usages of ICTs. Finally, this study aggregated all ICTs into one category. What this type of analysis cannot delineate is just how different communication technologies—such as the mobile phone or the internet—are impacting human development. Either fieldwork analysis or more comprehensive data is needed to unravel these relationships.

Although this paper left the researchers with a plethora of questions it also makes numerous important contributions to the technology for development discourse. As was previously mentioned, our main finding is that investments in ICTs will more effectively impact human development when they are synergized with others such as healthcare and

education. As such, making the simplistic assumption that communication technologies are conduits of development may result in ineffective ICT4D strategies and the misallocation of vital resources. Although we do not deny that ICTs can significantly contribute to development we also acknowledge that more research is needed to examine just how these technologies are fostering the developmental process, and exactly who is benefiting from the integration into the so-called information society.

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7. APPENDIX

Appendix 1

The log linear regression equation that corresponds to this regression spline model is:

$\log_e GDP = 5.499 - 5.485 * BF1 - 2.079 * BF2 + 1.808 * BF3 - 4.425 * BF4 - 9.239 * BF6 + 7.982 * BF7 + 1.310 * BF8 + 3.514 * BF11 - 10.908 * BF15 + 11.207 * BF17;$

Table A1: Impact of Investments in ICT on GDP (T: ICT; **D**: Education; **H**: Health)

$\log_e T$	$\log_e H$	**Basis Functions & Impact Formula(s)**	**Direction of Impact**
(-∞, -1.566]	(-∞, 0.182]	BF2 = max(0, - 1.313 - $\log_e$T); BF3 = max(0, $\log_e$D - 1.808) *max(0, - 1.313 - $\log_e$T); -2.079*BF2 + 1.808*BF3	Positive if $\log_e D < \log_e D_0$ Negative if $\log_e D > \log_e D_0$ where $\log_e D_0$ = 1.808 + (2.079/1.808) = 2.958
	(0.182, 0.231]	BF2 = max(0, - 1.313 – $\log_e$T); BF3 = max(0, $\log_e$D – 1.808) *max(0, - 1.313 – $\log_e$T); -2.079*BF2 + 1.808*BF3	Positive if $\log_e D < \log_e D_0$ Negative if $\log_e D > \log_e D_0$ where $\log_e D_0$ = 1.808 + (2.079/1.808) = 2.958
	(0.231, +∞)	BF2 = max(0, - 1.313 - $\log_e$T); BF3 = max(0, $\log_e$D - 1.808) *max(0, - 1.313 - $\log_e$T); -2.079*BF2 + 1.808*BF3	Positive if $\log_e D < \log_e D_0$ Negative if $\log_e D > \log_e D_0$ where $\log_e D_0$ = 1.808 + (2.079/1.808) = 2.958
(-1.566, -1.313]	(-∞, 0.182]	BF2 = max(0, - 1.313 - $\log_e$T); BF3 = max(0, $\log_e$D - 1.808) *max(0, - 1.313 - $\log_e$T); -2.079*BF2 + 1.808*BF3	Positive if $\log_e D < \log_e D_0$ Negative if $\log_e D > \log_e D_0$ where $\log_e D_0$ = 1.808 + (2.079/1.808) = 2.958

	(0.182, 0.231]	BF2 = max(0, - 1.313 - $\log_e$T);
		BF3 = max(0, $\log_e$D - 1.808)
		*max(0, - 1.313 - $\log_e$T);
		BF17 = max(0, $\log_e$H - 0.182)
		*max(0, $\log_e$T + 1.556);
		-2.079*BF2 + 1.808*BF3 + 11.207*BF17
			Positive if $\log_e H > \log_e H_0$
			Negative if $\log_e H < \log_e H_0$
			
			where $\log_e H_0 = (1.808/11.207)*\log_e D + 0.182 – (2.079 + 1.808^2)/11.207$
			$= 0.161*\log_e D – 0.295$

	(0.231, +∞)	BF2 = max(0, - 1.313 - $\log_e$T);
		BF3 = max(0, $\log_e$D - 1.808)
		*max(0, - 1.313 - $\log_e$T);
		BF17 = max(0, $\log_e$H - 0.182)
		*max(0, $\log_e$T + 1.556);
		-2.079*BF2 + 1.808*BF3 + 11.207*BF17
			Positive if $\log_e H > \log_e H_0$
			Negative if $\log_e H < \log_e H_0$
			
			where $\log_e H_0 = (1.808/11.207)*\log_e D + 0.182 – (2.079 + 1.808^2)/11.207$
			$= 0.161*\log_e D – 0.295$

(-1.313, +∞)	(-∞, 0.182]	BF1 = max(0, $\log_e$T + 1.313); BF7 = max(0, 0.231 - $\log_e$H) *max(0, $\log_e$T + 1.313); -5.485*BF1 + 7.982*BF7	Positive if $\log_e H < \log_e H_0$ Negative if $\log_e H > \log_e H_0$ where $\log_e H_0$ = 0.231 - (5.485/7.982) = -0.456

	(0.182, 0.231]	BF1 = max(0, $\log_e$T + 1.313);
		BF7 = max(0, 0.231 - $\log_e$H)
		*max(0, $\log_e$T + 1.313);
		BF17 = max(0, $\log_e$H - 0.182)
		*max(0, $\log_e$T + 1.556);
		-5.485*BF1 + 7.982*BF7 + 11.207*BF17
			Positive if $\log_e H > \log_e H_0$
			Negative if $\log_e H < \log_e H_0$
			
			where $\log_e H_0$ = (5.485 + 11.207*0.182 – 7.982*0.231)/(11.207 – 7.982) = 1.761

	(0.231, +∞)	BF1 = max(0, $\log_e$T + 1.313);
		BF6 = max(0, $\log_e$H - 0.231)
		*max(0, $\log_e$T + 1.313);
		
		BF17 = max(0, $\log_e$H - 0.182)
		*max(0, $\log_e$T + 1.556);
		-5.485*BF1 - 9.239*BF6 + 11.207*BF17
			Positive if $\log_e H > \log_e H_0$
			Negative if $\log_e H < \log_e H_0$
			
			where $\log_e H_0$ = (5.485 +11.207*0.182 - 9.239*0.231)/(11.207 - 9.239) = 2.739

Appendix 2: Impact of Investments in ICT on Literacy Rate

The log linear regression equation that corresponds to this regression spline model is:

$$\log_e LitRate = 3.722 - 0.864 * BF1 - 4.173 * BF2 + 1.101 * BF4 + 3.229 * BF5 + 1.128 * BF6$$

Table A2: Impact of Investment in ICT on Literacy Rate (T: ICT; **D**: Education; **H**: Health)

$\log_e$**T**	**Basis Functions & Impact Formula(s)**	**Direction of Impact**
$(-\infty, -1.313]$	BF2 = max(0, -1.313 - $\log_e$T); BF5 = max(0, $\log_e$D - 1.808)*max(0, -1.313 - $\log_e$T); -4.173 * BF2 + 3.229 * BF5	Positive if $\log_e D < \log_e D_0$; Negative if $\log_e D > \log_e D_0$; where $\log_e D_0$ = 1.808 + (4.173/3.229) = 3.11
(-1.313 , -0.868]	BF1 = max(0, $\log_e$T + 1.313); -0.864*BF1	Negative (since -0.864*1 <0)
(-0.868 , $+\infty$)	BF1 = max(0, $\log_e$T + 1.313); BF6 = max(0, $\log_e$T + 0.868); -0.864 * BF1 + 1.128 * BF6	Positive (since -0.864*1 + 1.228*1 > 0)

Appendix 3: Impact of Investments on Life Expectancy

The log linear regression equation that corresponds to this regression spline model is:

$\log_e$LifeExp = 3.649 + 0.614*BF2 +0.126*BF3 – 0.385**BF5 + 0.278*BF9 +0.677*BF11+0.082*BF14-0.413*BF15

Table A3: Impact of Investments on Life Expectancy (T: ICT, **D**: Education, **H**: Health)

$\log_e$**T**	$\log_e$**H**	**Impact Formula(s)**	**Direction of Impact**
(-∞, -2.659]	(-∞, 0.336]	BF2 = max(0, 0.336 - $\log_e$H); BF10 = max(0, -1.168 - $\log_e$T); BF11 = max(0, $\log_e$D - 2.682) *max(0, -1.168 - $\log_e$T); BF14 = max(0, 3.165 - $\log_e$D); + 0.614*BF2 + 0.677*BF11 + 0.082*BF14	<u>None</u> if $\log_e$D < 2.682 <u>Negative</u> if $\log_e$D > 2.682
	(0.336, +∞)	BF10 = max(0, -1.168 - $\log_e$T); BF11 = max(0, $\log_e$D - 2.682) *max(0, -1.168 - $\log_e$T); BF14 = max(0, 3.165 - $\log_e$D); + 0.677*BF11 + 0.082*BF14	<u>None</u> if $\log_e$D < 2.682 <u>Negative</u> if $\log_e$D > 2.682
(-2.659, -1.168]	(-∞, 0.336]	BF2 = max(0, 0.336 - $\log_e$H); BF3 = max(0, $\log_e$T + 2.659); BF5 = max(0, 0.336 - $\log_e$H) *max(0, $\log_e$T + 2.659) BF10 = max(0, -1.168 - $\log_e$T); BF11 = max(0, $\log_e$D - 2.682) *max(0, -1.168 - $\log_e$T); BF14 = max(0, 3.165 - $\log_e$D); + 0.614*BF2 + 0.126*BF3 - 0.385*BF5 + 0.677*BF11 + 0.082*BF14	<u>Positive</u> if $\log_e$H > $\log_e$$H_0$ <u>Negative</u> if $\log_e$H < $\log_e$$H_0$ where $\log_e$$H_0$ = 0.336 - (0.126/0.385) + (0.677/0.385)*max(0, $\log_e$D - 2.682) = 0.009 + 1.758* max(0, $\log_e$D - 2.682)
	(0.336, +∞)	BF3 = max(0, $\log_e$T + 2.659); BF10 = max(0, -1.168 - $\log_e$T); BF11 = max(0, $\log_e$D - 2.682) *max(0, -1.168 - $\log_e$T); BF14 = max(0, 3.165 - $\log_e$D); + 0.126*BF3 + 0.677*BF11 + 0.082*BF14	<u>Positive</u> if $\log_e$H > $\log_e$$H_0$ <u>Negative</u> if $\log_e$H < $\log_e$$H_0$ where $\log_e$$H_0$ = 0.336 - (0.126 + 0.278)/0.385 + (0.677/0.385)*max(0, $\log_e$D - 2.682) = -0.713 + 1.758* max(0, $\log_e$D - 2.682)
(-1.168, -0.868]	(-∞, 0.336]	BF2 = max(0, 0.336 - $\log_e$H); BF3 = max(0, $\log_e$T + 2.659); BF5 = max(0, 0.336 - $\log_e$H) *max(0, $\log_e$T + 2.659) BF9 = max(0, $\log_e$T + 1.168); BF14 = max(0, 3.165 - $\log_e$D); 0.126*BF3 - 0.385*BF5 + 0.278*BF9 + 0.082*BF14	<u>Positive</u> if $\log_e$H > $\log_e$$H_0$ <u>Negative</u> if $\log_e$H < $\log_e$$H_0$ where $\log_e$$H_0$ = 0.336 - (0.126 + 0.278)/0.385 = -0.713
	(0.336, +∞)	BF3 = max(0, $\log_e$T + 2.659); BF9 = max(0, $\log_e$T + 1.168); BF14 = max(0, 3.165 - $\log_e$D); 0.126*BF3 + 0.278*BF9 + 0.082*BF14	<u>Positive</u> (Since 0.126 + 0.278 > 0)

(-0.868, +∝)	(-∝, 0.336]	BF2 = max(0, 0.336 - $\log_e$H); BF3 = max(0, $\log_e$T + 2.659); BF5 = max(0, 0.336 - $\log_e$H) *max(0, $\log_e$T + 2.659) BF9 = max(0, $\log_e$T + 1.168); BF14 = max(0, 3.165 - $\log_e$D); BF15 = max(0, $\log_e$T + 0.868); + 0.614*BF2 + 0.126*BF3 - 0.385*BF5 + 0.278*BF9 + 0.082*BF14 - 0.413*BF15	<u>Positive</u> if $\log_e$H > $\log_e$$H_0$ <u>Negative</u> if $\log_e$H < $\log_e$$H_0$ where $\log_e$$H_0$ = 0.336 - (0.126 + 0.278 - 0.413)/0.385 = 0.359
	(0.336, +∝)	BF3 = max(0, $\log_e$T + 2.659); BF9 = max(0, $\log_e$T + 1.168); BF14 = max(0, 3.165 - $\log_e$D); BF15 = max(0, $\log_e$T + 0.868); 0.126*BF3 + 0.278*BF9 + 0.082*BF14 - 0.413*BF15	<u>Positive</u> if $\log_e$H > $\log_e$$H_0$ <u>Negative</u> if $\log_e$H < $\log_e$$H_0$ where $\log_e$$H_0$ = 0.126 + 0.278 - 0.413 = -0.009