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Effectiveness and Efficiency of National Systems of Innovation: the importance of ICT, the Cases of Ghana and Kenya

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Abstract: This paper presents a comparative analysis of the determinants of the Effectiveness and Efficiency of the Ghana National System of Innovation (GNSI) and the Kenya National System of Innovation (KNSI). Two regression analyses is performed on the level of innovativeness of Business Enterprises (BE) (Effectiveness) and of the strength of linkages between Research institutes (RI) and the Production System (Efficiency) with respect to an array of independent variables of the National System of Innovation (NSI). We find that the GNSI and the KNSI are conformed by actor linkages and ICT positively with respect to Ghana and negatively in the case of Kenya. Lack of Finance is a significant determinant in the GNSI whereas adequacy of Human Resources is a significant determinant for the KNSI. In both countries Level of Innovativeness of BEs and Strength of RI Linkages with the Production System are significant in the modeling.

Keywords: National System of Innovation, Ghana, Kenya, ICT, Effectiveness, Efficiency, Regression

1. Introduction

Innovation, as the driving force of economic development [1][2], is crucial for economies to develop, maintain and improve competitive advantages [3][4][5][6]. An effective and efficient National System of Innovation (NSI) is therefore vital for countries to be internationally competitive in achieving high output and employment [7][8]. Analysis by [9] suggests that a well-developed innovation system is essential for countries grow and to catch up with the advanced industrialized countries.

Since the genesis of the expression NSI[1] in the early 1980's [10][11][12] extensive studies have been performed using this conceptual framework to understand the determinants of, and relationships within, NSI. This work, due to the intellectual movement away from thinking about an economy in terms of factors of production [13] towards that of the knowledge-based economy, and with the emergence of ICT as a conduit for knowledge flow [14] in terms of storage and communication [15], provides a new model of development [16][17].

As a result, "knowledge is now recognised as the driver of productivity and economic growth... and there is a new focus on the role of information, technology and learning in economic performance" [18].

[1] Throughout the literature on systems of innovation both National Systems of Innovation (NSI) and National Innovation Systems have been used interchangeably. For a historical overview of the concept see Teixeira (2008) and Godin (2009). In this body of work the term the term NSI is used apart from when making reference to works from a specific author.

In practical terms, the operative core of NSI is the intra- and inter-relationships of firms, markets and industry; knowledge-based institutions (KBIs); government; and the capital and finance system in terms of the structural dynamics of the market, knowledge management, government-business relations, and policy decision-making regarding innovation in the national economy [19]. There is “a plethora of definitions for innovation types [which] has resulted in an ambiguity in the way the terms ‘innovation’ and ‘innovativeness’ are operationalised” [20]. The definition of NSI herein is that of [21] “The envelope of conforming policies as well as private and public organisations, their distributed institutional relations, and their coherent social and capital formations, that determine the vector of technological change, learning and application in the national economy”. This definition underscores the importance of policy as a part of the NSI, and as stated by [22] the measurement and management of NSI remains crucial for policy craft.

The NSI can be visualised in the Triple Helix model (TH) of [23]. However, ICT, as an important factor, is not reflected directly in the Helix model. In order to address such *lacunae* we extend the traditional TH model is extended to the TH-Type IV model which in addition to Government, Knowledge-Based institutions and Medium and High-Tech Industry, includes Arbitrageurs[2] as an independent actor, and the presence of diffused ICT[3]. A full review of this extension is found in [24][25][26].

This paper examines the role of ICT and NSI in Ghana and Kenya, both of which have a clear and coherent ICT policy as framed within respective national development strategies. The paper presents the comparative results of two regression models for each country; the first model measuring the effectiveness, and the second measuring the efficiency, of the respective NSI.

The rest of this paper is organized as follows. Section 2 addresses the importance of evidence based policy. Section 3 examines the policy and development strategies of Ghana and Kenya in terms of ICT and NSI. Section 4 presents the methodological approach and models to be tested. Section 5 presents and discusses results from the Ghana National System of Innovation (GNSI) and Kenya National System of Innovation (KNSI) Surveys and relates them to ICT. Section 6 concludes with policy recommendations and areas of further research.

2. Importance of Evidence-Based Policy

As the production, distribution and processing of knowledge (especially scientific and technological) is increasingly performed within the domain of ICT, ICT emerges as the new paradigm for economic development [37].

In order to reap the opportunities offered by ICT it is necessary to gauge the effectiveness of current policy, and/or develop a set of policies to encourage the creation, diffusion and use of knowledge. However, it is often the case that policy is adopted without consideration of the local environment [38]. In this light when decisions are made in an unstructured manner the overall desired objectives are impeded [39]. ICT policy should “address the question of digital divide (in comparison with the rest of the world, but also the internal digital divide faced by the underprivileged strata of the population). The basic

[2] This set of actors is of “crucial importance as the innovation process requires internal and external knowledge which has led to the emergence of new business models and new types of companies. As such, knowledge brokers and venture capitalists fill this gap through the provision of links, knowledge sources and even technical knowledge so that firms can improve their performance in terms of survival rate as well as accelerate and increase the effectiveness of their innovation processes [27][28][29]. Their resource allocation role is based on the assessment of advantages in information asymmetries [30][31][32]”[33].

[3] ICT in the conceptualisation of TH-Type IV is not based solely on the based solely on the concept of access, but the work of[34] who “view[s] the digital divide as being attributable to issues of storage, the ability to compute and transmit digital information; to contextualize not just the quantity of hardware but also the corresponding performance in relation to all three NSI actors” [35][36].

dimensions of the digital divide includes issues of access (connectivity, costs), skills (digital literacy) and content (localization of content)" [40].

Increasing emphasis is placed on evidence-based policy [41][42][43]; the premise being that "policy decisions should be better informed by available evidence and should include rational analysis" [44][45].

Unfortunately often in the developing country context "economic, social and political environments are diverse and often more complicated; capacity is more limited; resources are scarcer. In addition, international actors have a substantial impact on research and policy processes" [46]. However, despite the challenges evidence-based policy tools are still relevant.

3. ICT and development strategies of Ghana and Kenya

The Ghana ICT for Accelerated Development Policy (2003)[47] represents the vision for Ghana in the Information Age. The policy is designed to assist Ghana's development by addressing key challenges such as under-developed physical communications infrastructure and limited human resource skills capacity in general, and in ICT in particular, characterised by the low professional, technical and managerial manpower-base available nationally [48]. However, for Ghana to move towards an information- and knowledge-driven economy, it needs to develop and implement comprehensive integrated ICT-led, socio-economic development policies, strategies and plans.

In relation to civil and public services, the deployment and exploitation of ICT is cardinal to operations and activities. Thus, the aim of the Ghana ICT for Accelerated Development Policy (2003) is to engineer an ICT-led, socio-economic development process transforming Ghana into a middle-income, "information-rich, knowledge-based and technology-driven economy" [49]. This is complimented by targets of the National Science Technology and Innovation Policy, which aims to promote the use of ICT at all levels of society. Specific ICT strategies include: "to ensure STI capabilities exist to integrate ICT into all sectors of the economy including education, industry, agriculture and health; [to] develop a national competence for computer hardware and software engineering and information security; [and to] facilitate the development of a modern ICT infrastructure to improve teaching, learning and research" [50]. The Education Strategic Plan 2010-2020, aims, *inter alia*, to modernise and extend ICT, science education, technical and vocational education and training, and to enhance skills development at all levels [51].

In addition, from an industrial policy perspective, ICT is also crucial as the Government of Ghana has considered the use of ICT as a means to leverage the country's industrial development in that the "adoption and effective use of ICT in the manufacturing sector will drive competitiveness" [52].

In comparison a review of Kenya's policies shows that ICT is a core component of Kenya's overall development strategy, as is exemplified by its representation throughout Kenya's Vision 2030. The pivotal role of ICT is recognised in Kenya's education policy, where emphasis is placed on "technology, innovation and entrepreneurship, talent development, and the need for schooling to be more closely related to the world of work. Because technology relies heavily on the use of ICT, the provision of ICT facilities across the education sector shall be a Government spending priority" [53]. From a Science Technology and Innovation policy standpoint, the linkage between ICT and innovation is clear. The Ministry of Science and Technology (2012, pg. V) states that "Universities and research institutions will be critical drivers of innovation systems and the resultant developments in ST&I and application of knowledge, especially in biotechnology, value–addition, manufacturing, Information and Communication Technologies (ICT)". The Science, Technology and Innovation Medium Term Plan for 2008 – 2012 states that "Global competitiveness and innovativeness are needed for leapfrogging trade, industry and manufacturing products and services... [and] ICT will [be] the necessary stimulation and support needed for simplifying information search and registration procedures, narrowing the digital divide and enabling and empowering communities to gain access to scientific and technological opportunities [54].

Finally the movement away from an agrarian economy requires value addition and the use of ICT to bolster forward value chain linkages. The ICT sector is seen as a crucial support for manufacturing. The Ministry of Trade and Industry [55] states that: "the government should be geared towards policies which promote internal enterprise innovations so that they can attain improvement in quality and productivity for their sustainable growth because increasing global competition" .

In both countries, policies have a strong ICT component. The question is how much of this policy evidence-based?

4. Methodological Approach and Models to be Tested

We analyze the contextual determinants of innovation, regarding the effectiveness and efficiency of the GNSI and KNSI, which are represented respectively by the dependent variables: level of innovativeness of business enterprises; and the strength of the linkages between research institutes and the production system, and an array of independent variables related to the NSI environment[4].

4.1 Survey and data

The GNSI and KNSI surveys map and measure the NSI[5] – that is the inter- and intra-relationships (institutional linkages, policy proximity, convergence or divergence, and connectedness) between policy decision-makers at the highest level in Government (GOV), Medium and High-Technology Industry (MHTI), Knowledge-Based Institutions (KBIs), and Arbitrageurs (ARBs), (comprising Financial Institutions (FIs), Venture Capitalists/Knowledge Brokers), respectively[6] – as opposed to carrying out solely a survey of innovation in companies or a review of indicators and policy[7].
The following nomenclature is used (see table 1):

Table 1. *Nomenclature of actors*

NSI Actor	Abbreviation	
All Actors	ALL_G	ALL_K
Government	GOV_G	GOV_K
Institutions Supporting Technical Change	$ISTC_G$	$ISTC_K$
Medium- and High- Technology Industry	$MHTI_G$	$MHTI_K$
Business Enterprises	$BE(s)_G$	$BE(s)_K$
Knowledge-Based Institutions	$KBI(s)_G$	$KBI(s)_K$
Higher Education	HE_G	HE_K
Research Institutions	$RI(s)_G$	$RI(s)_K$
Arbitrageurs	$ARB(s)_G$	$ARB(s)_K$
Financial Institutions	$FI(s)_G$	$FI(s)_K$

[4] Due to limitations of space, the array of variables is not presented herein but are available on request to the authors.
[5] These surveys were performed by the Authors Frank L. Bartels and Ritin Koria in their respective capacities as Senior Advisor to the Deputy to the Director General, UNIDO and UNIDO Consultant.
[6] From here on in Actors will referred to by their abbreviation when appropriate, with respect to ease of readability.
[7] [56][57].

Table 2 below portrays the surveys in terms of the universal population, convenient sample and Respondents of the four Actors.

Table 2. NSI Universe and Convenient Sample of Respondents.

Actors	Universe of respondents		Convenient Sample (Accessible Potential Respondents)		(%) Percentage of Universe of Respondents	
	Ghana	Kenya	Ghana	Kenya	Ghana	Kenya
Government	260	49	166	40	63.85	81.63
MHT Industry	120	170	87	94	70.83	55.29
Knowledge-Based Institutions	182	427	175	327	96.15	76.58
Arbitrageurs	16	120	16	91	100	83.33
Totals	578	766	444	552	76.82	72.06

Table 3 below indicates the percentage response rate per Actor.

Table 3. Distribution of GNSI Survey Returns by Actor[8].

Actor	Convenient Sample		Responses		Response Rate (%)	
	Ghana	Kenya	Ghana	Kenya	Ghana	Kenya
Government Policy-Makers	166	40	39	6	33.6	15.0
MHT Industry	87	94	60	34	68.9	36.17
Knowledge-Based Institutions	175	327	129	146	73.3	44.6
Arbitrageurs (Venture Capitalists/ Knowledge Brokers	16	91	6	25	37.5	27.5
All Actors	444	552	234	211	52.7	38.2

Arbitrageurs complement the Triple Helix model by intermediating the provision of funds, links, knowledge sources and even technical knowledge [58][59]. This enables firms to improve performance, survival rates, accelerate and increase the effectiveness of their innovation processes [60][61][62]. The intermediation and resource allocation role of Arbitrageurs is based on their assessment of competitive advantages in information asymmetries [63][64][65].

The NSI surveys obtained quantitative data on five dimensions of the NSI, namely Constitution of the NSI, Components of the NSI, Barriers to Innovation, Policy Processes, and Measuring Innovative Performance.

4.2 Modelling

The empirical study estimates the effectiveness and efficiency of the GNSI and KNSI using 80 independent variables in nine categories. The models have one criterion variable each which measure: the effectiveness of NSI as the level of innovativeness of business enterprises; and the efficiency of NSI as the strength of the linkages between research institutes and the production system[9].

[8] In surveys directed towards senior management the general response rate is at 30%. [66]. Response Styles in Cross-National Survey Research. A 26-country Study. The international Journal of Cross Cultural Management 6 (2), 243-266. We survey: Leadership in government (Minister, Deputy Minister and Chief Director) policy making; High level management in Medium-High-Technology Industry (MHTI)-(Chief Executive Officers); Leadership in Knowledge-Based Institutions (KBI) (faculty deans and departmental heads); Chief Executive Officers.

[9] The dependent factors are categorical variables, with values ranging from 1 to 5, where 1 corresponds to a very high level of innovativeness of BEs; and to a very strong level of the linkages between research institutes

We present an Ordinary Least Squares (OLS) regression analysis of two different models used to measure the effectiveness and efficiency of the GNSI and KNSI. Beside OLS estimates, we regress the same models by adding the option of robust standard errors and test for the robustness of the results with respect to the *composition* of the sample by re-estimating the relationship with a robust regression technique - the iteratively reweighted least squares[10] (IRLS) – which tests for the impact of outliers. We discuss those variables that influence the independent variables at the 5% and 1% level of significance across techniques.

In the first model, we evaluate effectiveness of the respective NSI as the level of innovativeness of business enterprises. The model[11] is:

(1) (*Level of BEs Innovativeness*[12]) $_i$ = β_1 + (*Importance of the Actors*) $_i$ * β_2 + (*Linkages among the Actors*) $_i$ * β_3 + (*Number of Tertiary Graduates*) $_i$ * β_4 + (*RI Linkages to Production*) $_i$ * β_5 + (*Diffusion of ICT*) $_i$ * β_6 + (*Success of Policy Instruments*) $_i$ * β_7 + (*Barriers to Innovation*) $_i$ * β_8 + (*Governance Innovativeness*) $_i$ * β_9 + e_i .

By analyzing the second model, we capture the efficiency of the respective NSI as the relationships between the independent variables and the strength of the linkages between research institutes (RI) and the production system (PS). The model[13] is:

(2) (*RI Linkages to Production*) $_i$ = β_1 + (*Importance of the Actors*) $_i$ * β_2 + (*Linkages among the Actors*) $_i$ * β_3 + (*Number of Tertiary Graduates*) $_i$ * β_4 + (*Diffusion of ICT*) $_i$ * β_5 + (*Level of BEs Innovativeness*) $_i$ * β_6 + (*Success of Policy Instruments*) $_i$ * β_7 + (*Barriers to Innovation*) $_i$ * β_8 + (*Governance Innovativeness*) $_i$ * β_9 + e_i .

4.3 Methodological issues

The data arise from five-point Likert scale measures. Likert data are often used in OLS regression analysis. However, estimating and analyzing continuous relationships with ordinal categorical measures implies a measurement problem since the degree of association (i.e. R-squared) and the estimated relationships between the criterion variable (i.e. Y) and the predictors (i.e. Xs) differ when continuous or Likert scale variables are used [68]. Indeed, when variables are Likert scale points, the implicit assumption of the linear regression model that the dependent variable (i.e. Y) is continuous is violated. Nevertheless, ordinal categorical data, or Likert scale data, can be considered as continuous data with equal accuracy and as linear monotonic transformations of the underlying continuous variables, which enables us to analyze Likert scale variables as continuous factors [69][70][71][72][73]. Owuor [74] shows that the mean percent bias of R-squared is asymptotic at the four-point Likert scale and beyond and demonstrates the robustness of the relative Pratt index to Likert scale data conditions. Since our data is based on a five-point Likert scale, first we assume insubstantial underestimation of the R-squared and second we use the relative Pratt index as control.

The relative Pratt index is the measure of the relative importance of covariates X_i in a regression model and it is measured by the proportion of the variance in the criterion variable accounted for by X_i [75][76][77][78][79]. Relative Pratt indices determine the

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and the production system, whereas 5 corresponds to a very low level of innovativeness of BEs; and to a very weak level of the linkages between research institutes and the production system.

[10] Iteratively reweighted least squares is a robust regression technique, which assigns a weight to each observation, with lower weights given to outliers.

[11] As a matter of formality, we present the 8 categories as vectors. They are n x k matrices, where n is the number of observations and k is the number of variables that are used to express the category singularly. In this way the beta coefficients, as reported in the model, are k x 1 vectors.

[12] Defined as the extent to which an agent is relatively earlier to adopt than others [67].

[13] See note 10.

proportion of the model R-squared that is attributable to each independent variable as predictor – this is used as a measure of the variables' importance in the model.

5. Results and Discussion

The datasets are composed of 234 and 249 observations respectively for Ghana and Kenya. Missing data[14] are substituted by the mode – "mode as the 'central tendency' because the arithmetical manipulations required to calculate the mean (…) are inappropriate for ordinal data" [80]. In Ghana the perception on the extent and effectiveness of the NSI is generally more positive than in Kenya. Table 4 below indicates the determinants of the effectiveness of the GNSI.

Table 4. Effectiveness of the GNSI (Level of Innovativeness of Business Enterprises in Ghana)

	(1)	(2)	(3)
Estimation method:	OLS	OLS (robust SE)	Iteratively reweighted least squares
BEs linked to BEs	0.1753**	0.1753**	0.1856**
	(0.0271)	(0.0106)	(0.0108)
BEs linked to GOV	0.2435**	0.2435**	0.4446***
	(0.0171)	(0.0346)	(0.0000)
Linkages between RIs and the PS	0.1979***	0.1979***	0.2397***
	(0.0025)	(0.0014)	(0.0001)
Diffusion of ICT	0.3636***	0.3636***	0.3504***
	(0.0000)	(0.0000)	(0.0000)
Success of standard setting	0.1679**	0.1679**	0.2264***
	(0.0465)	(0.0342)	(0.0036)
ICT Capacity	0.1843**	0.1843**	0.3467***
	(0.0457)	(0.0468)	(0.0001)
constant	0.4839	0.4839	0.6947*
	(0.2194)	(0.2548)	(0.0551)
N	234	234	234
R-sq	0.6148	0.6148	0.7005
Prob > F	0.0000	0.0000	0.0000

p-values in parentheses * p<0.10 ** p<0.05 *** p<0.01

In the first two regressions the R-squared is equal to 0.6148, meaning that the independent variables explain 61.48% of the variability of the dependent variable, whereas in the third regression the R-squared increases to 70.05%. By mitigating the impact of outliers, the goodness of fit increases. The results indicate that the model is significantly different from zero (Prob > F = 0.0000).

Table 4 shows that in Ghana Actor linkages, ICT (diffusion and capacity), and the success of standards setting are positively and significantly associated with the level of innovativeness of business enterprises. The improvement of the strength of the linkages among business enterprises and between business enterprises and the government, as well

[14] In the sample relative to Ghana, only 4 per cent of the observations is missing, whereas the Kenyan dataset does not present missing values.

as between RIs and the production system are highly associated with the improvement of the level of innovativeness of business enterprises.

Of the determinants, ICT variables have the second and third highest impact. These findings support the finding by Fagerberg and Srholec [81] that a well-developed ICT infrastructure is a critical factor for the ability to develop and exploit new technology.

Table 5 presents the relative Pratt indexes of each predictor variable. The table indicates variables that contribute to the improvement of the level of innovativeness of business enterprises, and are relatively important in the linear regression model.

Table 5. Relative Pratt index d_i associated with predictor X_i[15] (Effectiveness of the GNSI).

Variable	Significant	Relative Pratt Index OLS	Relative Pratt Index IRLS
BEs linked to BEs	yes	0.0533	0.0495
BEs linked to GOV	yes	0.1351	0.2164
Linkages between RIs and the PS	yes	0.1423	0.1512
Diffusion of ICT	yes	0.2744	0.2321
Success of standard setting	yes	0.0825	0.0976
ICT capacity	yes		

All predictors – except ICT capacity – which are significant for the model across techniques meet the condition $d_i > 1 / 2p$, across techniques, and account for a percentage of the R-squared. The linkages among business enterprises, between business enterprises and the government and between research institutes and the production system account for 4.95%, 21.64% and 15.12%, respectively, of the R-squared. The significant variable which matters the most in explaining the R-squared is the diffusion of ICT accounting for 23.21%.

Given trade-offs, policy options open to resource constrained policy makers emerge from a judicious ranking of the significantly influential variables and a view of the weight of the variables in the regression dynamics. The IRLS regression provides the three most significant and descending rank order beta coefficients of the variables: BEs-GOV linkages; diffusion of ICT; and ICT capacity. The associated relative Pratt index (IRLS) discloses in descending rank order: diffusion of ICT; BEs-GOV linkages; and RIs linkages to the production system; accounting for 23.2%, 21.6% and 15.1% of the model's R-squared value. Thus we construe the equation (3) as

(3) (*Level of Innovativeness of BEs*) = 0.6947 + 0.4446 * (*BEs-GOV*) + 0.3504 * (*Diffusion of ICT*) + 0.3467 * (*ICT Capacity*) + 0.2397 * (*RIs-PS*) + 0.2264 * (*Success of Standards Setting*) + 0.1856 * (*BEs-BEs*) .

Therefore, in Ghana a 1% increase in the strength of BEs-GOV inter-linkages is associated with a 0.44% increase in the level of innovativeness of business enterprises. Likewise a 1% increase in the ICT parameters is associated with a 0.35% increase in the dependent variable. Policy advisory choices suggest that increasing ICT infrastructure is the best option in Ghana. Intensifying BEs-government linkages carries transactions costs of coordination and controlling managerial utility. The former has economy wide externalities compared to the latter which has the potential of regulatory capture [82]. The overall key policy implication is that without the requisite ICT infrastructure and capacity economy wide innovation is difficult to attain.

To test if the above-mentioned variables are truly important and robust in explaining the level of BEs innovativeness and to assess that they are significant only due to the inclusion

[15] Blank cells are those relative Pratt indices that do not meet the condition $d_i > 1 / 2p$.

of the other predictors, we consider the case where the level of BEs innovativeness is regressed only on the significant variables expressed in equation (3). The results (not presented) show that all the independent variables – except for the linkages between BEs[16] – are significantly (at 1% and 5% level) correlated to the level of BEs innovativeness. The results indicate consistently how important is the diffusion of ICT to the level of innovativeness of BEs. The coefficient is two and a half to nearly three times as powerful as the other significant variables.

Table 6 presents the effectiveness of the KNSI (level of innovativeness of BEs in Kenya) and shows the variables significantly associated with the dependent variable across techniques at 1 and 5 per cent level of significance.

Table 6. Effectiveness of the KNSI (Level of Innovativeness of Business Enterprises in Kenya)

	(1)	(2)	(3)
Estimation method:	OLS	OLS (robust SE)	Iteratively reweighted least squares
RIs linked to RIs	-0.2396**	-0.2396**	-0.2916***
	(0.0219)	(0.0264)	(0.0064)
BEs linked to BEs	0.2551**	0.2551**	0.3346***
	(0.0152)	(0.0190)	(0.0019)
Adequacy of HR in S&T	0.1828***	0.1828**	0.1404**
	(0.0038)	(0.0106)	(0.0285)
Linkages between RIs and the PS	0.1602**	0.1602**	0.1956**
	(0.0326)	(0.0423)	(0.0109)
constant	1.1783**	1.1783**	1.1242**
	(0.0164)	(0.0127)	(0.0249)
N	249	249	249
R-sq	0.4994	0.4994	0.5309
Prob > F	0.0000	0.0000	0.0000

p-values in parentheses * p<0.10 ** p<0.05 *** p<0.01

The R-squared equals 0.4994 and 0.5309 in the OLS (and robust OLS) and IRLS, respectively. This indicates that independent variables explain from the 49.94 to the 53.09 per cent of the variability of the level of innovativeness of BEs.

The results in Table 6 indicate that, in Kenya, Actor Linkages, the linkages between RIs and the production system and the adequacy of human resources in Science and Technology are significantly associated with the level of innovativeness of BEs. What is unexpected is that linkages among research institutes are negatively and highly significantly associated with the level of innovativeness of BEs. We discuss this below.

In Ghana and Kenya the linkages between RIs and the production system and in and among BEs are positively associated with the independent variables level of innovativeness of BEs, indicating that these Actor Linkages are critical factors for the ability of business enterprises to innovate in both the countries.

Table 7 presents the relative Pratt indexes of each predictor variable. The table indicates variables significantly associated with the level of innovativeness of business enterprises, are relatively important in the linear regression model.

[16] The coefficient of the variable itself was the smallest one among the coefficients of significant variables.

Table 7. Relative Pratt index d_i associated with predictor X_i[17](effectiveness of the KNSI).

Variable	Significant	Relative Pratt Index OLS	Relative Pratt Index IRLS
RIs linked to RIs	yes		
BEs linked to BEs	yes	0.1297	0.1601
Adequacy of HR in S&T	yes	0.1464	0.1058
Linkages between RIs and the PS	yes	0.0969	0.1113

All the predictors – except the linkages between RIs variable – which are significant for the model across techniques meet the condition $d_i > 1 / 2p$, and account for a percentage of the R-squared. The linkages among business enterprises and between research institutes and the production system account for 16.01% and 11.13%, respectively, of the R-squared, whereas the adequacy of human resources in science and technology account for 10.58% of the goodness of fit.

Given trade-offs, policy options open to resource constrained policy makers in Kenya emerge from a judicious ranking of the significantly influential variables and a view of the weight of the variables in the regression dynamics. The IRLS regression provides the two most significant and descending rank order beta coefficients of the variables: BEs-BEs linkages and RIs-RIs linkages. The associated relative Pratt index (IRLS) discloses in descending rank order: BEs-BEs linkages; RIs linkages to the production system; and adequacy of human resources in science and technology. Thus we construe the equation (4) as

(4) (*Level of Innovativeness of BEs*) = 1.1242 + 0.3346 * (*BEs-BEs*) - 0.2916 * (*RIs-RIs*) + 0.1956 * (*RIs-PS*) + 0.1404 * (*Adequacy of HR in S&T*) .

Therefore, in Kenya a 1% increase in the strength of BEs-BEs and RIs-PS inter-linkages are respectively associated with a 0.33 and 0.20% increase in the level of innovativeness of business enterprises. Likewise, a 1% increase in the adequacy of HR in science and technology is associated with a 14% increase in the level of innovativeness of BEs. On the contrary, and unexpectedly, a 1% increase in the strength of RIs-RIs inter-linkages is associated with a 0.29% decrease in the dependent variable. Unlike Ghana, policy advisory choices suggest that, strengthening Actor Linkages (BEs-BEs and RIs-PS) is the best option in Kenya, although their intensification carries transactions costs of coordination and controlling managerial utility.

The policy implications of strengthening BE-BE linkages are that there is a greater ability to tap into and exploit stocks and flows of knowledge within the group, thus increasing the efficiency of the NSI. Additionally through the strengthening of RIs-PS linkages there would be greater externalities from the public goods of funding RI.

To test if the variables are truly important and robust in explaining the level of BEs innovativeness and to assess their significance is only due to inclusion of other predictors, we regress the level of BEs innovativeness only on the significant variables expressed in equation (4). The results (not presented) show that all the independent variables are significantly (at 1% level) correlated to the level of BEs innovativeness.

The results indicate consistently how important are linkages among BEs to their level of innovativeness.

Comparing the determinants of effectiveness of GNSI and KNSI, similarities are the significance of actor linkages and the linkages of RIs with the Production System.

[17] Blank cells are those relative Pratt indices that do not meet the condition $d_i > 1 / 2p$.

Differences are while ICT (Diffusion and Capacity) is significant in GNSI effectiveness, these variables are not significant in the case of KNSI.

Table 8 presents the significant estimates' coefficients of the models used to predict the determinants of efficiency of the GNSI proxied by the linkages between research institutes and the production system in Ghana.

Table 8. Efficiency of the GNSI (Linkages between Research Institutes and the Production System in Ghana)

	(1)	(2)	(3)
Estimation method:	OLS	OLS (robust SE)	Iteratively reweighted least squares
Diffusion of ICT	0.2462**	0.2462**	0.2636**
	(0.0241)	(0.0314)	(0.0141)
Level of innovativeness of BEs	0.2933***	0.2933***	0.2150**
	(0.0025)	(0.0022)	(0.0233)
Lack of finance	-0.2252**	-0.2252**	-0.2621**
	(0.0314)	(0.0434)	(0.0110)
Rate of access to ICT	0.2529**	0.2529**	0.2457**
	(0.0216)	(0.0243)	(0.0230)
constant	0.4331	0.4331	0.7715
	(0.3672)	(0.4162)	(0.1030)
N	234	234	234
R-sq	0.5849	0.5849	0.6006
Prob > F	0.0000	0.0000	0.0000

p-values in parentheses * p<0.10 ** p<0.05 *** p<0.01

As indicated in Table 8, the independent variables explain the 58.49% to 60.06% of the variability of the dependent variable in the regressions. The results indicate that the model is significantly different from zero (Prob > F = 0.0000). The greater the diffusion of ICT, the greater the strength of the linkages between research institutes and the production system. These results are robust, since from the IRLS regression the significance holds and the explanatory power of the model increases. The level of innovativeness of business enterprises is significantly associated with the linkages between research institutes and the production system. The more innovative business enterprises are, the greater the strength of the linkages, and *vice versa*. The results remain robust across techniques. Also the rate of access to ICT is positively associated with the linkages between RIs and the production system in terms that the higher the rate of ICT access the stronger the RIs-production system linkages.

Regarding the factors which constrain innovation, the relationship between the lack of finance and the linkages between RI and the production system is significantly negative. This is consistent with cost barriers to innovation [83].

Table 9 presents results for the relative Pratt indices. All the significant variables – the diffusion of ICT, the level of innovativeness of business enterprises and the lack of finance – are important among the set of predictors in the regression models with the exception of the rate of access to ICT predictor.

Table 9. Relative Pratt index d_i associated with predictor X_i[18](Efficiency of the GNSI).

Variable	Significant	Relative Pratt Index OLS	Relative Pratt Index IRLS
Diffusion of ICT	yes	0.1743	0.1817
Level of innovativeness of BEs	yes	0.2216	0.1582
Lack of finance	yes	0.0943	0.1069
Rate of access to ICT	yes		

The diffusion of ICT and the level of innovativeness of business enterprises respectively account for 18.17% and 15.82% of the R-squared. The lack of finance variable accounts for 10.69% of the R-squared.

The descending order ranked IRLS regression independent variables are: diffusion of ICT; lack of finance; rate of access to ICT; and level of innovativeness of BEs. The associated relative Pratt index discloses the descending order rank as: diffusion of ICT; level of BEs innovativeness and lack of finance. We construct the equation (5) as

(5) (*Strength of RIs-production system linkages*) = 0.7715 + 0.2636 * (*Diffusion of ICT*) - 0.2621 * (*Lack of Finance*) + 0.2457 * (*Rate of Access to ICT*) + 0.2150 * (*Level of BEs Innovativeness*) .

From a policy perspective, a 1% increase in the diffusion of ICT is associated with a 0.26% increase in the strength of RIs-production system linkages. A 1% reduction in the lack of finance is related to a 0.26% increase in the dependent variable strength of RIs-production system linkages. Similarly, a 1% increase in rate of access to ICT and level of BEs innovativeness is associated with a 0.25% and 0.21% increase in the dependent variable respectively.

Once again the issue of choice of intervention arises. As previously indicated ICT is key to facilitating communication and thus acts as a conduit for system wide innovation. Alternatively, increasing the availability of finance through the recalibration of policy tools such as Government-Backed Venture Capital, Donor Funds, Government Procurement and Regulation would have a marked impact on the efficiency on the NSI.

Again, to test if the above-mentioned variables are truly significant and robust, linkages between RIs and the production system is regressed only on the significant variables expressed in equation (5). The results (not reported) show that all four variables significantly influence the linkages between RIs and the production system at the 1%, 5%.

If these relationships are considered as causal, we would conclude that the most important policy choices, in resource constrained circumstances, for strengthening the RIs linkages to the production system in rank order are: firstly increasing the diffusion of ICT in terms of ICT infrastructure capacity and capability (i.e. storage capacity and speed) in order to increase the rate of access to ICT[19]. Secondly, making increasing financial resources available through either fiscal incentives or monetary grants geared to the inter-linkages between RIs and the production system; as well as performance requirements imposed on RIs on the one hand, and on the other hand the production system via higher resolution standards, would improve RIs-production system linkages. Thirdly, increasing the level of BEs innovativeness through a coherent mix of fiscal and monetary incentives, regulation and standards setting, and performance requirements (for example using government procurement terms and conditions) would enhance the efficiency of the GNSI.

[18] Blank cells are those relative Pratt indices that do not meet the condition $d_i > 1 / 2 p$.

[19] This implies reform in terms of the role of ICT in education at all levels as well as supporting industry in general to upgrade its ICT and using standards setting to produce improvements in the use of ICT.

In Table 10 we present the significant coefficients of the critical factors that determine the efficiency of the KNSI proxied by the strength of the linkages between research institutes and the production systems in Kenya.

Table 10. *Efficiency of the KNSI (Linkages between Research Institutes and the Production System in Kenya),*

	(1)	(2)	(3)
Estimation method:	OLS	OLS (robust SE)	Iteratively reweighted least squares
RIs linked to RIs	0.2465**	0.2465**	0.2748***
	(0.0212)	(0.0146)	(0.0066)
BEs linked to ARBs	0.2252**	0.2252**	0.1785**
	(0.0193)	(0.0118)	(0.0487)
ARBs and FIs linked to HE system	0.2922**	0.2922**	0.3005**
	(0.0284)	(0.0257)	(0.0170)
Diffusion of ICT	0.2032**	0.2032**	0.3329***
	(0.0458)	(0.0457)	(0.0006)
Level of innovativeness of BEs	0.1678**	0.1678**	0.1659**
	(0.0326)	(0.0276)	(0.0252)
Rate of access to ICT	-0.3303***	-0.3303***	-0.2489**
	(0.0023)	(0.0088)	(0.0145)
constant	0.7565	0.7565	0.8686*
	(0.1344)	(0.1693)	(0.0688)
N	249	249	249
R-sq	0.5828	0.5828	0.6424
Prob > F	0.0000	0.0000	0.0000

p-values in parentheses * p<0.10 ** p<0.05 *** p<0.01

As indicated in Table 10, the independent variables explain the 58.28% to 64.24% of the variability of the dependent variable in the regressions. The results indicate that the model is significantly different from zero (Prob > F = 0.0000).

Actor Linkages are positively associated with the linkages between research institutes and the production system. In particular, the linkages among research institutes are positively associated with the dependent variable as are linkages between business enterprises and arbitrageurs; the linkages between arbitrageurs and higher education systems. These results are robust. Also the diffusion of ICT and the level of business enterprises are significantly and positively associated with the linkages between research institutes and the production system. Thus, the more diffused the ICT and/or the more innovative BEs are, the greater the strength of the linkages, and *vice versa*.

Unexpectedly, the rate of access to ICT is negatively associated with the strength of the linkages between research institutes and the production system. The absolute value of this relationship is much higher than the absolute value of any other association in the model although it decreases when applying the robust technique (IRLS).

Interestingly, unlike Ghana, in Kenya the rate of access to ICT is negatively associated with the dependent variable. As in Ghana, the improved level of innovativeness of BEs and the increased level of diffusion of ICT are significantly associated with the strength of the linkages between RIs and the production system.

Table 11 presents results for the relative Pratt indices. All the significant variables – the linkages among RIs, between BEs and ARBs, between ARBs and HE systems, the diffusion of ICT, the level of innovativeness of BEs, and the rate of access to ICT – are important among the set of predictors in the regression models.

Table 11. Relative Pratt index d_i associated with predictor X_i (Efficiency of the KNSI).

Variable	Significant	Relative Pratt Index OLS	Relative Pratt Index IRLS
RIs linked to RIs		0.0876	0.0885
BEs linked to ARBs		0.1152	0.0828
ARBs and FIs linked to HE system		0.1935	0.1806
Diffusion of ICT		0.1248	0.1855
Level of innovativeness of BEs		0.0870	0.0780
Rate of access to ICT		0.0788	0.0539

Actors Linkages (RIs-RIs, BEs-ARBs and ARBs-HE systems) respectively account for 8.85%, 8.28%, and 18.06% of the R-squared, whereas the relative Pratt index of the diffusion of ICT, the level of innovativeness of BEs and the rate of access to ICT variables account for 18.85%, 7.80%, and 5.39%, respectively.

The descending order ranked IRLS regression independent variables are: diffusion of ICT[20]; ARBs-HE systems inter-linkages; RIs-RIs inter-linkages; rate of access to ICT; BEs-ARBs inter-linkages; and level of innovativeness of BEs. The associated relative Pratt index discloses the same descending order rank – except for rate of access to ICT – as: diffusion of ICT; ARBs-HE systems inter-linkages; RIs-RIs inter-linkages; BEs-ARBs inter-linkages; level of innovativeness of BEs; and rate of access to ICT. We construct the equation (6) as

(6) (*Strength of RIs-production system linkages*) = 0.8686 + 0.3329 * (*Diffusion of ICT*) + 0.3005 * (*ARBs-HE systems linkages*) + 0.2748 * (*RIs-RIs linkages*) - 0.2489 * (*Rate of Access to ICT*) + 0.1785 * (*BEs-ARBs linkages*) + 0.1659 * (*Level of BEs Innovativeness*) .

From a policy perspective, a 1% increase in the diffusion of ICT is associated with a 0.33% increase in the strength of RIs-production system linkages. A 1% increase in Actor Linkages' strength (ARBs-HE systems, RIs-RIs and BEs-ARBs) is respectively related to a 0.30%, 0.28% and 0.18% increase in the strength of the linkages between RIs and the production system. Again unexpectedly, a 1% reduction in the rate of access to ICT is associated with a 0.25% increase in the dependent variable strength of RIs-production system linkages. Similarly, a 1% increase in level of BEs innovativeness is associated with a 0.17% in the dependent variable.

In the case of Kenya the policy implications are oriented around the diffusion of ICT and Actor linkages. Specifically, given the spatial distribution of the Actors, upgrading the information infrastructure to enable ICT diffusion in the form of 'supercorridors' and 'super regions' would enhance the efficiency of the NSI through better transfer of Data Information Statistics and Knowledge (DISK). With respect to enhanced Actor linkages, particularly between Arbitrageurs and Higher Education, there would be an increased market intelligence therefore leading to marketisation of research.

Again, to test if the above-mentioned variables are truly significant and robust, linkages between RIs and the production system is regressed only on the significant variables expressed in equation (6). From the results (not presented) we deduce that only ARBs-HE

[20] The association between the linkages between RIs and the production system and the diffusion of ICT has the highest value also in the model for Ghana.

systems inter-linkages, the ICT diffusion and the rate of access are significantly associated with the linkages between RIs and the production system.

Finally, given that the causality of the independent variables on the linkages between research institutes and the production system is not straightforward, the important policy tools for strengthening the RIs linkages to the production system are similarly to Ghana, the first choice is to increase the diffusion of ICT. These findings imply that ICT coverage should increase and ICT should be expanded to industries which do not have access yet, whereas support to those already benefiting from high rate of access to ICT should be [word]. In addition, strengthening the linkages between arbitrageurs and higher education systems and among research institutes, through giving incentives to the arbitrageurs which intermediate between universities and industry would enhance the efficiency of the KNSI.

It should be noted that in the case of Ghana correlations between the variables: Level of Innovativeness of BEs; Linkages between RIs and the Production System; Diffusion of ICT; ICT capacity; and Rate of Access to ICT were examined. Additionally in case of Kenya correlations between: Level of Innovativeness of BEs; Linkages between RIs and the Production System; Diffusion of ICT; ICT Capacity; and Rate of Access to ICT were examined. Due to the constraints of space these results are not reported here but can be viewed upon request.

The regression finding in the case of the KNSI, compared to the GNSI, of significant negative association of the rate of access to ICT with strength of RIs – Production System Linkages is unexpected and paradoxical. According to Pilat (2004) [84], aggregate, or system-wide (as in our study), evidence may generate paradoxes whilst micro-level or firm level data provides little or no such evidence. A number of reasons for this dichotomy between system and components of the system may be advanced. First, given the positive correlation between Rate of Access to ICT and ICT Capacity, the role of ICT, its impacts on, and in relation to, the Efficiency of the KNSI are likely also to depend on other factors (such as skills, organisational factors, innovation, competition dynamics, firm demographics, and lags) as well as policy changes [85] .

Secondly, despite Kenya's acknowledged sophisticated ICT infrastructure relative to other Sub-Saharan African countries, benefits of Rate of Access to ICT at the micro-level may be insufficient to manifest at the level of the KNSI. Thirdly, as we map and measure the NSI we may miss firm-level effects. Fourthly, competition dynamics may play a role in deciding extracts the lion's share of returns to ICT investments. Low competitive environments would tend to limit spillovers.

Nevertheless, the contrast between GNSI and KNSI presents a challenge.

According to ITU (2013), Kenya's access to ICT has been improving in the last years – over a sample of 157 countries, Kenya was 123rd in 2011 and jumped to the 113rd place in 2012 – being the bandwidth-richest country in Africa, but ICT use has not increased as much as its access in the same period. In Ghana, the access to ICT has improved in the period 2011-2012, but not at the same level as in Kenya. However, the use of ICT is higher in Ghana than in Kenya. Indeed, Ghana is the 94th out of 157 countries, whereas Kenya is only the 109th. In comparison according to the Global Information Technology Report 2013, Ghana is ranked 95 out of 144 compared to Kenya's rank of 92 in terms of networked readiness index [86].

6. Policy Recommendations, Conclusions and Issues for Further Research

Given the equations 3, 4, 5 and 6 on the effectiveness and efficiency of the GNSI and KNSI, policy means to improve the functioning of the two respective NSIs rests on enhancing Actor Linkages, ICT Standards Setting, and Finance in the case of Ghana. In the case of Kenya the policy variables to be enhanced are Actor Linkages and Human

Resources in Science and Technology, Diffusion of ICT. In both countries strengthening RIs Link with the Production System and the Level of Innovativeness of BEs leads to increased GNSI and KNSI Effectiveness and Efficiency. The diffusion of ICT is crucial to the efficiency of both the GNSI and the KNSI [87]. The ICT paradox in the case of the KNSI but not the GNSI indicates that, while ICT is a significant variable in terms of 'stocks' and 'flows' within NSI Effectiveness and Efficiency, the relationship is not straightforward given the different dimensions of ICT (diffusion, access, capacity, storage, speed, usage, skills, hardware and software). Further cross-country and cross-sectional analyses will assist in addressing this issue and generate further insights to the role of ICT in NSI Efficacity. Relating the Efficacity of the overall business environment to that of the NSI may also assist in illuminating the ICT paradox. Finally, analyses of firm level dynamics in Kenya may shed light on the role ICT plays in the KNSI.

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