IST-Africa 2012 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2012
ISBN: 978-1-905824-34-2

Free Open Source Software (FOSS) and Survey Methodologies: The case of the Ghana National System of Innovation Survey

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Abstract: In today's global knowledge-based economy, it is evident that knowledge, its accumulation and distribution, through institutions of human and social capital, plays an increasingly crucial role as a key factor in economic development. The production, distribution and processing of knowledge (especially scientific and technological) is increasingly performed within the domain of computational information and communication technologies (ICTs). Even though there is an uneven distribution of the ICT resource, particularly within developing countries the emergence of Free Open Source Software (FOSS) can act as a means to bridge the 'digital divide'. This paper looks at how FOSS has been utilized in Ghana for the purposes of mapping the National System of Innovation (NSI) and creating evidence based policy.

Keywords: Free Open Source Software (FOSS), Knowledge transfer, Knowledge accumulation, National Systems of Innovation (NSI), Ghana

1. Introduction

In today's global knowledge-based economy, it is evident that knowledge, its accumulation and distribution, through institutions of human and social capital, plays an increasingly crucial role as a key economic factor [1][2]. Since the 1950's the ability of policy makers and economists to explain fully the determinants of, and growth rates for, Western Industrialised Economies in terms of traditional production factors such as land, labour, and capital has become increasingly problematic. [3][4]. The 'residual' [5][6] has been explained in terms of: upgrading of the labour force; surplus generated by interaction effects; and by the increasing role of knowledge in the economy [7]. To further underscore the increasingly strategic economic role of knowledge the work of Lastres et al. (2005) presents three interrelated arguments. Firstly, "the proportion of labour that handles tangible goods has become smaller than the proportion engaged in the production, distribution and processing of knowledge"; secondly, "the share of codified knowledge and information in the value of many products and services is significantly increasing"; and finally, "knowledge-intensive activities are rapidly growing" [8]. This

production, distribution and processing of knowledge (especially scientific and technological) is increasingly performed within the domain of computational ICT.

This paper emphasizes the importance of ICT, particularly FOSS in the measurement of the main actors' perspectives and interactions—as development assets—within the NSI of Ghana as a valid means to effectively implement the achievement of national targets of innovation, science and technology policy.

With the aforementioned in mind, designing policy for the right social institutions to absorb, retain, advance, distribute and sustain knowledge becomes vital to a nation's global economic positioning. However this process of design poses serious challenges. "In addition to understanding the importance of codified and tacit knowledge, it is also important for governments concerned with competitiveness to efficiently utilize policy instruments and internal resources (economic agents and institutions) if they are to achieve competitive advantage" [9]. A framework that enables this process of design is the National Systems of Innovation (NSI). The definition of NSI is varied and a good overview of how the concept has evolved can be found in the work of Freeman (1995) [10]. Based on the evolution in this body of work we embrace the description of Lundval (1992) who defines a NSI as 'the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge ... and are either located within or rooted inside the borders of a nation state' [11]. However to this succinct definition we add an additional dimension as framed in the definition of Bartels et al. (2012), which is 'the envelope of conforming policies as well as private and public institutional relations, and their coherent social and capital formations, that determine the vector of technological change, learning and application in the national economy' [12]. Through these definitions the importance of the non-recursive relationship between knowledge and policy becomes clear.

However, given the definition that alludes to the 'envelope' of conforming policies, there are two aspects that are excluded from the traditional framing of NSI, particularly in the context of developing countries, which we include in our model, namely the effects of diffused information and communication technologies (ICTs) and arbitrageurs. Through the spread of digital information and ICTs a new mode of development has evolved [13][14]. Our conceptualization of ICT in NSI is not based solely on the concept of access, but the work of [15] Hilbert et al. (2010) who view 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. Within the developing country context the three actors are perceived to hold relatively traditional and separate roles, with little or no overlap in functional relationships, i.e. "entrepreneurial academics, academic industrialists, and business strategy in government" [16]. This is evidenced by the lack of bodies such as technology transfer or licensing offices within universities, or the widespread presence of venture capitalists. Therefore, access to the necessary financial and information resources would lead to the need for independent institutions, namely arbitrageurs. Figure 1 illustrates this concept.

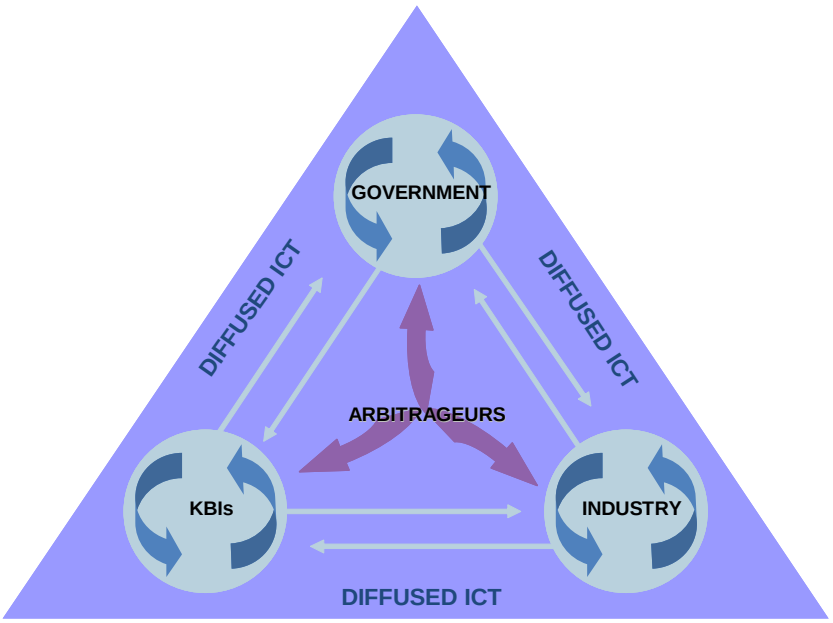

Fig. 1

As indicated by Leydersdorff and Ektowitz (1996) [17], the characteristics of NSI—that is, the strength and quality of interactions between government, knowledge-based institutions (KBIs) and industry—are critical determinants of efficiency and effectiveness in the creation and dissemination of both tacit and codified knowledge.

It should also be understood that "policy is a part of the system, and it has outcomes and impacts, just as a new technology or business process does" [18]. From a developing country perspective it should be noted that there are good and some better ways to develop policy, but above all, it is important to "avoid copying the latest policy fashion" [19]. Thus, informed policy requires an understanding of the characteristics of the relevant actors within a system, their inter-relational dynamics and their individual requirements. This can only be achieved through effective systemic measurement of NSI, which is a complex affair that often requires the deployment of already limited resources both in terms of finances and human capital (particularly in a developing country context).

The aim of this paper is to highlight the importance of ICT, particularly FOSS in the measurement of the main actors' perspectives and interactions—as development assets—within the NSI of Ghana; consequently providing a strong basis for validity, and therefore the development of policy to effectively achieve national targets of innovation, science and technology policy.

Section 2 of the paper addresses the difficulties of data collection particularly within a developing country context and highlights the importance of FOSS. Section 3 presents the case of the Ghana National System of Innovation (GNSI) Survey and how through the use of ICT and open sourced software barriers to data collection can be overcome. Section 4 looks at the results gained from the GNSI survey and relates them to the use of FOSS. Section 5 concludes with policy recommendations and areas of further research.

2. Data collection and Free Open Sourced Software

At the most elementary level, "evidence based policy making refers to the notion that policy intervention and direction are underpinned by an understanding of how things develop" [20]. In order to facilitate this there is the need for measurement and hence effective data collection. Essentially there are two basic forms of data collection, namely, interviews and self-administered questionnaires [21]. In both cases the process is complex and requires the careful consideration of a multitude of parameters, including: nature and scope of the enquiry; availability of financial resources; availability of time; access to necessary manpower; degree of accuracy required, type of collection method to be used [22] as well as issues of statistical reliability and validity.

Traditionally methods of data collection and knowledge codification have involved mail, face-to-face, and telephone based approaches. The main facets of which are outlined below:

Mail Surveys

- Mail surveys are less intrusive than interviews: respondents may answer at leisure in their own time and there is no interviewer present who may inhibit free answers to more sensitive topics.
- Mail surveys lack the flexibility and interviewer support of interview surveys, which limits the complexity of the questionnaire. This is partly mitigated as visual stimuli, such as pictures and graphics can be used.
- Access to lists of the target population should be available but may difficult to obtain.
- Mail surveys have a longer turn-around than telephone surveys, but face-to-face interviewing takes even longer.
- Mail surveys may be less costly than face-to-face, however when the distribution is at an international level, greater costs should be anticipated.

Face-to-face Interviews

- Face-to-face interviewing has the highest potential with respect to types of questions and complexity. To realize this potential one needs both well trained interviewers and well tested questionnaires, and a qualified field staff in order to take care of logistics.
- Face-to-face interviewing can be costly and time consuming.
- Face-to-face interviewing has also the highest potential regarding coverage and sampling, but again it can be very costly, especially if the country is large and/or sparsely populated.
- The greatest asset of a face-to-face interview – the presence of an interviewer is also its greatest weakness. Their presence may influence answers the respondents give, especially when sensitive questions are being asked.
- In general there may be a contribution to total survey error due to the variance of the skill of interviewers.

Telephone Interviews

- Telephone interviews have less potential with respect to types of questions than face-to-face interviews, because there is no visual communication.
- Interviewers are able to assist the respondents and complex questionnaires may be used.
- Fewer questions can be asked, a general rule is 20-30 minutes although longer questionnaires have been successfully completed.

- In situations where access to landlines or mobile phones is limited, results may be sub-optimal.
- If good contact lists are available them from a sampling perspective, telephone interviews are comparable to face–to-face interviews.
- If the sample dispersion if too high then telephone interviews are the optimal method.
    - Telephone interviews can be less costly than face-to-face interviews.

To summarise, the main issues that arise across all three data collection methods are: cost, coverage, and quality of response.

However, the emergence and proliferation of the "new techno-economic paradigm, centred on information and communication technologies (ICT), have accelerated and deepened both the codification of knowledge and the spread of information" [23], as well as the overall quality of data acquisition and responses to surveys.

As highlighted above the ability to access information and knowledge are key factors in developing competitiveness and being able to engage globally. In particular, in the creation, dissemination, accumulation and application of information and knowledge; ICT acts as a conduit facilitating this process [24]. Regrettably, "there is an uneven distribution of this resource, which directly impacts on developing countries' capacity to fully participate in today's global information economy" [25]. This visible "digital divide" is partly due to the minimal availability of ICT access in developing countries as compared to developed countries. "Limited resources in developing countries, Africa in particular, act as a barrier to investment in expensive communication infrastructure, applications and hardware. Many countries are more concerned with basic economic priorities as housing, water and energy. Bridging the digital divide through digital inclusion may provide a possible means to make globalisation work for the poor" [26].

FOSS presents an access solution for developing countries to adopt affordable software applications thus facilitating the bridging of the digital divide. FOSS by its constitution – non-rivalry and non-excludability [27] – acts as a public good. The consumption of a non-rival good by one consumer does not decrease its utility for another consumer. FOSS programs can be copied and distributed at near zero costs without the application losing its quality. Non-excludability is defined as the characteristic, which makes it difficult or impossible to charge people for the use of a good. The distribution of the source code of FOSS underlines this characteristic.

Conversely there arises the issue of sustainability as, according to public choice theory, FOSS developers would cease to invest time and expertise in developing programs that could otherwise be used by free riders and the FOSS movement would unravel, and contributions would cease. However in practice, there are few grounds to assume this outcome as FOSS projects are growing around the globe. For example, there are long running FOSS projects such as GNU/Linux, Apache or even the internet browser Mozilla's Firefox. This brings up the question of why talented programmers would offer their expertise for free and also why developing countries would actively participate and contribute to FOSS distribution and development.

It has been noted that there is a positive correlation between the growth of a FOSS developer base and the innovative capacities of an economy [28]. Therefore FOSS has the inherent capacity for development of local nascent capacity by fueling innovation through knowledge transfer. With this in mind there needs to be a rethinking of the use of proprietary software by developing

countries, as this may not be the optimal strategy for technological or human resource development.

3. Methodology – Ghana National System of Innovation Survey

This section discusses the steps involved in planning and executing the Ghana NSI, along with the problems associated with a study of this type, and the innovative measures taken to address these issues through the use of the FOSS application Lime Survey. Figure 2 below provides a graphical overview of the methodology used in conducting the Ghana NSI survey.

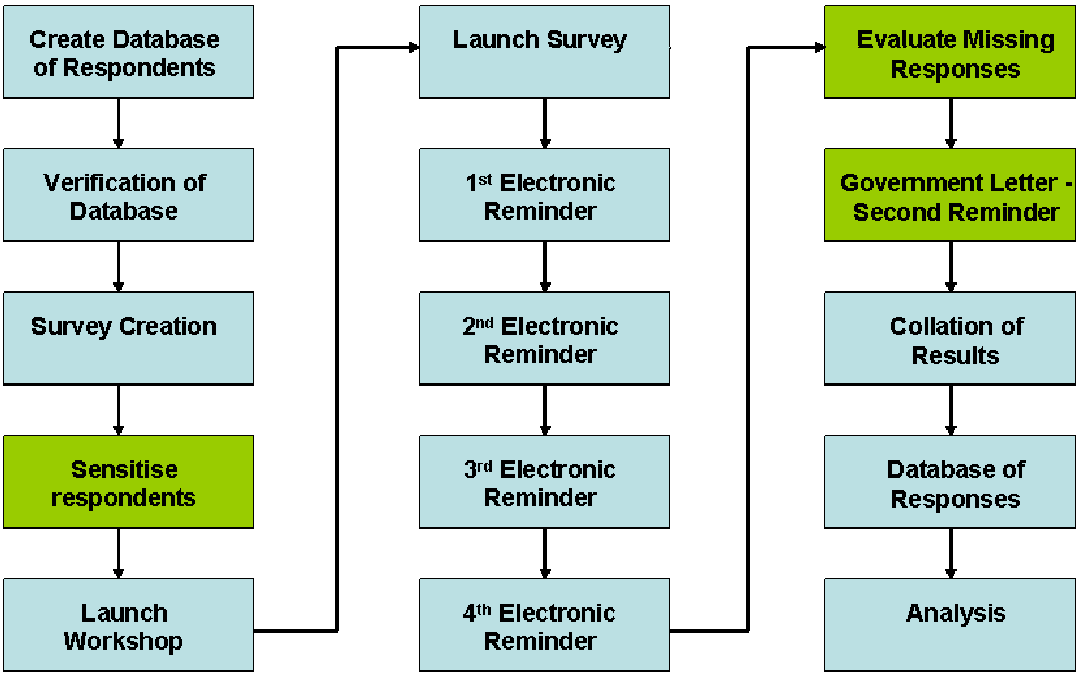

Figure 2

The following [29] quoted *in extenso* portrays the methodological approach used in the GNSI survey. "The first step in the survey process is the identification and creation of a comprehensive database of respondents. The target respondents chosen were derived from the three main NSI actor groups, according to the 'triple helix model' proposed by [30] Leydesdorff and Etzkowitz (1996), and an extra intermediary body, namely:

First, the policy community (essentially the Government) is represented by officials working in the relevant division of public institutions who are directly or indirectly responsible for innovation. These include institutions such as the Ministry of Science and Technology, Economy, Finance, Trade, Education and Industry. Government funded research institutes are also included in this category.

Secondly, the knowledge community (KBIs) is represented by heads of university and innovation-related faculties/departments (economics, science, engineering and business) as well as heads of think tanks and research institutes. Privately funded research institutes are also considered in this category.

Thirdly, the industrial community is represented by the CEOs of firms in the medium- and high-technology manufacturing sector in accordance with the sectoral ISIC Rev. 3 classification.

Finally, the intermediary actors selected was that of arbitrageurs, i.e., venture capitalists and knowledge brokers. This group of actors is not represented in the traditional TH model, but 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 [31][32][33]. Their resource allocation role is based on the assessment of advantages in information asymmetries [34][35][36].

For all selected actors full contact details were obtained: those of government representatives were provided by the Ministry of Trade and Industry (MoTI) and the Ministry of Environment Science and Technology (MEST); the contact details of industry CEOs were retrieved from the online business directories such as Kompass, which was chosen on account of its comprehensive list of worldwide companies and the function allowing to find multiple e-mail addresses, and those for KBIs and arbitrageurs were obtained through desk research.

The next point of discussion is response rate. Low response rates are seen as problematic by the researcher as sampling error increases to the odds that samples are too small from which to draw any meaningful conclusions [37]. Overall response rates have been found to differ significantly, both across different professions and occupational groups as well as across countries. Evidence suggests that response rates by managerial staff are lower than those of non-managerial staff [38]. In a recent meta analysis, [39] Cycyota and Harrison (2006) identified an overall top manager response rate of 32 per cent. In an international research context, these rates are, on average, likely to represent an upper boundary, however, steps were taken to maximize the response rate and will be addressed in more detail below.

The next step, one that requires a great deal of thought, is survey design. Generally, questionnaire length is considered an important predictor of response rate [40][41]. With respect to the Ghana NSI survey, the variables were developed based on a review of NSI literature by the UNIDO Statistical Research and Regional Analysis Unit. This initially consisted of 300 comprehensive variables. In order to ensure the highest possible response rate, the survey instrument was revised and the number of variables reduced to 138[1].

Empirical evidence supports the treatment of ordinal variables as conforming to interval scales [42][43][44]. For this reason and for the purpose of clarity and ease, direction and strength of the response scales were carefully considered within the design process. [45] Matell and Jacoby (1972) state that as the number of steps in a scale increases the number of respondents who use the midpoint decreases. However, the exclusion of a midpoint in a scale leads to a greater negative bias within the results [46]. In light of this, the Ghana NSI survey incorporated a five-point Likert scale which utilized a midpoint, thus reducing the bias towards both extreme answers and towards false negatives.

The next step in the survey process is the choice of method for survey delivery of which numerous types exist within the literature, each with differing perspectives and assessments. From the list of mail, telephone, interactive voice response and internet[2], we chose the latter

1 The selection and drafting of the survey instrument was based on deliberations from an earlier version tested in seven Emerging Market Economies (EMEs) – Morocco, Egypt, Chile, Peru, Malaysia, Thailand, and Ukraine, in 2007. The test of the 2007 pilot also utilized the Lime Survey FOSS tool.

2 Given the specific targeting of respondents in the four communities respectively, the survey participation invitation email, sent en-masse to all respondents, contains a link leading to the electronic questionnaire. To enhance data reliability and validity the link was equipped with an authorization token to restrict the access of people who have not received a token and ensure that each respondent was only able to answer the questionnaire once.

based on the following justifications: i) In terms of maximizing the use of the budget, internet surveys can cover a much larger sample size than the conventional mail survey [47]; ii) The time dimension associated with conducting web-based surveys is much lower in comparison to other forms [48]; iii) The quality of retrieved data is higher in terms of non-response and the ability to include conditionality in a discreet manner [49]; iv) Higher reliability of data is achieved due to the reduced need for data entry [50][51][52]. However, there is need for caution when sampling using a web-based survey. In particular, careful attention needs to be paid to the level of computer access of the target population [53]. In the case of the Ghana NSI survey, the target population is a sub-population with very high internet access, even within the developing country context, and therefore this concern is of less relevance.

As previously noted, maximizing the response rate is crucial to achieve good survey results. Various strategies associated with the survey process exist to increase response rates. In general, it is advantageous to follow a multi-stage survey process that includes the circulation of an announcement letter and the distribution of reminders [54]. Announcement letters and reminders also have a secondary benefit, namely the creation of sponsorship. [55] Harzing (2004) discusses the importance of sponsorship, particularly given the geographical and cultural distance between researchers and respondents. Generally, sponsorship can be provided by an international professional organization, participating organization, international committee of recommendations or at the level of the individual unit of analysis. Conversely, a negative aspect of sponsorship is the creation of the Hawthorne effect [56]."

4. Results

Considering the challenges of surveying in developing countries, the results of the GNSI survey are very encouraging. As previously mentioned the sample population is composed of senior persons within the hierarchy of each of the four actor groups (Government, KBIs, Industry and Arbitrageurs), and the rate of response from this group is expected at best to be in the range of 32% [57]. For the GNSI survey a universe of 557 was identified. From this, due to changes in contact information and inability to access current information and inactive email addresses, a convenient sample of 417 was obtained. The convenient sample was surveyed for a period of 6 months[3], the end result being a total number of 224 responses (54%) at the time of writing. This figure is considerably higher than the aforementioned maximal response rate of 32%.

It should be noted that, in the case of the GNSI survey, the survey is the data base because of the unique properties of FOSS Lime Survey. As responses are remotely completed they are automatically translated into the database, therefore attributing a high level of fidelity to the responses as error from data transcription is avoided.

In terms of validity: i) the level of internal and construct validity is high as variables were extracted from a comprehensive review of literature; ii) Due to the elevated response rate the external validity, or the gerneralizability, of the results is also high; finally iii) an elevated degree of face validity is achieved as the FOSS Lime Survey tool facilitates accurate and efficient measurement.

3 The risk of the survey becoming longitudinal is low as the rate of institutional change within Ghana is low.

5. Conclusions and Policy Recommendations

Policy for enhancing the role of innovation, science and technology, in terms of knowledge that drives performance as well as application across the economy, is increasingly seen as crucial for national economic development and industrial competitiveness. However, reliable policy craft (mapping, measurement, analysis and control) and operable and valid policy instruments (performance requirements, regulations, fiscal and monetary incentives) continue to elude, to a large extent, the developing countries in general and the least developed countries in particular. The reasons for this are many and range from sheer institutional capacity constraints, budgetary limitations and inappropriate priorities to the lack of know-how by the policy making community and the problematics of corruption, managerial utility and perverse incentives. While these challenges may not be tractable simultaneously, developing country policy makers can make relatively easy choices to alleviate their problems of inadequate policy craft and unsuitable policy instruments.

The first is the necessary adoption of a posture for longitudinal mapping, measurement, analysis and control of the variables of innovation, science and technology policy in terms of NSI. Such a posture enables policy to be ultimately evidence-based. The consequences of misinformed and incorrectly targeted policy is confirmed by the mapping of the Canadian innovation system, in that only certain human resource groups were targeted by programmes and policy which subsequently resulted in creating serious gaps [58]

Secondly, recognizing the crucial role of computational ICT (internet access, storage capacity and processing capability) in the health of the national economy, ICT infrastructure needs to be prioritized in developing country government budgetary expenditures. This progressively provides an effective and efficient medium in which the accumulation of knowledge, its diffusion and spatial distribution, through the economic institutions of human and social capital, can take place.

Thirdly, in terms of late-comer advantages and learning, the use of FOSS (such as Lime Survey) for longitudinal mapping, measurement, analysis and control of the variables of innovation, science and technology represents all the value of a public good to the developing country without legacy and sunk costs. The question of who should lead in making such choices comes to the fore. Clearly, given the strategic value of NSI, computational ICT, and innovation, science and technology in the economy, it falls to governments of developing countries to lead. This can be accomplished judiciously in a number of ways namely: (i) compiling and maintaining a database of FOSS; (ii) by example in using intelligently FOSS within government work; (iii) incentivizing KBIs to employ wisely FOSS in their research and policy work and in government awarded contracts; (iv) requiring the application of FOSS in tendering for government contracts; and (v) ensuring that the intellectual property rights regime is compatible with the computational ICT infrastructure and exploitation of FOSS.

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