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Capacity versus incentive factors explaining research productivity: Comparative and multilevel analysis of Nigeria and Ghana agricultural research systems

Ragasa Catherine

Development Strategy and Governance Division International Food Policy Research Institute (IFPRI) 2033 K Street, NW Washington, DC 20006 USA.

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This paper analyzes factors that explain variations in research productivity and outreach among 344 agricultural scientists in Nigeria and 237 agricultural scientists in Ghana using multilevel analysis. Education level, years of experience, and perceived adequacy of funding, physical and human resources are significant capacity actors explaining research productivity. In addition to capacity factors, incentives also showed to be significant in explaining research productivity. Reported staff satisfaction on organizational climate, presence of strong M&E system and presence of flexible-type organizational culture are consistently significant incentive factors explaining productivity. Results revealed that quantity and quality of human resources seem to be the priority for Ghana; while adequacy of physical and financial resources and implementation of organizational management systems seem to be the priority for Nigeria.

Key words: Agricultural productivity, agricultural research, organizational culture, multilevel analysis, Africa.

INTRODUCTION

Improved agricultural technologies and increasing agricultural productivity have been emphasized as key in solving the world's crises in food and natural resource degradation (World Bank, 2007; Food and agricultural Organization (FAO) and World Food Programme (WFP), 2009; International Food Policy Research Institute (IFPRI), 2011). Agricultural researchers and their organizations can play a vital role as innovators to bring forth improvements in agricultural productivity and growth. But despite various attempts by the development partners and other international organizations to strengthen the capacity of researchers and their organizations in many developing countries, various studies find that their productivity, outreach and impact remain low (Eicher,

E-mail: c.ragasa@cgiar.org. Tel: +1 (202) 8624613.

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2001; IAC, 2004; Clark, 2005). Various reasons that were cited by past studies for the inability of these systems to respond to producer demands and new sectoral challenges and can be summed up into lack of *capacity* (in terms of funding, skill sets, training, education, human resources, infrastructure, and mobility) (Beintema and Stads, 2014; Spielman and Birner, 2008; IAC, 2004; Clark, 2005; Alene et al., 2007) and lack of *incentive* (lack of vision and mission orientation, leadership, different mindsets, different priorities with the organizations, emphasis in outputs and deliverables rather than impact on the ground, low salaries and compensation, and prominence of culture of complacency rather than culture of quality and impact within the organization or research systems (Eicher, 2001; Byerlee 2004; Ragasa et al., 2011). While low adoption and returns can reflect weakness in the agricultural extension system or input distribution system, organizational and institutional bottlenecks at the research organizations can possibly hinder farmers' demand articulation and engagement in research processes and the effective translation of research into useful innovations.

One key area addressed in other fields and relevant to agricultural research is the need to distinguish between *capacity* and *incentive* (Ragasa et al., 2013a, b, 2014) and between organization and institution (Raina, 2003). On agricultural extension, Anderson and Feder (2004) and Ragasa et al. (2013b) indicated the lack of *incentives* of public extension providers as the main cause of the problem. The recognition of the incentive problem has led to various solutions, including privately provided but publicly funded extension (for example, Chapman and Tripp, 2003). On the other hand, there are studies which indicate that lack of *capacity* (that is, inadequate training, knowledge on recent innovations, and lack of proper skills and methods for communication) was the most important reason for the ineffectiveness of extension systems (Bandiera and Rasul, 2006; Feder and Savastano, 2006). On agricultural policymaking processes, Ragasa et al. (2014) showed that both capacity challenges and more so incentive factors are impeding the effective design and implementation of food and agricultural policy and institutional reform processes in the Democratic Republic of Congo. On food safety certification, Ragasa et al. (2013a) showed that incentives (in terms of price differentials in alternative markets) were more important factors in explaining continued certification than capacity of compliance of processing firms in the Philippines. On agricultural research, Raina (2003) stresses the need to distinguish between organizational management systems and institutional reform, which is critical for the effectiveness of both policy and of innovation processes. Organizational management often includes formal structures, such as recruitment policies, staff appraisal systems, and other plans, whereas institutional reform emphasizes organizational values, culture, motivations, and staff accountability. In addition to organizational management constraints, Raina (2003) emphasizes the need to look at institutional constraints that can block the innovation process, as well as sources of motivation that can improve performance.

Therefore, exploring and differentiating between capacities and incentives and between organizational and institutional factors within the research system will contribute to the existing literature at the same time help understand bottlenecks to increasing research productivity and their impact on agricultural productivity.

GHANA AND NIGERIA CASE STUDIES

The cases of Nigeria and Ghana were used because both have had similar significant periods of agricultural policy changes and structural adjustment over the years and are considered two of the largest countries in terms of the size and growth of agricultural R&D expenditures, while still struggling with low productivity and high yield gaps in their major commodities. In terms of their national agricultural research systems (NARS), Nigeria and Ghana are two of the biggest in sub-Saharan Africa (SSA), contributing 24 and 4%, respectively, to the continental funding of 1.7 billion dollars in 2011 (raw data from Beintema and Stads, 2014). We choose these two countries to enable comparison of the two biggest R&D systems in SSA, and also because funding for the data collection and analysis for this paper was available for these countries. The socioeconomic indicators for Nigeria and Ghana are shown in Table 1.

The public agricultural research systems in both countries are structured similarly, although Nigeria is substantially larger and more complex in terms of size and number of institutions involved. In Nigeria, there are 15 agricultural research institutes and 11 federal agricultural colleges under the umbrella organization, Agricultural Council of Nigeria (ARCN), and a significant number of agricultural higher education agencies conduct agricultural research at both federal and state levels (including 122 specialized universities, colleges, faculties, and departments based on latest estimate by ASTI). In Ghana, 30 public agencies conduct agricultural research – 10 agricultural research institutes are under the main government umbrella research organization, Council for Scientific and Industrial Research (CSIR), Cocoa Research Institute of Ghana (CRIG), which conducts research on tree crops (cocoa, coffee, kola, and cashews), Marine Fisheries Research Division, which focuses on marine fisheries, and 18 universities and colleges.

The government remains the largest contributor to public agricultural research in both countries, although in more recent years, greater proportion of donor contribution

Table 1. Summary of socioeconomic statistics and description of the agricultural research systems in Nigeria and Ghana.

Indicators	Nigeria	Ghana
Social and economic indicators		
Population (2010)	158,258,917	24,332,755
Poverty headcount ratio at national poverty line (% of population) (2009)*	64.4%	35.5%
GNI per capita US$ (2010)	1,180	1,240
Life Expectancy in years (2009)	48	57
Literacy Rate (% of population) (2009)	61	67
GDP growth rate* (2009)	2.9%	4.5%
Malnutrition rates* (2009)	28.7%	13.9%
Share of agriculture in GDP	33% (2006-2007)	31% (2006-2009)
Percentage of agricultural investment to total public expenditure* (2009)	4.5%	5.8%
Ratio of agricultural investments to AgGDP* (2009)	<5%	<2%
AgGDP growth rate* (2009)	-0.3% (2009)	4.5% (2009)
Agricultural research system**		
Number of technology produced (1997-2008)	207	106
Ratio of technology produced (1998-2008) to total number of researchers [FTE] (1990-2005) (Technology/researcher)	6	4
Number of researchers ([FTE] (2008)	2062	537
Number of researchers ([FTE] (1990-2005)	1,250	390
Number of rural population per FTE researcher	39,300	21,800
Agricultural research expenditure (million PPP dollars) [2008]	392	95
Agricultural research expenditure (million PPP dollars) [1990-2005]	170	38
Agricultural research expenditure (% of AgGDP) (2008)	0.40%	0.53%

Source: World Bank - http://data.worldbank.org/country/ (accessed 3rd Sept. 2011) if not specified; *Omilola and Lambert (2010). **Ragasa et al. (2011).

is observed in Ghana compared to Nigeria. In Ghana, 8 to 14% of total funding were from donor contributions from 2009 to 2011, while only 1% in 2009 and none in 2010 to 2011 in Nigeria. In both countries, there has been substantial increases in total government research funding in the 2000s in contrasts to stagnating funding in the 1990s. Despite more erratic funding owing to a historical backdrop of unstable governance and institutions in Nigeria, some improvements are observed. Nigeria has been relying less on donor funding in recent years. Nigeria has been allotting greater proportion of funding for capital expenditure in more recent years (10 to 21% in 2009 to 2011) while Ghana persistently has the highest proportion of its total research expenditure for salaries and none for capital expenditure (76 to 81% in 2009 to 2011). Both countries have instituted a series of NARS reforms, but have limited documentation and evidence of their effectiveness or the responsiveness of their research institutions to the needs of poor farmers. For example, while there is strong agricultural output growth (4.6% from 1991 to 2009) that has played an important role in Ghana's development, much of this growth has been due to the expansion of cultivated areas rather than increases in productivity, indicating limited impact of decades of research investment. Total factor productivity (TFP) growth has averaged only 1.2% annually for Ghana during the period from 2001 to 2009 - higher than the African average of 0.5%, but below the global average of 1.8% (Fuglie, 2012). While Nigeria's agricultural output and TFP growth in the 1990s have been higher than average in SSA and the world, its agricultural output and TFP growth after the 1990s have been far lower than the global average and even lower than the SSA average, indicating the limited impact of decades of research investment in Nigeria.

This paper aims to provide a better understanding of factors contributing to limited productivity and impact of agricultural researchers and research organizations. This remains a large gap in the literature. We take advantage of the differences across organizations within each country to provide insights as to what organization and institutional factors contribute to improving organization performance. We also explore the differences between individual researchers within the organizations and across organizations within the country to provide insights on the organizational and institutional factors that contribute to improving individual productivity and research outreach. Our results show that in addition to

individual characteristics, organizational and institutional factors are statistically significant in explaining research productivity. Both capacity and incentive factors play a role in explaining research productivity across various research organizations in Ghana and Nigeria. In this paper, the evidence for this conclusion is presented. First, the measures and definitions of performance in agricultural research system and factors that explain it was presented based on the literature review. In the next section, the materials, data sources and analytical methods used are discussed. Then, the main results are presented and the implications discussed. Lastly, conclusion is drawn with key messages for Nigeria, Ghana and wider research and development community, and future research agenda.

LITERATURE REVIEW AND FRAMEWORK

This paper combines elements of organizational design and collaboration-scientific productivity linkages (Peterson et al., 2003; Duque et al., 2005; Lee and Bozeman, 2005); conventional agricultural research productivity analysis (Bantilan et al., 2004); institutional theory and public-sector motivation literature (Manning et al., 2000; Raina, 2003); and agricultural innovation systems perspective (Hall et al., 2003; Spielman and Birner, 2008) to measure and explain variations in researchers' and their organizations' performance. Figure 1 shows the conceptual framework of the different factors explaining individual and organizational performance.

Measuring and defining performance

Organizational performance - the focus of this study - is measured using four sets of indicators drawn from the literature: (1) conventional measures of research productivity, including quantification of technology developed and publications produced at a given time (Peterson et al., 2003; Bantilan et al., 2004); (2) agricultural innovation systems indicators emphasizing connectivity and linkages among various innovation actors, and measures of use and impact of innovations generated by the system (Hall et al., 2003; Spielman and Birner, 2008); (3) dissemination of research outputs; and (4) technology adoption.

Technology involves all new varieties or new breeds that were developed by researchers (together with other staff) and were registered or released in the last five years (2005 to 2009), and including biological, chemical, and mechanical technologies and improved production, management, conservation, and marketing practices. Publications include books, book chapters, and other peer-reviewed publications (particularly scholarly articles in international and national scientific journals), published as first author or coauthor in the last three years (2007 to 2009). Due to limited availability of international databases of locally produced journals and books in many developing countries, this paper relied on self-reported number of publications and technologies verified through their CVs and organization heads.[1]

Innovation system indicators include presence of any interaction or linkages with other actors; the frequency of interactions with other innovation actors and end-users, and the satisfaction by researchers on the benefits of these interactions. These linkages and interactions were asked both at the level of organizations (whether the organizations has formal and informal linkages with other organizations and individuals) and at the individual researcher's level (whether individual researchers have external collaborators) in developing their publications and technologies. While research collaboration can improve productivity, several empirical studies (Dugue et al., 2005; Lee and Bozeman, 2005) show that they are not necessarily and statistically linked. However, external collaborators could bring other intangible benefits such as greater knowledge and exposure, staff morale, greater social capital, and better likelihood of publication use and technology uptake that cannot easily show up and be captured in publications and technologies generated within a given short period. For these reasons, we also included external collaboration on publications and in technology development as one of the outcome variables. In addition, indicators were used on linkages at the organizational level as explanatory variables explaining quantity of publication and technology generated and adoption levels.

Other outcome variables measured and used are the number of dissemination events, defined as the number of conferences, seminars and meetings where research results and findings from the reported publications were presented and disseminated. Lastly, researchers were asked about the adoption level of the technologies they produced, together with other staff in the organizations. An indicator of the knowledge and awareness of any evaluation or adoption rate of technologies produced is also included. Table 2 shows the descriptive statistics of the different outcome variables used in this paper.

Factors explaining performance

Performance can be explained by capacity and incentive factors at the individual and organization levels. Commonly

[1] To minimize the bias in self-reporting, the questionnaires were kept anonymous and confidential, which was emphasized to the respondents. It was emphasized by the organization heads and interviewers to answer the questions as honest and accurately as possible to help analyze important factors on how productivity and performance can be improved. Organization heads also helped verified the accuracy of the responses of the survey respondents. In most cases, CVs were requested to be printed, so that respondents will find it easier in answering the questionnaires and minimize errors in self-reporting. It was also emphasized that the survey will help in identifying areas of capacity strengthening with the aim of minimizing any overstatement of accomplishments in terms of technologies and publications produced.

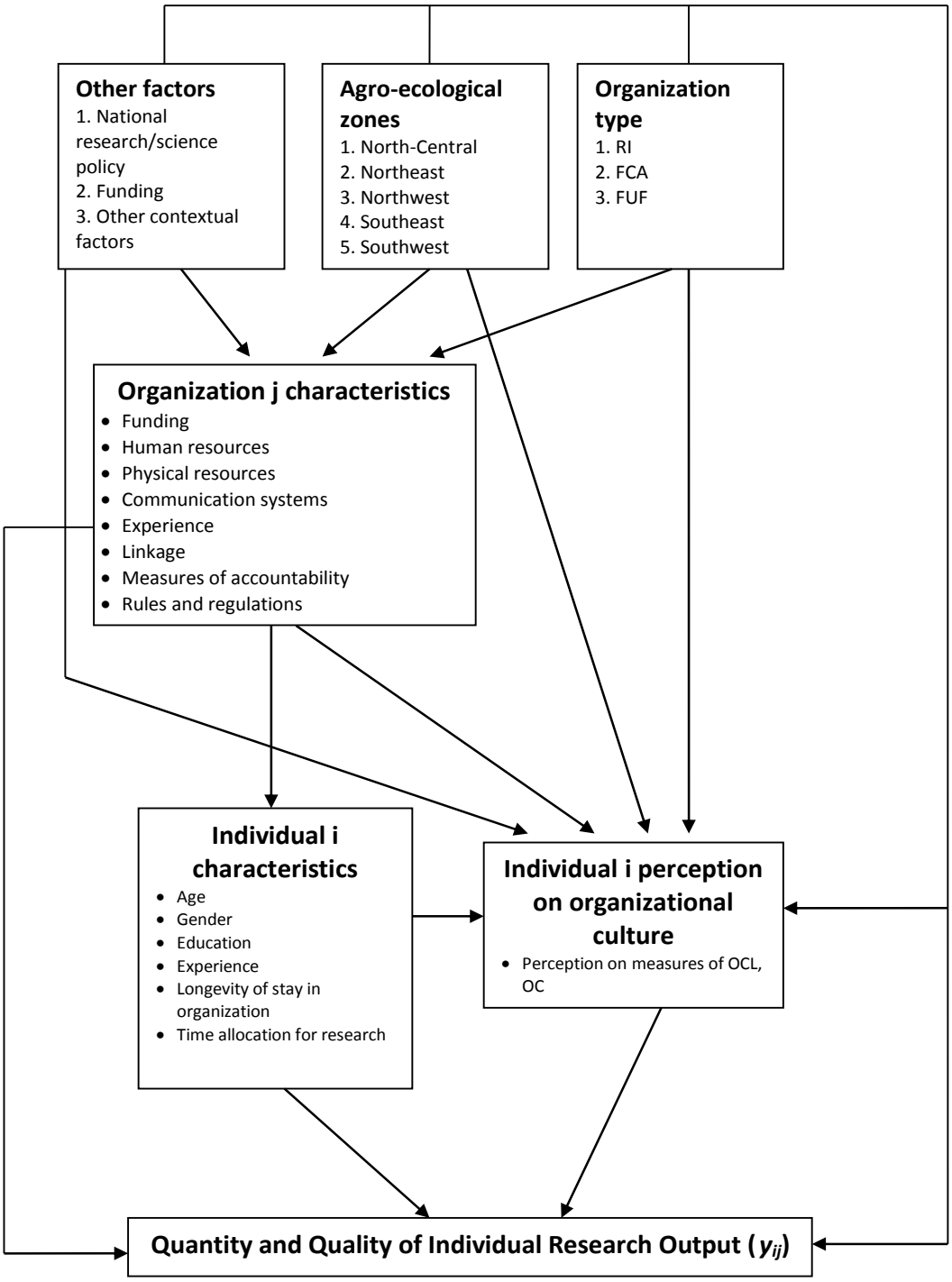

Figure 1. Framework for modeling individual and organizational characteristics to explain researcher performance. Source: Authors. Note: RI=Research institutes; FCA=federal colleges of agriculture; FUF=faculties of agriculture or veterinary medicine at federal universities. OCL=Organizational climate; OC=Organizational culture.

significant individual characteristics include age, gender, education, discipline, experience, position or job classification, linkages and affiliations, and reputation (Gulbrandsen and Smeby, 2005; Gonzalez-Brambila and Veloso, 2007; Manjarres-Henriquez et al., 2009; Abramo et al., 2009; Ponomariov and Boardman, 2010; Costas et

Table 2. Descriptive statistics of agricultural researcher's output and other outcome variables, Nigeria and Ghana, 2010.

Outcome variables	Nigeria				Ghana			
	Ave.	SD	Min	Max	Ave.	SD	Min	Max
Technology produced (2005-2009) (count data)	0.76	2.22	0.00	22.00	2.27	3.51	0	21
Publication (2007-2009) (count data)	8.28	10.09	0.00	25.00	3.63	5.43	0	21
With international collaborator in producing publication (dummy)	0.37		0.00	1.00	0.49		0	1
With national collaborator in producing publications (dummy)	0.78		0.00	1.00	0.77		0	1
Number of dissemination events (count data)	5.03	4.01	0.00	52.00	4.20	5.04	0	40
With international collaborator in developing technologies (dummy)	0.29		0.00	1.00	0.32		0	1
With national collaborator in producing technologies (dummy)	0.51		0.00	1.00	0.39		0	1
With knowledge on the adoption level of technologies produced (dummy)	0.38		0.00	1.00	0.20		0	1

Source: IFPRI-ARCN survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011).

al., 2010 for more recent studies). The findings in the literature for these factors are summarized in Table 3 and the descriptive statistics are in Table 4.

While many studies have analyzed individual capacity factors, there is dearth of studies that look at individual incentives. This paper aimed to add to the literature by using various indicators to capture individual-level incentive factors. First, time devoted to research was used, which proxies the organization's mission, orientation and incentives toward doing research compared to other work. Second, staff satisfaction or rating on salary and compensation at the individual level was used (perceived competitiveness of salaries and adequacy of salaries relative to living expenses). Since there is no data of individual salary levels, organizational-level salary costs per full-time equivalent was used as another measure of financial incentives. Third, individual score or rating on organizational climate were collected and used (OCL). OCL can also be thought of as related to the concept of staff morale or staff satisfaction discussed by Manning et al. (2000) or the institutional factors emphasized by Raina (2003) as important consideration in studying agricultural research organizations. Authors such as Gregory et al. (2009) and Henri (2006) used a wider classification of OCL combining measures of transparency, fairness, political autonomy, coherence, mobility, openness, responsiveness, flexibility, participatory leadership, adequacy of resources, and employee morale or satisfaction. In this paper, this classification of OCL was used and 20 questions were utilized which reflected survey respondents' perception on the organizational climate in their respective organizations. Survey respondents were asked to rate using Likert scale (scale from 1 to 4; 1 being the most conducive) their satisfaction on transparency, fairness, political autonomy, coherence, mobility, openness, responsiveness, flexibility, participatory leadership, and adequacy of resources in the organization and their employee morale or satisfaction of the organization overall. An overall index generated from factor analysis was used to capture these 20 different indicators of organizational culture. Table 4 shows the descriptive statistics of these indicators.

At the organization level, only a few studies have investigated organizational factors. Among them, Gulbrandsen and Smeby (2005) showed that funding received by organization appeared to be significant in explaining research output. Bonaccorsi and Daraio (2003) performed an efficiency analysis using biometrics data as output and found location and geographical agglomeration to be significant in determining research outputs in French institutes but not in Italian institutes. Lorenz and Lundvall (2010) showed that creative employees were over-presented in business services and social and community services than in manufacturing, construction, and utilities. The authors showed that institutional and national context had a significant direct impact on the individual creativity at work across 27 European research organizations.

This paper aimed to add to the literature by using various indicators to capture organization-level factors. In terms of organizational-level capacity factors, staff's satisfaction or rating on the adequacy of funding, human resources, communication system, physical resources (that is, research facilities and infrastructure), and extent of organizational linkages was used. Survey respondents were asked to rate adequacy of resources, systems or linkages using a scale of 1 to 5, with 5 being the highest or most preferred. To ensure that these organizational characteristics correspond to the period when publications and technologies were produced, survey respondents were asked to rate the conditions of resources and systems in the last 5 years, instead of their conditions today.

In terms of organization-level incentive factors, three indicators were used. First, staff's satisfaction or rating were requested and used on the monitoring and evaluation system of the organization. Second, the scores of OCL of individual staff were averaged (as described above) to make an organization-level indicator

Table 3. Hypothesized factors explaining research productivity, and summary of significance of these factors in this paper

Factors	Related literature	Hypothesis	Results in this paper
Individual level			
Capacity			
Education	Gonzalez-Brambila and Veloso (2007) use three different break points associated with three different cohorts (namely the early-educated group of researchers, the middle years, and the latest educated) and find no significant difference between the first and the latest educated and that the second cohort is slightly more productive than the latest educated.	+	Education is positively related to number of publication, technology, international and national research collaboration, dissemination events in both countries and international technology collaboration in Nigeria
Gender	Female researchers tend to publish less compared to male researchers (Gonzalez-Brambila and Veloso, 2007; Turner and Mairesse, 2003; Xie and Shauman, 1998; Cole and Zuckerman, 1984). Ponomariov and Boardman (2010) find gender not significant.	Female (-), due to social norms, more limited opportunities, and more severe time burden	Mixed results, no consistent evidence that female researchers have less research productivity. Female researchers have fewer publications and fewer technologies in Nigeria and fewer dissemination events in Ghana, but they have greater number of publications in Ghana.
Reputation or experience	Gonzalez-Brambila and Veloso (2007) find that reputation (measured in terms of 10-year stock of publication and citations) is positively related to research output.	Good reputation (+); more experience (+)	No available data on reputation and experience. Bu we used proxies such as years since latest degree and years in the organization. We find mixed results in this paper.
Funding received	Gulbrandsen and Smeby (2005) found that size, structure, and source of funding received by researchers are significant factors in explaining researchers' outputs.	+	No available data at individual researcher's level but there is data at organization level (see below)
Incentive			
Time allotted for research		+	Mixed results
Individual salary		+	Not significant
Individual perception on organizational climate (OCL)	OCL can affect employee satisfaction (Gregory et al. 2009); staff turnover (Stone et al., 2007); motivation of staff and managers (Moynihan and Pandey, 2007); extent of knowledge sharing (Willem and Buelens, 2007); organizational performance and effectiveness (Ogbonna and Harris, 2000); and the diversity and nature of use of performance measure systems (Henri, 2006)	Conducive organizational culture (+)	
Both capacity and incentive			
Age	Costas and van Leeuwen (2010) shows that top-publishing scientists in the Spanish National Research Council are the youngest within each professional category.	Quadratic relationship	Quadratic relationship between age and number of publication in Nigeria and number of dissemination events in Ghana
Age squared	Gonzalez-Brambila and Veloso (2007) find a quadratic relationship between age and the number of publications of a researcher		
Organizational level			
Capacity			
Organization's funding	Gulbrandsen and Smeby (2005) find + relationship with research output	+	+ in most models for Nigeria
Adequacy of human resources		+	+ in most models for Ghana

Table 3. Contd.

Adequacy of communication system		+	+ in most models for both countries
Adequacy of physical resources		+	+ in most models for Nigeria
Organizational linkages		+ (more connections, more resources, more opportunities)	Mixed results; mostly not significant
Location	Bonaccorsi and Daraio (2003) perform an efficiency analysis using biometrics data as output and find that location and geographical agglomeration to be significant in determining research outputs in French institutes but not in Italian institutes	significant (due to spillover effect and infrastructure and policies available in certain locations)	
Incentive			
M&E system		+	+ in most models for Nigeria
Perception on organizational climate (OCL)	OCL can affect employee satisfaction (Gregory et al. 2009); staff turnover (Stone et al. 2007); motivation of staff and managers (Moynihan and Pandey 2007); extent of knowledge sharing (Willem and Buelens 2007); organizational performance and effectiveness (Ogbonna and Harris 2000); and the diversity and nature of use of performance measure systems (Henri 2006)	Conducive organizational culture (+)	Significant in most models for both countries
Type of organizational culture	Quinn and Rohrbaugh (1983) and Gregory et al. (2009) have done empirical work on organizational culture and results are mixed. Most studies show that control-type OC are linked to less creativity and productivity.	Control-type (-)	Control-type (-)
Both capacity and incentive			
Type of organization	Lorenz and Lundvall (2010) show that creative employees are over-presented in business services and social and community services than in manufacturing, construction, and utilities.	significant (as it may dictate the type of funding, policies and/or incentive systems)	
Institutional or national context	The authors show that institutional and national context have a significant direct impact on the individual creativity at work across 27 European research organizations.	significant (as it may dictate the type of funding, policies and/or incentive systems)	

Source: Compiled by authors from various studies.

for OCL. Third, types of organizational culture (OC) were used - classified into (1) flexible-dominant and group-oriented type; or (2) control-dominant and hierarchical-oriented type - as another indicator. OC represents "the collection of traditions, values, policies, beliefs and attitudes that constitute a pervasive context for everything done and thought in an organization" (Marshall and McLean, 1988: 32). Gregory et al. (2009) carried out an empirical work on organizational culture using a "competing values" model that incorporates two sets of competing values within the organizations: (1) the *control* versus *flexibility* dilemma, which refers to preferences about structure, stability, and change, and (2) the *people* versus *organization* dilemma, which refers to differences in organizational focus. Therefore, OC is reflected in the degree of control or flexibility, and inward and outward orientation, focus, and leadership type in the organization. These authors emphasize that the absence of any dominant type, that is balanced culture type, is the most preferred and most effective type, and it is still subject to empirical research whether control-versus

Table 4. Descriptive statistics of capacity and incentive factors of sample individual agricultural researchers, Nigeria and Ghana, 2010.

Variable	Nigeria		Ghana
Capacity factors			
Highest level of education			
BSc	11		5
MSc	40		55
PhD	49		40
Dummy for gender (1=FEMALE)	**0.31 (0.46)**	/a	**0.20 (0.40)**
Number of years after last degree			
< 1 year	6		9
1-4 years	34		23
5-7 years	22		24
8-10 years	12		10
> 10 years	26		34
Number of years in the organization			
< 1 year	5		7
1-4 years	10		17
5-7 years	18		11
8-10 years	22		9
> 10 years	45		55
Incentive factors			
Percentage of time allocated to research	**39.76 (21.80)**	/a	**53.17 (23.61)**
Satisfaction with salary and compensation (1-5 scale, 5 is the most preferred)	**1.88**		**1.97**
Individual score for organization climate (1-4, 1 is the most preferred)	**2.2**		**2.08**
Both capacity and incentive			
Age group			
≤ 20	3	/b	0
21-30	5		6
31-40	38		27
41-50	37		35
≥ 51	17		32

Source: IFPRI-ARCN survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011). Note: /a Figures represent the mean and the ones in parentheses are the standard deviation. /b Percentage to total respondents per category.

flexible-dominant culture type is more effective. The findings in the literature for these factors are summarized in Table 3 and the descriptive statistics are in Table 5.

MATERIALS AND METHODS

Data source

The data and information used in this paper were collected using multiple sources. A total of 344 agricultural scientists in Nigeria and 237 agricultural scientists in Ghana were interviewed through a face-to-face survey using computer-assisted personal interview mobile device jointly conducted by IFPRI and the Agricultural Research Council of Nigeria (ARCN) in Nigeria between May and July, 2010 and jointly conducted by IFPRI and the Science and Technology Policy Research Institute (STEPRI) in Ghana between May and July, 2011. This survey was complemented by key informants' interviews and review of relevant literature.

In Nigeria, a total of 47 relevant public-sector organizations involved in agricultural research were interviewed, including all 15 of ARCN's agricultural research institutes, all 11 federal colleges of agriculture (FCA), and 21 of 48 faculties of agriculture and veterinary medicine in federal universities (based on the willingness of organizations to participate and respond to the survey). In Ghana, a total of 16 public-sector organizations involved in agricultural research were interviewed, including all nine agriculture-related research institutes under Council for Scientific and Industrial Research (CSIR); one of three relevant non - CSIR research centers, the Cocoa Research Institute of Ghana (CRIG), based on the willingness of organizations to participate in and respond to the

survey; and six of 15 faculties of agriculture in public universities identified by Science and Technology Policy Research Institute (STEPRI) and ASTI (Flaherty et al., 2010). Despite the limited sample of agricultural education institutes and relying on the willingness of organizations to respond to the survey, ex post analysis of the sample organizations reveal that the larger agricultural education institutes in Nigeria were covered and, therefore, the dataset should be interpreted as those covering the larger agricultural education institutes and does not represent those smaller ones. In Ghana, the larger agricultural universities are covered, except University of Cape Coast. However, further investigation reveals that agriculture research and the level and nature of agricultural technology development in UCC would be similar to that of other larger universities included in the sample. Therefore, for both Nigeria and Ghana, the dataset could be interpreted to include all agricultural research institutes and represents larger agricultural education institutes in those two countries.

Face-to-face surveys of a range of 3 to 20 randomly selected staff per organization were then conducted by the IFPRI–ARCN–STEPRI teams. The actual sample size was based on the total number of research staff (for example, a range from 26 to 140 research staff in research institutes and a range from 5 to 214 staff conducting research in universities in Nigeria; and a range from 10 to 77 research staff in research institutes and a range from 5 to 29 staff working on research in universities in Ghana). Research staff was selected from each organization's nominal roll or list of research staff, stratified into top management, middle management, and junior research staff. For smaller organizations, one staff in each of the strata was selected randomly; while larger organization had 2 to 7 staff in each of the strata randomly selected depending on the size of the organization. In Nigeria, a total of 344 sample researchers were interviewed out of 3,920 individual researchers (9%). In Ghana, out of a total of 706 researchers, 237 individual researchers were randomly selected and interviewed (33%).

Two sets of questionnaires were used - one questionnaire for organizations, to be answered by organization heads or a designated representative, and another for individual researchers. The questionnaire for organizations included questions on the organization's mission; research management issues and training needs; scientific and technical training needs; the availability of physical and human resources; research outputs; management systems and procedures; partnerships and linkages; accountability and motivations; and funding sources. The questionnaire for individual researchers covered demographic and individual characteristics; research outputs; workload; linkages; research issues and training needs; motivation and incentives; and perception of the organization's culture.

Analytical method

This paper utilized a multi-level analysis following a conceptual framework presented in Figure 1. Multi-level modeling allows to model processes at multiple levels of the population hierarchy. By simultaneously modeling at multiple levels it is possible to determine where and how effects are occurring (Lorenz and Lundvall, 2010; Rasbash et al., 2005; Goldstein, 2003). Multilevel modeling also responds to the criticism often made of single-level models that too much emphasis is placed on individual's characteristics and neglect the social, institutional, or organizational context (Lorenz and Lundvall, 2010; Rasbash et al., 2005; Goldstein, 2003). Failure to take into account the hierarchically structured nature of the data may lead to serious technical problems, with standard errors of the regression coefficients being underestimated.

The analysis of research productivity operates at two levels, with individual employees at level-1 being clustered within organization at level-2. The variables characterizing employees at level-1 are derived from the individual responses to IFPRI-ARCN and IFPRI-STEPRI individual-level survey questionnaire; while variables characterizing the organizational context at level-2 are derived from the IFPRI-ARCN and IFPRI-STEPRI organization-level survey questionnaire administered with heads or designated representative of organizations. In a simple two-level model, the linear predictor with random intercept and coefficient for organization *j* is given as:

$$\eta_{ij}(y_{ij}) = \sum_{l=1}^{k} x_{ij}\beta_{lj} + \upsilon_{lj} \quad (1)$$

Where η_{ij} is the linear predictor (with represents a functional form of the model); y_{ij} is the outcome variable; x_{ij} is the vector of covariates with fixed effects or the standard coefficient β and $\beta = (\beta_{1j}, \beta_{2j}, \ldots, \beta_{kj})$ are unknown *k*-dimensional column vector of coefficients; the subscript *i* represents the individual scientists (level-1 units), and subscript *j* represents organizations (level-2 units); and υ_{lj} is the random effect (one for each organization). These random effects represent the influence of organization *j* on individual *i* that is not captured by the observed covariates. These are treated as random effects because the sampled organizations represent a population of organizations, and they are assumed to be distributed as $\mathcal{N}(0, \sigma_v^2)$.

Since several measures of research output (y_{ij}) are being used with varying structure and nature of the data (Table 2), different functional forms or models are employed for estimation in this paper. For the number of publication and number of dissemination events for publications, characterized as over dispersed count data variables, this paper uses the generalized Poisson regression (GPR).[2] The generalized Poisson regression (GPR) model $f(\mu_i, \alpha; y_i)$ is adopted from Famoye and Singh (2006) and is given by:

$$f(u_{ij}, \propto; y_{ij}) = \left(\frac{\mu_{ij}}{1+\propto\mu_{ij}}\right)^{y_{ij}} \frac{(1+\propto y_{ij})^{y_{ij}-1}}{y_{ij!}} exp\left[\frac{-\mu_{ij}(1+\alpha y_{ij})}{1+\alpha\mu_{ij}}\right] \quad (2)$$

Where the mean of y_{ij} is given by $\mu_{ij}(x_{ij}, \upsilon_j)$ and the variance of y_{ij} is given by $V(y_{ij} \mid x_{ij}, \upsilon_j) = \mu_{ij}(1 + \alpha\mu_{ij})^2$; and α is the dispersion parameter. For the number of technologies produced, counting data with excess zeros, this paper uses a zero-inflated generalized poisson (ZIGP) model adopted from Famoye and Singh (2006) and is given by:

$$P(Y = y_{ij} \mid \upsilon_i, x_{ij}, z_{ij}) = \varphi_{ij} + (1 - \varphi_{ij})\, f(\mu_{ij}, \alpha; 0), \quad y_{ij} = 0$$

$$= (1 - \varphi_{ij})\, f(\mu_{ij}, \alpha; 0), \quad y_{ij} > 0 \quad (3)$$

Where $f(\mu_{ij}, \alpha; y_{ij})$, $y_{ij} = 0, 1, 2, \ldots$ is the GPR model in equation (2); $0 < \varphi_{ij} < 1$; x_{ij} represents the set of covariates affecting μ_{ij}; and z_{ij} represents the set of covariates affecting φ_{ij}. The model in equation (3) reduces to the GPR model when $\varphi_{ij} = 0$. For positive values of φ_{ij}, it represents the zero-inflated generalized Poisson regression model.

[2] An alternative is negative binomial regression (NBR) model which assumes that $\sigma^2 > 1$, so that there cannot be underdispersion. Generalized Poisson Regression (GPR) allows for all types of dispersion. GPR has been a good competitor of NBR and in some instances, it may also have some advantages (Famoye and Singh 2006). In the Famoye and Singh (2006) paper, they successfully fitted the ZIGP regression model to all datasets, but in a few cases, the iterative technique to estimate the parameters of ZINB regression model did not converge. Moreover, GPR has an edge over NBR for estimating parameters of the conditional mean (Wooldridge 2002).

For the dummy variables representing presence of at least one international or national research collaborator and knowledge and awareness of adoption level of technologies produced, binary response variables, the paper uses logit regression model with response probability (Equation 4) and logit link (Equation 5) given as:

$$p(x_{ijl}) \equiv P(y_{ij} = 1|\, v_{il}; x_{ijl}\,) = P(y_{ij}^{*} > 0|\, x_{ijl}\,) = \frac{\exp(\sum_{l=1}^{k} x_{ijl}\beta_{lj} + v_{lj})}{1+\exp(\sum_{l=1}^{k} x_{ijl}\beta_{lj+v_{lj}})} \quad (4)$$

$$\eta_{ij} = \Lambda(\sum_{l=1}^{k} x_{ijl}\beta_{lj}) = logit(\pi_{ij}) = log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \sum_{l=1}^{k} x_{ijl}\beta_{lj} + v_{lj} \quad (5)$$

Where y^{*} is a latent variable determined by $y^{*} = \sum_{l=1}^{k} x_{ijl}\beta_{lj} + e, y = 1[y^{*} > 0]$, e is the disturbance term; π_{ij} is the underlying probability that *y=1*; and Λ is the logit model.

The types of organizations (research or higher education institute) are controlled in the models: whether they are in research institutes (RI), where researchers are expected to do mainly research; federal colleges of agriculture (FCAs), which are linked to the RIs and staff are expected to do research, training, and outreach activities; and federal universities, where staff are expected to do mainly teaching and part-time research and outreach.. The GLLAMM command in STATA was used in modeling and adaptive quadrature was utilized to perform the integration over random-effects distribution.

Econometric issues

Two potential econometric issues are considered: heterogeneity and endogeneity. For example, good researchers tend to work at the best institutions, if they can choose where to work. The organizational variables can be contemporaneous with the outcome variables if measured in the same period in which the scientific output is measured, and therefore the organizational variables cannot explain the scientific output. It is likely that the factor that explains the scientific performance can also explain the organization characteristics, hence the organizational characteristics are endogenous in the model.

These issues could have been best addressed by having a panel dataset. Given that our dataset is cross-section and not a panel one, we address these issues by the following considerations. First, to ensure that the organizational characteristics correspond to the period when publications and technologies were produced, survey respondents were asked to rate the conditions of resources and systems in the last 5 years, instead of their conditions today or in the previous couple of years. Second, there was control for several factors that explain observed heterogeneity in the data, for instance, type of organization, location, and time allotted for research. Third, a model was run which explained OCL index, a variable that describes organizational features and may be correlated with exogenous variables that do not directly explain research productivity. Several potential instruments were tried to address endogeneity issue. For the instruments to be valid, the F-statistics of the instruments in the first-stage regression should be significant and not in the second regression (Di Falco et al., 2011) or the instruments are statistically correlated with OCL index but not statistically correlated with the error term in the second equation (with publication and technology as the outcome variables) (Lee and Bozeman, 2005). The valid instruments that qualified based on this criterion include the agro-ecological zone where the organization's headquarters is located, whether the organization is officially under the ministry of agriculture or education, reasons why the individual staff chose the job, and the individual's perception on the central goal of the organization. OCL index was tested to be endogenous and therefore we used the predicted value of OCL index from the first equation modelling into the second equation explaining the different outcome variables (technology, publication, collaboration, dissemination events and knowledge of adoption levels).

Limitations of the study

While this paper provides useful insights and policy implications, it is constrained by several limitations of data. First, emphasis was that despite the considerations to address heterogeneity and endogeneity in the econometrics, the results on the coefficients of the explanatory variables should be interpreted as associations or correlates rather than as casual effects or impacts.

Second, the dataset used in this study include small number of observations per organization (3 to 15 researchers per organization) although they were selected randomly and experts' opinion suggests that the sample is representative.

Third, measures of research output are based on self-reported values. Anonymity of the responses was important to the research design due to the possible sensitivities of the responses in perceptions. Moreover, locally-produced journals and publications in Nigeria and Ghana and in other developing countries are often not comprehensively available in international databases and search engines. For these reasons, this paper used self-reporting rather than bibliometrics data, but several measures have been implemented to ensure that bias of self-reporting were and verifications were made. To minimize the bias in self-reporting, the questionnaires were kept anonymous and confidential, which was emphasized to the respondents. It was emphasized by the organization heads and interviewers to answer the questions as honest and accurately as possible to help analyze important factors on how productivity and performance can be improved. In most cases, resumes were requested to be printed, so that respondents will find it easier in answering the questionnaires and minimize errors in self-reporting. It was also emphasized that the survey will help in identifying areas of capacity strengthening and not an evaluation of efforts or performance which likely minimized incentive to over-report.

Fourth, indicators on outreach of publications and technologies produced have been included, and is an improvement to just reporting on research outputs. In addition, publications and technologies were disaggregated by type for comparability. For publications, the analysis was disaggregated into books and book chapters, international journals, and national journals. For technologies, the analysis was disaggregated into varieties or biological technologies, mechanical technologies, chemical technologies, and management practices. While these are value additions of the paper, alternative measures can be explored. While this study measures presence of external collaborator, extent of dissemination, and extent of knowledge and awareness of adoption levels, it does not include measures of impact of these publications due to the inherent difficulty of measuring research. While this study is innovative in including a measure of perceived adoption levels of technologies produced, it does not include a more objective and actual adoption rates of these technologies.

RESULTS

The results of the various models estimated suggest that

Table 5. Descriptive statistics of capacity and incentive factors of sample agricultural research organizations, Nigeria and Ghana, 2010.

Categories	Nigeria		Ghana	
	Ave.	SD	Ave.	SD
Capacity factors				
Funding				
Satisfaction with organizational funding (1-5 scale)	1.98	1.84	2.01	1.00
Human resources				
Satisfaction [1] with human resources (1-5 scale)	2.81	0.97	2.60	0.95
Communication system				
Satisfaction[1] with the adequacy of ICT (1-5 scale)	2.28	0.99	2.01	1.00
Physical resources				
Satisfaction[1] with the adequacy of laboratory and research facilities (1-5 scale)	2.3	1.08	2.18	1.00
Satisfaction[1] with the adequacy of computers (1-5 scale)	1.7	0.69	2.12	1.09
Organizational linkages				
With international linkages (dummy)	0.32	0.47	0.75	0.44
With linkages with training institute (dummy)	0.38	0.49	0.38	0.5
With linkages with research institute (dummy)	0.66	0.48	0.75	0.44
With linkages with universities or colleges (dummy)	0.40	0.50	0.88	0.34
With linkages with private sector (dummy)	0.17	0.38	0.5	0.52
Incentive factors				
Satisfaction[1] with M&E system (1-5 scale)	1.98	1.84	3.54	0.52
Average rating on organizational climate				
Perception on Organizational climate (1-4 scale; 1 being the most preferred)	2.2	0.45	2.08	0.33
Dominant organizational cultural types				
Flexibility-dominant type (dummy)			69	(percentage)
Control-dominant type (dummy)			31	(percentage)

[1] As perceived by the head or representative of the organization interviewed; with scale 1 (not satisfied) to 5 (very satisfied). Source: IFPRI-ARCN survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011).

both individual characteristics and organizational factors are statistically significant in explaining research productivity of individual staff in the sample organizations in Nigeria and Ghana. Moreover, various indicators of capacity and more so of incentives are significant. However, there are major differences in the statistical significance and direction of correlation of these factors between Ghana and Nigeria and depending on the measures of research output quantity and outreach used. Summary tables of results are in Tables 6 to 8. The goodness-of-fit measures of the logit models indicate that the selected explanatory variables explain most of the variations of the outcome variables; while the insignificance of the Pearson goodness-of-fit tests of the poison models indicate that the model specification selected are appropriate (Tables 6 to 8).

Publication

In terms of individual capacity, it is consistent that education is a highly significant factor in explaining individual productivity in both countries. This seems to be consistent with past studies. Length of stay in the organizations (proxy of experience and familiarity in the organization) is also consistently significant. Gender is also significant, but of different signs between Nigeria and Ghana. Female researchers reported more

Table 6. Results of Poisson models explaining the number of publications and technologies produced, Nigeria and Ghana, 2010.

Variables	Publication						Technology									
	Nigeria			Ghana			Nigeria						Ghana			
	Poisson			Poisson			Logit			Poisson			Logit		Poisson	
	Coef. [a]	Std. Err. [b]		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	Coef.	Std. Err.	
Individual level																	
Capacity																	
Education	0.42	0.03	***	0.31	0.05	***	0.13	0.22		0.33	0.11	***	-0.56	0.19	0.20	0.07	***
Years post degree	0.00	0.08		0.24	0.08	***	0.14	0.55		-0.07	0.24		-0.14	0.42	0.27	0.12	**
Years post degree squared	0.01	0.01		-0.02	0.01	***	-0.01	0.06		0.00	0.03		0.03	0.04	-0.03	0.01	**
Years in current organization	0.06	0.03	**	0.10	0.02	***	-0.83	0.27	***	-0.52	0.12	***	-0.02	0.12	0.08	0.04	**
Female (dummy)	-0.32	0.05	***	0.22	0.10	**	-0.09	0.42		-0.37	0.22	*	-0.17	0.49	0.20	0.12	
Incentive																	
Time for research (%)	0.01	0.00	***	0.00	0.00		-0.01	0.01		0.01	0.00	***	-0.02	0.01	-0.01	0.00	***
Satisfaction with salary	-0.11	0.12		0.14	0.46		-0.40	0.33		0.30	0.28		0.19	0.39	0.22	0.25	
Individual score for OC	-0.39	0.16	*	-0.14	0.06	**	-0.22	0.41		-0.98	0.24	***	0.06	0.21	-0.13	0.05	**
Both capacity and incentive																	
Age	0.51	0.15	***	0.75	0.50		-1.33	1.31		0.09	0.58		-1.85	1.90	0.44	0.64	
Age squared	-0.10	0.02	***	-0.08	0.06		0.16	0.18		0.01	0.08		0.22	0.25	-0.05	0.08	
Organizational level																	
Capacity																	
Score for org. funding	0.35	0.13	***	-0.15	0.39		0.44	0.20	**	0.44	0.08	***	-0.08	0.42	-0.18	0.19	
Score for human resources	0.01	0.14		1.08	0.51	**	-0.48	0.20	**	0.00	0.11		-0.93	0.81	0.30	0.16	**
Score for ICT	-0.11	0.14		0.15	0.56		-0.40	0.24	*	-0.30	0.09	***	0.18	0.89	0.43	0.26	*
Score for physical resources	0.34	0.13	***	-0.14	0.39		0.42	0.21	**	0.42	0.09	***	-0.06	0.62	-0.15	0.19	
Score for org. linkages	-0.08	0.13		0.05	0.39		-0.35	0.23		-0.55	0.09	***	0.38	0.55	0.07	0.17	
Incentive																	
Score for M&E system	0.26	0.13	*	-0.31	0.27		0.74	0.25	***	0.35	0.12	***	-0.63	0.46	0.00	0.15	
Org. average for OC	-0.39	0.18	*	-0.13	0.05	**	-0.22	0.41		-0.99	0.25	***	0.05	0.21	-0.13	0.06	**
Control-type (dummy)				-0.13	0.06	**							0.09	0.10	-0.13	0.03	**
Both capacity and incentive																	
Research Institute (dummy)	1.17	0.20	***	0.28	0.40		-0.70	0.62		0.88	0.32	***	0.60	0.81	0.28	0.24	

Table 6. Contd.

Constant	**-1.20**	**0.55**	**	**0.93**	**2.69**		**7.61**	**2.87**	***	**-0.07**	**1.56**		**3.16**	**5.49**	**-0.09**	**1.83**
Random effect (Intercept)	**0.79**	**0.12**	***	**0.45**	**0.10**	***				**0.90**	**0.19**	***			**0.31**	**0.10**
N	**344**			**237**			**344**						**237**			
Log likelihood	**-1495.34**			**-573.73**			**-301.15**						**-404.62**			
Pearson Chi-squared	**230.12**			**289.57**			**349.01**						**236.03**			
P-value	**0.42**			**0.38**			**0.32**						**0.24**			
Pseudo R-squared	**0.66**			**0.63**			**0.54**						**0.58**			

[/a] Reported values are the coefficients and not the marginal effects. [/b] Figures are the coefficients and the ones in parentheses are the standard errors. *Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level. OC=organizational culture; org.=organizational; ICT=Information and communication technologies.

Table 7. Results of logit and poisson models explaining the extent of external collaboration and dissemination of publications produced, Nigeria and Ghana, 2010.

Variables	National research collaboration (dummy)				International research collaboration (dummy)				Number of dissemination events (count data)			
	Nigeria		Ghana		Nigeria		Ghana		Nigeria		Ghana	
	Coef. [/a]	Std. Err. [/b]	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Individual level												
Capacity												
Education	-0.38	0.16**	-0.43	0.30	0.36	0.18**	0.42	0.23*	0.22	0.04***	0.12	0.07*
Years post degree	-0.86	0.41**	-0.16	0.47	-0.20	0.47	0.40	0.42	-0.32	0.10***	0.30	0.13**
Years post degree squared	0.10	0.04**	-0.01	0.05	0.03	0.05	-0.06	0.04	0.04	0.01***	-0.02	0.01**
Years in current organization	0.24	0.17	-0.04	0.14	-0.03	0.17	0.21	0.12*	0.06	0.04	0.10	0.03***
Female (dummy)	0.23	0.32	0.08	0.55	0.01	0.35	0.43	0.50	-0.06	0.08	-0.37	0.15**
Incentive												
Time for research (%)	0.00	0.01	-0.03	0.02*	0.01	0.01	-0.02	0.02	-0.01	0.00***	0.02	0.00***
Satisfaction with salary	0.05	0.16	-1.15	0.95	-0.13	0.18	0.53	0.82	0.01	0.10	0.71	0.54
Individual score for OC	-0.11	0.34	0.32	0.23	-0.10	0.36	-0.34	0.23	-0.45	0.07***	-0.09	0.07
Both capacity and incentive												
Age	2.01	1.44	1.60	2.44	2.40	1.72	-1.70	2.06	0.25	0.19	1.58	0.70**
Age squared	-0.25	0.19	-0.11	0.32	-0.28	0.22	0.19	0.27	-0.04	0.03	-0.21	0.09**
Organizational level												
Capacity												
Score for org. funding	0.05	0.16	-1.17	0.92	-0.13	0.18	-0.45	0.72	-0.02	0.10	0.81	0.24***
Score for human resources	-0.14	0.15	-2.16	1.37	-0.04	0.17	0.13	1.13	0.12	0.10	0.10	0.31

Table 7. Contd.

Score for ICT	0.05	0.17	2.00	1.19*	0.29	0.19	1.50	1.09	-0.04	0.11	-0.31	0.30
Score for physical resources	0.04	0.16	-1.15	0.95	-0.12	0.18	-0.43	0.82	-0.01	0.10	0.91	0.24***
Score for org. linkages									-0.14	0.09	0.32	0.19*
Incentive												
Score for M&E system	-0.05	0.16	0.32	0.67	0.20	0.18	-0.67	0.58	-0.08	0.10	-0.10	0.15
Org. average score for OC	-0.12	0.34	0.31	0.23	-0.10	0.36	-0.33	0.23	-0.47	0.17***	-0.09	0.07
Control-type (dummy)			0.15	0.14			-0.02	0.14			0.04	0.03
Both Capacity and Incentive												
Research Institute (dummy)	-0.43	0.46	1.83	1.15	-0.12	0.46	0.58	0.96	0.95	0.21***	-1.98	0.30***
Constant	**-2.47**	**2.70**	**-2.01**	**7.27**	**-7.32**	**3.40****	**1.33**	**6.60**	**-0.04**	**0.54**	**-5.65**	**1.81*****
Random effect (Intercept)	**0.00**	**0.39**	**0.00**	**0.38**	**0.00**	**0.31**	**0.52**	**0.31**	**0.54**	**0.10**	**0.00**	**0.08**
N	***344***		***237***		***344***		***237***				***344***	***237***
Log Likelihood	***-152.58***		***-67.65***		***-139.42***		***-85.16***				***-1097.40***	***350.72***
Pseudo R-squared	***.34***		***.36***		***.38***		***.43***				***.55***	***.58***
% correctly predicted	***67%***		***75%***		***62%***		***71%***					
Pearson Chi-squared											***103.23***	***256.32***
P-value											***.43***	***.35***

[/a] Reported values are the coefficients; [/b] Figures are the coefficients and the ones in parentheses are the standard errors. *Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level. OC=organizational culture; org.=organizational, ICT=information and communication technologies.

publications in Ghana than male researchers; and it is the opposite in Nigeria. The results here are less conclusive than those reported in past studies.

In terms of individual incentives, time for research is positively related to the number of publications in Nigeria, as expected, but not in Ghana. Individual score for organizational climate is significant in explaining the number of publications in both countries. There is a quadratic relationship between age and number of publications in Nigeria, which is expected, but none in Ghana. Satisfaction with salary and compensation did not seem to be significant in explaining variations in the number of publication produced. Efforts were also made to use organization-level per-person salary costs (that is, salary cost as a ratio of full-time equivalent staff), and this indicator is also not significant.

In terms of organizational capacity, scores for funding and physical resources seem to be significant in Nigeria, while score for human resources adequacy seems to be significant in Ghana. In terms of organizational incentive, score for M&E system seems to be significant in Nigeria, and not in Ghana.

The score for organizational climate is significant for both Ghana and Nigeria. Organizations with control-type OC are more likely to have fewer publications than those with flexible-type OC.

The random-effect intercept, after controlling for organizational-level factors, remains significant, which means that the nature and other characteristics of the sample organizations are important factors in explaining individual productivity other than those used in the regression estimation.

Technology

In terms of individual capacity, similar to publications produced, the education level of researchers is significant in explaining variations

Table 8. Results of logit models explaining the extent of external collaboration and knowledge of adoption of technologies produced, Nigeria and Ghana, 2010.

Variables	International technology collaboration (dummy)				National technology collaboration (dummy)				Knowledge of adoption or evaluation (dummy)			
	Nigeria		Ghana		Nigeria		Ghana		Nigeria		Ghana	
	Coef. [a]	Std. Err. [b]	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Individual level												
Capacity												
Education	1.57	0.94*	0.36	0.28	0.10	0.32	0.07	0.25	-1.06	0.40	-0.22	0.40
Years post degree	4.00	3.11	0.78	0.55	-0.45	0.79	0.40	0.47	1.02	0.85	-0.18	0.81
Years post degree squared	-0.44	0.33	-0.03	0.05	0.04	0.09	-0.03	0.05	-0.12	0.09	0.02	0.09
Years in organization	0.76	1.10	0.17	0.15	0.39	0.42	0.00	0.14	0.85	0.46*	0.37	0.25
Female (dummy)	2.83	1.89	0.22	0.60	-0.11	0.59	0.59	0.56	0.00	0.70	-0.19	0.81
Incentive												
Time for research (%)	-0.02	0.03	0.04	0.02**	-0.01	0.01	0.01	0.02	0.00	0.02	0.02	0.03
Satisfaction with salary	0.09	0.45	0.51	1.02	0.27	0.32	0.87	1.29	0.03	0.41	2.97	2.75
Individual score for OC	-2.53	1.98	0.15	0.22	-0.93	0.66	0.17	0.25	-0.83	0.36**	-0.85	0.43*
Both Capacity and Incentive												
Age	-2.15	2.97	-0.71	2.35	-0.78	1.87	2.45	2.48	1.16	2.17	3.82	3.90
Age squared	0.27	0.42	0.02	0.31	0.08	0.25	-0.31	0.32	-0.06	0.30	-0.47	0.50
Organizational level												
Capacity												
Score for org. funding	0.33	0.72	1.94	0.73**	0.34	0.28	0.65	0.93	0.35	0.33	3.91	3.02
Score of human resources	-0.09	0.86	0.41	1.45	-0.25	0.33	-0.99	1.39	0.02	0.41	-6.97	104.75
Score for ICT	-0.41	0.81	-2.55	1.11**	-0.01	0.32	-2.57	1.20**	0.00	0.40	-12.86	109.86
Score for physical resources	0.32	0.74	1.84	0.83**	0.44	0.28	0.55	0.94	0.35	0.33	4.91	24.02
Score for org. linkages									-0.62	0.39	12.69	102.36
Incentive												
Score for M&E system	0.41	0.88	0.39	0.64	0.23	0.31	0.36	0.72	0.11	0.37	7.43	18.15
Org. average score for OC	-3.53	2.54	0.13	0.27	-0.92	0.66	0.15	0.25	-0.83	0.36**	-0.73	0.43*
Control-type (dummy)			-0.22	0.16			-0.08	0.17			-0.09	0.69
Both Capacity and Incentive												
Research Institute (dummy)	3.47	2.59	-0.19	1.02	-0.36	0.82	0.90	1.07	2.04	1.01**	10.09	107.67
Constant	**-20.00**	**12.53**	**6.02**	**7.45**	**0.87**	**4.71**	**-0.67**	**8.00**	**-7.00**	**5.49**	**-1.00**	**203.97**
Random effect (Intercept)	**2.16**	**1.60**	**0.18**	**0.96**	**0.00**	**2.32**	**0.57**	**0.39**	**0.41**	**1.26**	**0.00**	**0.32**
N	**344**		**237**		**344**		**237**		**344**		**237**	
Log Likelihood	**-29.74**		**-57.71**		**-50.78**		**-69.91**		**-42.65**		**-33.48**	
Pseudo R-squared	**0.30**		**0.28**		**0.31**		**0.30**		**0.32**		**0.29**	
% correctly predicted	**65%**		**62%**		**72%**		**60%**		**68%**		**70%**	

Note: [a] Reported values are the coefficients; [b] Figures are the coefficients and the ones in parentheses are the standard errors. *Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level. OC=organizational culture; org.=organizational; ICT=Information and communication technologies

in individual productivity in both Nigeria and Ghana. The number of years after highest educational attainment is significant in Ghana but not in Nigeria, and the direction of effect are opposite between these two countries. The

number of years in the organization is significant for both countries but of different direction. More number of years in the current organization is negatively associated with the number of technologies produced by individual researchers in Nigeria and positively associated with technologies produced by individual researchers in Ghana. In Nigeria, female staff has reported fewer technologies produced than male researchers; while in Ghana, it is the opposite, that is, female researchers produced more than their male counterparts, although it is not statistically significant.

In terms of individual incentive, more time allocated for research is positively associated with technology produced by individual researchers in Nigeria and negatively related to technologies produced by individual researchers in Ghana. Similar to publications above, individual score for organizational climate is significant in explaining the number of technologies in both countries. Satisfaction with salary and compensation did not seem to be significant in explaining variations in the number of technologies produced. Efforts were also made to use organization-level per-person salary costs (that is, salary cost as a ratio of full-time equivalent staff), and this indicator is also not significant. There is no relationship between age and number of technologies produced per staff for both countries.

In terms of organizational capacity, scores for funding, ICT, physical resources seem to be significant in Nigeria, while score for human resources adequacy and ICT system seems to be significant in Ghana. In terms of organizational incentive, score for M&E system seems to be significant in Nigeria, and not in Ghana. The score for organizational climate is significant for both Ghana and Nigeria. Organizations with control-type OC are more likely to have fewer technologies generated per staff than those with flexible-type OC.

The random-effect intercept, after controlling for organizational-level factors, remains significant, which means that the nature and other characteristics of the sample organizations are important factors in explaining individual productivity other than those used in the regression estimation.

Collaboration in publications

Individual capacity factors are associated with international research collaboration in Ghana and Nigeria and national research collaboration in Nigeria (Table 7). Education level is consistently significant in explaining the international research collaboration and number of dissemination events by individual researchers in Ghana and Nigeria, which is expected. However, a surprising result is on the direction of significance in explaining national research collaboration in both countries, that is, the higher the education level, the less likely individual researchers collaborate with other researchers in their publications. There seems to be a substitution of international collaboration from national collaboration as one achieves higher education background in both countries.

Except of a slight significance of index for communication system (explaining national research collaboration), there seems to be no organizational factors that are statistically significant in explaining both national and international research collaboration. It seems that international and national collaboration of researchers in their publications are explained mainly by differences in individual characteristics, especially education level and years of experience, and not on the nature or characteristics of organizations they are in.

Collaboration in technology development

Only education is significant in explaining variations in technology development collaboration in Nigeria (Table 8). Higher education level is positively associated with presence of international collaboration in technology development. No variable (both individual and organizational level factors) is statistically significant in explaining national collaboration in technology development in Nigeria in our models. For Ghana, there are no individual factors that are statistically significant in explaining both national and international collaboration in technology development, except for time allocated for research.

More time for research is positively associated with international collaboration in technology development. In terms of organizational factors, the score for physical resources is positively associated related to national and international collaboration. However, score for communication system is negatively associated with both national and international collaboration.

Dissemination of publications

Both individual and organizational factors are significant in explaining the number of dissemination events to communicate the findings of research (Table 7). Education level is consistently significant in explaining the number of dissemination events of sample agricultural researchers in Nigeria and Ghana, as expected. Higher education level is positively associated with more dissemination events. The number of years of experience after highest education attainment is also significant, although the effect is opposite for Nigeria and Ghana. More years in the current organization is positively associated with number of dissemination events in Ghana. Female researchers have less dissemination events for both Nigerian and Ghana (although it is not

significant for Nigeria). In terms of individual incentive, time for research is significant, but with opposite direction in Nigeria and Ghana. More time for research is associated with more dissemination events in Ghana, while time for research seems to be crowding out for time spent on dissemination of publications in Nigeria. Score for organizational climate is significant in Nigeria and not for Ghana. There is a quadratic relationship between age and dissemination of publications in Ghana, which is expected, but none in Nigeria.

In terms of organizational capacity, the score for physical and financial resources and score for organizational linkages are positively significant in Ghana, but not in Nigeria. In terms of organizational incentives, score for organizational climate is significant in Nigeria and not for Ghana. The type of OC is not significant in explaining dissemination of publications.

Knowledge of evaluation and adoption

More years in the current organization is positively associated with individual researcher's greater reported knowledge and awareness of adoption of technology produced in Nigeria, but no significance in Ghana (Table 8). Individual researcher's perception of organizational climate is significant in explaining knowledge on adoption or evaluation of technologies produced. More conducive work environment reported is associated with more knowledge on adoption and evaluation of technologies produced for both Nigeria and Ghana.

DISCUSSION

There is huge variability in the research outputs, productivity, organizational linkages, and extent of dissemination and knowledge of adoption of technologies produced among individual researchers and organizations involved in agricultural research in Nigeria and Ghana. Both individual and organizational characteristics and both capacity and incentive factors are significant in explaining variations in publications and technologies produced. Education level is strongly and positively significant in explaining variations in the number of publications and technologies produced external research collaboration, and the number of dissemination events for these publications. This implies that while interventions are needed to improve education level and skills development of staff, interventions to improve the workings of organizations will also be needed.

In terms of individual capacity, it is consistent that education is a highly significant factor. Length of stay in the organizations (proxy of experience and familiarity in the organization) is also consistently significant. Gender is also significant, but of different signs between Nigeria and Ghana. Female researchers are less likely to have more number of publications and more technologies produced than male researchers in Nigeria but it is the opposite in Ghana. Female researchers are more likely to have more publications and technologies produced but they are likely to have less dissemination events than their male counterparts in Ghana. This gendered pattern will need to be further investigated.

The pressing organizational constraints may be different from organization to organization and from country to country. For Ghana, score for human resources availability seem to be a significant factor in the number of publications and technology produced. In terms of external collaboration, other organizational factors including indices for communication system, linkages, physical resources, and the type of organizational culture become significant for Ghana. In Nigeria, scores for physical and financial resources and M&E system are statistically significant across different models. These imply the need for differentiated priorities and strategies needed in the reform processes in these countries.

For Nigeria, results suggest the need to strengthen and invest in physical resources and facilities upgrading and implementation of M&E systems if the Nigerian government aims to increase the research productivity of its agricultural research system. In 2010, only 30 organizations have M&E plans and a majority does not have strategic plan and intellectual property rights (IPR) policy. In the context of Nigeria, in terms of prioritization, human resources development seem to be the least of the problems compared to the serious deficiencies in laboratory, research facilities, and infrastructure and in poor implementation of management systems and M&E. Measures of availability and adequacy of physical resources and M&E and management systems seem to be more consistently significant than measures of availability of human resources in Nigerian case. Investing in physical resources and better enforcement organizational management systems seem to be the more important factors that would increase the likelihood of increasing research productivity.

For Ghana, the Council for Scientific and Industrial Research (CSIR) has to improve and invest on its human resources and communication and information systems, especially in its decentralized stations. It has to work on increasing research productivity (both technology and publication) and has to work more on increasing the level and quality of linkages and research collaboration. CSIR has to find a way to retain existing staff at the same time able to hire young staff, which will involve lifting the recruitment squeeze. There is also a need to look at better incentive system and higher compensation, especially in research institutes wherein staff turnover is a major problem and staff move to higher education

institutes due to better compensation and opportunities for staff development. All these actions require substantial investment needed from government and partners. While Ghana is almost to reach the target of 6 percent budget allocation to agriculture, Ghana's invest-ment is very low in relation to the size and importance of its agricultural sector (less than 2% compared to about 5% in Nigeria and 8 to 10% in agriculture-based Asian countries).

For both countries, it seems that organizational culture type and organizational climate directly research productivity. Attention must be paid to improve organizational climate in the R&D system. The gender of the organization head and of the researcher, are significant in most models. Further study is needed to understand why female researchers and researchers in organizations with female heads have lower indicators of organizational performance and individual research output. It might be that the gender effects in variations in productivity are due to gender differentials in access to opportunities and resources for research, collaboration, or dissemination.

Conclusions

Most studies on individual research productivity focus on individual characteristics, and this paper is among the first set of papers that models systematic variation in individual research productivity across organizations, and explicitly differentiating between capacity and incentive factors as well as organizational and institutional factors. Our exploratory study offers four concluding points and implications as well as several hypotheses that need further investigation. First, results of this study show that organizational factors matter in explaining variations in individual research productivity (measures in terms of quantity and quality of publications and technologies produced). Results of this study reinforces that improving organizational effectiveness can contribute to increased productivity of individual researchers. There are differences in the statistical significance and direction of correlation of various organizational-level factors between Nigeria and Ghana. This signifies local context matters and that various interventions need to be tailored to the specific context and constraints facing organizations and countries. In Ghana, quantity and quality of human resources seem to be the more pressing constraint; while in Nigeria, physical resources, and organizational M&E systems seem to be the more pressing constraints.

Second, organizational climate (enabling or disabling work environment) appears to be important in affecting research performance for both countries. Improving staff morale or simply making their staff satisfied and happy should be a major step to be followed for productivity and outreach to be improved. Improving on M&E system also reinforces greater incentive to produce more and better outreach, especially in the case of Nigeria. While improving capacity is important (through training and education of staff, or improving human, financial and physical resource), but improving the formal system of M&E and informal climate of the organization also matters in improving productivity and research outreach.

Third, organizational culture, reflecting the degree of control or flexibility, and inward and outward orientation, focus, and leadership type in the organization, is significant in explaining publications and technologies produced in Ghana. Organizations with flexible-dominated and group culture type have reported more publications and technologies generated than those in organizations with more control-dominated and hierarchical culture type. Unfortunately, we were not able to include this section of the questionnaire in Nigeria, and it would be great to know if this also applies there and in other countries.

Fourth, salary and benefit levels were consistently mentioned by researchers and heads of organizations, especially in Ghana, to be important motivating factor for increasing productivity but variations in the perceived competitiveness of salaries, adequacy of salaries relative to living expenses, and salary costs per FTE researcher did not appear to be statistically correlated with variations in any of the performance indicators. The majority of researchers suggested improvements in basic research facilities emphasized in both countries and skills development or capacity strengthening as emphasized in Ghana, which contrasts the much heavier emphasis on low salaries highlighted as the binding constraint in other studies, such as Byerlee (2004). Increasing capital investments and building physical resources seem to be important factors in both Nigeria and Ghana; and skills development in Ghana. But, further research is needed to investigate optimal salary levels, in recommending priority investments for increasing their productivity and output.

The paper should be taken as a pilot case, requiring further refinements to measurements and definitions, especially in the event that they are scaled out to other countries. As a future research agenda, better methods of collecting information as well as better indicators of adoption and impact of publications and technologies can be explored. A future line of inquiry will be to build up indicators of individual productivity of scientists and explore the relationship between individual and organizational productivity. It will also be useful to investigate further why female researchers appear to be more productive in Ghana and less productive in Nigeria than male researchers. The gender of the organization head is also statistically significant in explaining the presence of organizational management practices and organizational culture type across organizations. It might be that the gender effects in variations of productivity are

due to gender differentials in access to opportunities and resources for research, collaboration, or dissemination. Lastly, cross-sectoral or cross-national comparison can be explored further beyond and Nigeria to determine whether institutional or national context matter in explaining scientists' productivity.

Conflicts of Interest

The author has not declared any conflict of interest.

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