PUBLIC EXPENDITURES AND AGRICULTURAL PRODUCTIVITY GROWTH IN GHANA

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ABSTRACT

Using district- and regional-level public expenditure data and household-level production data, this paper estimates the agricultural productivity returns to different types of public expenditure across various agro-ecological zones of Ghana. The results reveal that provision of various public goods and services in the agricultural, education, health and rural roads sectors have substantial impact on agricultural productivity. A one percent increase in public spending on agriculture is associated with a 0.15 percent increase in agricultural labor productivity, with a benefit-cost ratio of 16.8. Spending on feeder roads ranks second (with a benefit-cost ratio of 5), followed by health (about one hundredth of the value). Formal education was negatively associated with agricultural productivity. The estimated marginal effects and returns differ for the four agro-ecological zones. Implications are drawn for prioritizing additional or future public resources.

Keywords: Agricultural Development, Ghana, Public Spending and Investments

1. INTRODUCTION

Public expenditure is perhaps the single most important policy instrument available to governments of most developing countries for promoting growth and equitable distribution. Governments of such countries tend to have fewer tax instruments than rich countries due to the large informal sector that is effectively immune from taxation, and imposing taxes on some branches of the economy and not on others create high economic distortions (Auriol and Warlters 2002). Besides being used to improve technology, human capital and infrastructure development necessary for growth, public expenditure also aims at providing the incentives and enabling environment to promote private sector investments to promote further growth. In light of the central role that agriculture plays in the development strategy of most developing countries (Diao et al. 2007), a number of key questions arise: How much public expenditure on the agricultural sector is required to achieve a country's growth and poverty reduction targets? Would allocating 10 percent of national budgetary resources to the agriculture sector, as declared by African heads of state under the Comprehensive Africa Agriculture Development Programme (CAADP) (AU/NEPAD 2003), be sufficient for achieving the millennium development goals (MDGs) in Africa? In the context of agricultural and rural development, how should public expenditure resources be allocated among different types of agricultural public goods and services (e.g. agricultural research, extension, farm input support, etc.), rural infrastructure (e.g. irrigation, roads, markets, etc.), rural social services (e.g. education, health, water, etc.), and across geographic areas for better or improved distributional outcomes and impacts? Answering these policy questions require information on the returns to public spending, particularly agricultural productivity returns to public spending on agriculture and other sectors of the rural economy; a fundamental but scarce knowledge. This paper contributes to the knowledge gap by using data on Ghana to estimate the agricultural productivity returns to public spending on agriculture, education, health and rural road infrastructure.

Empirical studies on returns to public investments in terms of productivity growth and poverty reduction is dominated by analyses of individual public investment programs only, such as agriculture research or extension (e.g. Evenson 2001; Alston et al. 2000; Evenson et al. 1999; Rosegrant and Evenson 1995), health (e.g. Collier et al. 2002), education and other social sectors (e.g. Gomanee et al. 2003), or infrastructure (see Guild 2000 for a review). These have limited application when considering prioritization of resources across alternative and often competing public investment programs in agriculture and other sectors of the economy. On the other hand, the literature that speaks to the prioritization of public investment programs is mostly limited to developed countries with studies scarcer in the developing country context. Rarer are studies on agricultural productivity growth returns to public spending on the agricultural sector relative to public spending on different types of other public goods and services in rural areas (e.g. roads, education, health, water, electrification). Some of the studies on developing countries that address the prioritization of resources in general include: Fan et al. (2000) on India; Fan and Zhang (2004) on China; Fan et al. (2008a) on 44 Developing countries, including 17 from Africa; and Fan et al. (2004, 2005) on Uganda and Tanzania, respectively; and Mogues et al. (2008) on Ethiopia. The limited evidence in developing countries is primarily due to lack of adequate spatially-disaggregated, time-series data on public expenditure. Adequate time-series data are necessary for this type of analysis since the effects of public investment programs commonly materialize with a lag, the length of which varies substantially by type of investment and the outcome of interest. Spatially-disaggregated data are important not only as the main basis of cross-sectional variation for econometric estimation, but for assessing the relative returns to spending in different geographic areas to address issue of decentralization (i.e. effect of spending across different local governments) or trickle-down effect (i.e. effect of spending in areas with different agricultural production potentials, for example).[1] Although theory is clear on the expected impacts of different types of public investment programs on growth and poverty reduction, there is a relatively large variation in the empirical findings on the magnitude of the impacts, and to some extent on the direction of impacts, due to variation in the methodologies and data that have been employed (IC 2007; Fan 2008). Differences arise from a number of considerations, such as the use of aggregate versus partial productivity measures in determining the agricultural productivity outcomes of public expenditures, treatment of the potential endogeneity of public investment programs, and length of time lag between spending and outcome variables, and interactions among different types of spending. Also important is the level of analysis, particularly in terms of unit of observation of outcomes (e.g. farm, household, district, province) and disaggregation of public spending variable, whether by sector (e.g. agriculture, education, health, transport), function (e.g. research, extension, irrigation, roads), economic (recurrent vs. development), and type of government (national, sub-national).

The rest of the paper is organized as follows. Next, we present the conceptual framework used to quantify and analyze the agricultural productivity impacts of government spending on agriculture and other sectors. The data, estimation procedure, and results are then presented, followed by conclusions and implications.

2. CONCEPTUAL FRAMEWORK AND EMPIRICAL APPROACH

2.1. Conceptual Framework

As the policy focus of the paper is how to use different types of public expenditures to stimulate agricultural production and productivity growth, we conceptualize it around three fundamental issues: public spending decision making; household agricultural production decision making; and the link between the two, i.e. public spending decision and agricultural production decision.

Public Spending Decision Making

The rationale for the provision of public goods and services is well known. In the context of this paper, it hinges on market failure including imperfect markets and information asymmetry for agricultural technology advancement as well as for promoting the adoption and use of those technologies and other productive investments by farmers. Public spending is also justified on social grounds for income distribution and poverty reduction. Thus, it seems logical that governments would spend on public goods and services or spend in areas where the impacts of the spending are likely to be greatest. This underlies the notion of program placement effects (Maddala 1983). That is, the decision to spend on a particular public good or service is likely to be influenced by the performance or outcome associated with the targeted population. In other words, the public spending decision making is endogenous, which when ignored could lead to

[1] The dataset used in the Fan et al. (2000 and 2004) studies in India and China, for example, exemplifies this standard, with public spending and other data spanning more than 25 years and disaggregated at sub-national level (14 states in the case of India and 29 provinces in the case of China).

biased estimates of the effects of public spending (Greene 1993). This notion that public spending is an endogenous process (or an outcome, rather than a cause, of growth) is a debatable and empirical issue (see Ansari et al. 1997; Zhang and Fan 2004).

Another issue in policy impact analysis in general is that the effects of public investment commonly materialize with a lag rather than contemporaneously, and so public spending decision at any time will depend on previous spending decisions and spending outcomes. The length of the lag depends on the type of spending as well as the performance indicator of interest. For example, the effect of public spending on agricultural R&D is expected to materialize over a longer time period (e.g. 15 years or more) than the effect of public spending on say input subsidies, which lasts a few years only.

Spending on a particular type of public good or service or spending in a particular geographic area can also affect the spending decisions on other types of public goods or services or spending in other geographic areas, respectively. The former is due to complementarity (or substitution effect) among different types of public spending. A typical example is the interaction effect between spending on agricultural R&D and spending on education. The notion is that modern technologies tend to be highly complex, knowledge-intensive, and location-specific, and so knowledge and skills are required for successful adoption. Spatial interaction effects, in the sense that the spending or tax decisions in one local jurisdiction can have positive or negative consequences on the fiscal choices and outcomes of other local jurisdictions (Oates and Schwab 1988), may be due to mobility and information asymmetries among local government officials and politicians (Case et al. 1993; Figlio et al. 1999). From the competitive standpoint and depending on the type of public spending, local governments are concerned about how their expenditures or taxes compare with those of their neighbors, and tend to adopt positions that are viewed better than their neighbors or at least not worse off (Case et al. 1993; Figlio et al. 1999). For example, if some local governments expand their spending on services (e.g. water, sanitation, and education) that tend to attract businesses and residents, there is a strong incentive for their neighbors to do the same in order to stay competitive. Spending on science and research, on the other hand, may be seen to be strategic substitutes. Jurisdictions would tend to decrease their spending in response to increased spending by their neighbors, since their residents will in general have access to the science and research outputs. Other determinants of public spending decision include budget constraint and various socio-cultural, political and institutional factors.

Agricultural Production Decision Making

To conceptualize the agricultural production decision making, we draw from the literature on agricultural household models (Singh et al. 1986; de Janvry et al. 1991), adoption of agricultural technologies (Feder et al. 1985; Feder and Umali 1993), and determinants of farm investments (Ervin and Ervin 1982). The fundamental notion in the context of this paper is that, due to market failure (including imperfect markets and information asymmetry) in input and output markets, household technology adoption and agricultural production decisions cannot be made independent of non-agricultural production and overall consumption decisions. Consequently, input and factor demands, supply, and consumption are no longer solely determined by exogenous market variables (e.g. input and output prices, land rents, wage rates, interest rates, etc.) and natural and biophysical characteristics (e.g. rainfall, temperature, etc.). They are now endogenously determined by farm, household and community characteristics, in addition to the market variables and natural and biophysical characteristics. Household and community characteristics include access to different types of public goods and services such as agricultural extension and other support services, input subsidies, credit and financial services, education and health services, and infrastructure (e.g. roads, input and output markets, marketing information, etc.), among others. These factors generally affect the household's ability to purchase, hire or use agricultural technologies,[2] which in turn would raise agricultural productivity.

Agricultural extension, for example, creates awareness of the technologies, shapes the perception of farmers, and helps to develop or strengthen their know-how and skills in using the technologies (Adesina and Baidu-Forson 1995). By creating awareness, extension also raises the ability of farmers to demand technologies and advisory services that meet their specific needs, including their local production and market conditions. Similarly, access to other support services such as pest and disease control, engineering services, and produce inspection/grading can help reduce farmers' post-harvest losses, improve the quality of their products, and raise the overall value of agricultural production.

Modern technologies, however, tend to be expensive or require large initial capital outlays to acquire them and so many farmers (especially the poor) may not be able to obtain them due to their own lack of financial capital or affordable credit and financial facilities. Thus, access to credit and subsidy programs can help farmers acquire the necessary technologies. Modern technologies also tend to be highly complex, knowledge-intensive, and location-specific, and so human capital development is critical for successful adoption. The link between human capital development and economic growth in general has long been established (Schultz 1982) and there is a large body of evidence showing substantial positive linkage effects, especially relating to education and health (see e.g. World Bank 2001; Fan 2008; Tompa 2002). Basically, highly educated farmers would be better positioned to adopt improved technologies and influence adoption among their colleagues. At the individual household level, however, it is important to note that improvements in human capital can have a negative impact on overall agricultural production and productivity when it promotes off-farm employment opportunities and exit options out of agriculture to the extent that it reduces the knowledge and skills of those left on the farm (Jolliffe 2004). The argument also holds for improvement in access to other public goods and services such as roads that promote exit options out of agriculture. The productivity impacts of better health are similar to those of better education, by contributing to human capital development. Health problems such as HIV/AIDS and tuberculosis, as well as other debilitating illnesses (e.g. malaria), have major negative economic effects, such as lost work days and wages, decreased productivity, and increased medical costs and burden of family care (Tompa 2002).

The literature, including those reviewed above, also shows that technology adoption and agricultural production decision making of the household is influenced by several other variables. Those that determine the profitability of agricultural production are especially important. They include: land tenure status, which affects the future returns from current practices (Otsuka et al. 1992; Otsuka and Hayami 1988); households' endowments of human, physical, financial and social capital, which are important for use of factors of production and inputs (land, labor, draft power, manure, etc.), especially where markets for such inputs are lacking (Holden et al. 2001); and biophysical factors such as and rainfall, population density and

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[2] Modern or improved technologies may be categorized broadly as: mechanical (e.g. tractors, harvesters); biological (e.g. hybrid seeds, agro-forestry, livestock cross-breeds); chemical (e.g. fertilizers, pesticides, de-wormers); physical (soil and water conservation, irrigation, kraals); and agronomic and animal husbandry (e.g. row planting, stall feeding).

other village-level factors, which affect local comparative advantages on and off the farm (Pender et al. 1999).

Link between Public Spending and Agricultural Growth

The issue of how public spending affects agricultural growth is well-established in a growing body of literature. The general notion is that public capital and private capital are complementary factors in the production process, so an increase in the public capital stock raises the productivity of all factors in production (Anderson et al. 2006). By raising the productivity of all factors in production, public capital investments crowd-in private capital investments leading to an increase in the private capital stock (David et al. 2000; Malla and Gray 2005; Kakwani and Son 2006), which further contributes to raising productivity. Of course, crowding-out of private capital investments, with contrasting effects on productivity growth, may also occur. This derives from the relative efficiency of public versus private investments, especially in many developing countries where public sector agencies compete directly with the private sector in the provision of private goods and services. This is because public and private spending is considered a zero-sum game, in the sense that government spending is financed by taxation of private investment. The findings of Ashipala and Haimbodi (2003) on Botswana, South Africa and Namibia, for example, show that private investment is more productive than public investment, suggesting that public investment will result in loss of growth, to the extent that publicly-financed activities were in direct competition with the private sector. It is also possible that public spending may not create any productive capital (Devarajan et al. 1996), so the link between public spending and productivity would be weak.

Therefore, we can conceptualize the link between the public spending decision and household agricultural production decision as: *direct*, where public spending affects factor productivity; and *indirect*, where public spending affects the use and amount of factors and inputs (or factor accumulation). For example, public spending on research, extension and education leading to improvements in the stock of modern technologies, knowledge and human capital would be expected to raise productivity of all factors of production. Public spending on agricultural input subsidies, on the other hand, would be expected to increase the use and amount of the subsidized inputs. However, an input subsidy can also have substantial indirect price effects on the use and amounts of other inputs. For example, recipients of a subsidy may alter their labor supply or spending and savings choices, which would in turn affect their farm and non-farm production and consumption decisions in a manner that may undermine the expected outcomes of the subsidy program (van de Walle 2003). By reducing transportation and transactions costs, lowering agricultural input prices and raising farm gate prices, public spending on infrastructure (e.g. roads, input and output markets, marketing information) would also be expected to greater factor accumulation as well as higher value of production. Public spending on the transport sector can also have other multiplier effect where it improves access to education, health, and other production support services.

2.2. Regression Model

Consistent with the conceptual framework presented in the preceding chapter, we use a simultaneous-equations approach to model household farm production and government spending decision making, where government spending on different types of public goods and services is the driving force behind agricultural productivity growth, controlling for other factors. Household farm production behavior is made up of two equations: (i) agricultural production, which is modeled as a function of public investments for agricultural and human capital development, private farm investments, input use, farm characteristics, household characteristics, and village-level biophysical and institutional characteristics; and (ii) private farm investments and input use, which is modeled as a function of public investments for agricultural, human capital and infrastructural development, farm characteristics, household characteristics, and village-level biophysical and institutional characteristics. Government spending behavior is modeled as government spending on the agricultural sector as a function of past agricultural sector performance, public investment for human capital and infrastructural development, and village-level socio-cultural, political and institutional factors. Assuming that the equations are correctly specified, the simultaneous-equations approach, similar to that of Fan et al. (2000, 2004), is superior to the reduced-form single-equation approach. Although the reduced-form single-equation specification potentially eliminates the endogeneity bias and allows the estimation of the total impacts of the exogenous explanatory variables on the dependent variable, the policy implications of the estimated parameters can be misleading; since changes in public investments are not linked one-to-one with changes in outcomes. Therefore, reduced-form estimates may not be appropriate when making recommendations about whether and how to increase or decrease public investments (Herrera 2007). Furthermore, the conceptual framework presented in the preceding chapter show that public investments affect productivity through multiple channels, which this paper aims to analyze. The system of equations and conceptual variables used in this study are shown in equations 1, 2 and 3.

$$AGOUT\_PC_h = f\,(PAGINV_d, OTHPINV_d, FARMINV_h, FARM\_XICS_h, HHD\_XICS_h, OTHER\_A_d; \boldsymbol{\beta}_A) \quad (1)$$

$$FARMINV_h = f\,(PAGINV_d, OTHPINV_d, FARM\_XICS_h, HHD\_XICS_h, OTHER\_F_d; \boldsymbol{\beta}_F) \quad (2)$$

$$PAGINV_d = f\,(AGPERF_d, OTHPINV_d, OTHER\_P_d; \boldsymbol{\beta}_P) \quad (3)$$

Equation (1) is a household agricultural production function, where the dependent variable $AGOUT\_PC_h$, measured as the value total agricultural output per capita of a household, is a function of public investments in agriculture ($PAGINV_d$) and the other sectors of education, health and rural roads ($OTHPINV_d$).[3] This captures the direct effects of public investments. Other determinants of the production function include the following measures: private farm investments and inputs in agricultural production ($FARMINV_h$); farm characteristics ($FARM\_XICS_h$) such as endowments of land, livestock and equipment; household characteristics (HHD_XICS_h) such as size, gender, age, and income strategies; and village-level biophysical factors and other factors affecting agricultural production ($OTHER\_A_d$). $\boldsymbol{\beta}_A$ $\boldsymbol{\beta}_F$ and $\boldsymbol{\beta}_P$ are vectors of parameters to be estimated for the respective equations.

In equation (2), private farm investment is derived as a function of public investments in agriculture and the other sectors, to capture the indirect effects of public investments. The other determinants are farm and household characteristics, as well as other factors affecting farm investments ($OTHER\_F_d$), as discussed above. Equation (3) models public investments in the agricultural sector as a function of past agricultural performance at the district level ($AGPERF_d$), such as value of crop production and productivity. Other factors affecting public investments

[3] Subscripts *h* and *d* denote household and district, respectively.

decision in agriculture include public investments in other sectors ($OTHPINV_d$), and various socio-economic, cultural, political and institutional factors ($OTHER\_P_d$). We use measures of poverty, ethnic and religious composition, size (e.g. population and land area), and agroecology of the district to capture these factors. Equation (3) is modeled after the notion of placement effects of public investment programs, where prior agricultural performance and district characteristics may have an impact on attracting resources into the district, both from the central government and from donors. By including public investments in other sectors in equation 3, we capture possible interaction effect between spending on the non-agricultural sectors and spending on the agricultural sector. Such effects could also be modeled by including interaction terms among the relevant public investment variables. The use of interaction terms, however, often introduces multicollinearity among the variables, which can cause the parameters to be estimated imprecisely (Greene 1993). While we recognize possible spending interactions across districts, as discussed previously, we do not have the spatial information necessary to model and assess such spillover effects of public spending.

Next, we present the estimators for the marginal effect of (and marginal returns to) different types of public spending on agricultural productivity and required amount of public agricultural spending to achieve a specific agricultural growth rate target.

Marginal Effect of Public Investments on Agricultural Productivity

The marginal effect of public investments on agricultural productivity can be calculated by totally differentiating the system of equations with respect to the particular public investments variable. This effect can be expressed in terms of elasticity, where the elasticity of agricultural productivity with respect to public investments in agriculture ($\in_{PAGINV}$), for example, is a function of $\boldsymbol{\beta}_A$ and $\boldsymbol{\beta}_F$ and can be obtained by:[4]

$$\in_{PAGINV} \equiv \frac{dAGOUT\_PC}{d\,PAGINV} = \frac{\partial AGOUT\_PC}{\partial PAGINV} + \frac{\partial AGOUT\_PC}{\partial FARMINV} \cdot \frac{\partial FARMINV}{\partial PAGINV} \quad (4)$$

The subscripts have been dropped for notational simplicity. The first term on the right-hand side captures the direct effect of public investments in agriculture, while the second and third terms together capture the indirect effect. The second term is the typical vector of production function estimates with respect to farm investments (i.e. factors of production and inputs). The third term captures the crowding-in (or crowding-out) effects of public investments in agriculture on private farm investments. Similarly, the elasticity of agricultural productivity with respect to public investment in the other sectors ($\in_{OTHPINVi}$), which is a function of $\boldsymbol{\beta}_A$ $\boldsymbol{\beta}_F$ and $\boldsymbol{\beta}_P$, can be obtained by:

$$\in_{OTHPINV_i} \equiv \frac{dAGOUT\_PC}{dOTHPINV_i} = \frac{\partial AGOUT\_PC}{\partial OTHPINV_i} + \frac{\partial AGOUT\_PC}{\partial FARMINV} \cdot \frac{\partial FARMINV}{\partial OTHPINV_i} + \in_{PAGINV} \cdot \frac{\partial PAGINV}{\partial OTHPINV_i} \quad (4')$$

The subscript i associated with $OTHPINV_i$ is used to capture the separate effects of different types of public investment in the non-agricultural sector (i.e. education, health, and rural roads). The interpretation of the first three terms on the right-hand side of the equation is

[4] To be consistent with any functional form, define $\partial y = \Delta y / y$ such that $\partial y / \partial x = (\Delta y / y)/(\Delta x / x)$.

similar to those given for the effect of public investment in agriculture. The last two terms together capture the interaction effect between public investment in the agricultural and non-agricultural sectors.

Marginal Returns to Public Spending

The marginal returns to public investments (i.e. the benefit-cost ratio or *BCR*) can be calculated by multiplying equations (4) and (4') with the respective ratio of agricultural output per capita to public investment according to:

$$BCR_{PAGINV} = \in_{PAGINV} \cdot \frac{AGOUT\_PC}{PAGINV} \tag{5}$$

$$BCR_{OTHPINVi} = \in_{OTHPINV_i} \cdot \frac{AGOUT\_PC}{OTHPINV_i} \tag{5'}$$

The marginal returns are measured as a ratio and provide information for comparing the relative benefits of an additional unit of spending on different sectors. The marginal returns can be compared across different sectors and used to infer future or additional public spending priorities for improving agricultural productivity. Similarly, the marginal returns to public spending on a particular sector can be obtained for and compared across different geographic areas, for example. This information can then be used for setting future priorities for public spending in different areas. On purely economic or efficiency grounds, resources available for raising agricultural productivity would be allocated across different sectors, sub-sectors and geographic areas in a manner that equalizes their marginal returns. Of course, equity and other social factors based on development objectives need to be taken into consideration—this is outside the scope of this paper. The marginal returns also can be used to calculate the level of public spending required to achieve a particular agricultural productivity growth target. [5]

3. DATA AND ESTIMATION

3.1. Data

The data used in this study are on Ghana and were obtained from various sources. Public agricultural spending is up of two components: district- and regional-level disaggregated data on expenditures of the Agriculture Services Sector Investment Programme (AgSSIP) and regional-level disaggregated data on expenditures of the Ministry of Food and Agriculture (MOFA).[6] The data are from 2001 to 2006 and were obtained from MoFA and the office of the controller and accountant general's department (CAGD 2007). Public spending on the non-agricultural sector are national-level expenditure data from 2001 to 2006 on education, health and feeder roads, obtained from the respective government ministries, departments and agencies. Agricultural production, private farm investments and data on other farm-household characteristics are from

[5] See Fan et al. (2008b) for method and application.

[6] These two sources of government expenditures on the agricultural sector do not include expenditures made at the national level. As such they do not include agricultural expenditures undertaken by ministries and government agencies other than the Ministry of Food and Agriculture (MOFA).

the most recent (2005/06) Ghana Living Standards Survey (GLSS5) (GSS 2007), data on access to education and health services are from the 1997 and 2003 Core Welfare Indicators Questionnaire (CWIQ) surveys (GSS 1998, 2004), and data on rural roads and related information are from the Ministry of Road Transport. Detail description and summary statistics of the variables used in the analysis, which capture the conceptual factors discussed earlier, are presented in Table 1. All monetary values were converted into 2000 constant prices using regional consumer price index to exclude the influence of inflation and other temporal monetary and fiscal trends. Below, we briefly discuss the public spending and private investment variables and how they were measured.

Public investment in agriculture ($PAGINV_d$). We first distributed the regional expenditures equally across the relevant districts, and then we constructed an agricultural public capital stock variable by applying a 10 percent depreciation rate and 16 percent discount rate, based on government practice (BOG 2007). As we expect the impacts of spending to differ by type of expenditure, we separated the public capital stock variable into two sources: recurrent spending ($PAGINV_d\_recurr$) and development spending ($PAGINV_d\_dev't$). To do this, we considered all of AgSSIP expenditures as development spending (World Bank 2000). For the other agriculture expenditure data, however, we used 0.10, 0.17, 0.15, 0.17 and 0.20 of the expenditures as development spending for 2002, 2003, 2004, 2005 and 2006, respectively, which are the shares of development spending for the respective years. The remaining shares were considered recurrent spending, which include expenditures on salaries, overheads, administration and operational cost for delivery of public goods and services.

Public investment in education, health and rural roads ($OTHPINV_d$). Unlike public spending information on the agriculture sector, we were unable to obtain any district-disaggregated expenditure data on the other sectors considered here, and so we used different measures to represent the stock of public capital in these sectors based on data availability. For education, we used the proportion of household members that have completed at least primary or middle or higher-levels of formal education (as opposed to those that have no formal education), using data from the 2003 CWIQ. The stock of public capital in the health sector was measured in similar fashion by the proportion households in the district that live within 15–29 minutes, 30–44 minutes, and more than 44 minutes from a health center (as opposed to those that live within 15 minutes). For rural roads, we used the rural road density in the district, measured as the number of kilometers of feeder roads per square kilometer of total land area in 2004 (MoRT 2007).

Private farm investments and assets. From the GLSS5 data, agricultural investments made by households were separated into initial stocks (i.e. holdings before the survey period) and flows (i.e. investments made during the survey period). Initial stocks are grouped into three categories: livestock assets, measured in tropical livestock units (TLUs); crop-production equipment; and other agricultural equipment. Flows during the survey period are aggregated across all categories (e.g. tractors, ploughs, spraying machines, livestock, outboard motors, fishing nets, improved seed, fertilizer, pesticide, feed, fuel, hired labor, etc.) into a single metric ($FARMINV_h$). It would have been ideal to assess the separate effects of the individual investments and inputs. However, not all households made investments in every category (e.g. tractors, ploughs, spraying machines, livestock, outboard motors, fishing nets, etc.) or used every input (e.g. improved seed, fertilizer, pesticide, feed, fuel, hired labor, etc.). Thus, there were a significant number of households with zero values (or truncated observations) for each type of investment or input. And so we aggregated the value of agricultural investments into a single metric.

Table 1. Description of variables and summary statistics

Variable name	Variable description	Mean	Std. Err.
$AGOUT\_PC_h$	Value of household total agricultural output per capita (2000 GH¢)	132.30	2.822
$FARMINV_h$	Value of total agricultural investments made and inputs used by the household in the survey year (2000 GH¢ per capita)	1,171.72	23.378
$PAGINV_d\_total$	Stock of public agricultural investments in district: based on MoFA and AgSSIP total expenditures (2000 GH¢, thousands)	162.04	0.585
$PAGINV_d\_dev't$	Based on developmental expenditures	54.13	0.156
$PAGINV_d\_recurr$	Based on recurrent expenditures	107.91	0.465
$OTHPINV_d$	Stock of public investments in education, health, rural roads		
Education (cf.: none)	Proportion of household members that have completed level of formal education (cf.: no formal education)		
Primary	Completed primary school	0.18	0.005
Middle	Completed middle school	0.14	0.005
Secondary or more	Completed at least secondary school ("O" level)	0.11	0.004
Health (cf.: <15 min)	Proportion of households living within vicinity of health facility: (cf.: up to 15 minutes)		
Health_15-29 min	15–29 minutes	0.08	0.001
Health_30-44 min	30–44 minutes	0.07	0.001
Health_gt 44 min	45 minutes or more	0.19	0.003
Rural roads	Rural road density in district (km per sq. km)	0.30	0.002
HHD_XICS_h	Household characteristics		
Household size	Number of household members (adult equivalents)	4.89	0.045
Gender of head	Dummy variable for head of household: 0=female, 1=male	0.79	0.006
Age of head	Age of household head (years)	46.85	0.242
Adult labor	Proportion of members aged 18 to 64	0.51	0.004
Male labor	Proportion of members that are male	0.50	0.004
Employment	Proportion of members employed	0.59	0.004
Income strategy (cf.: subsistence agriculture)	Proportion of members engaged in: (cf.: subsistence agriculture)		
Market crops	Market-oriented crops	0.23	0.005
Market other agriculture	Market-oriented other agriculture	0.05	0.003
Off-farm	Off-farm	0.10	0.003
$FARM\_XICS_h$	Farm characteristics (assets owned prior to the survey year)		
Farm size	Ares of farmland (1 are = 100 sq. meters)	278.59	11.513
Livestock assets	Number of tropical livestock units (1 TLU = 250 kg)	359.88	18.218
Crop equipment	Value of crop production equipment (2000 GH¢ per capita)	9.21	1.470
Other equipment	Value of non-crop production equipment (2000 GH¢ per capita)	5.51	1.978
District Level Factors			
$AGPERF_d$			
Crop production	1999-2003 average value of crop output (1000 GH¢)	155.49	10.96
Crop yield	1999-2003 average value of crop output per unit area cultivated (GH¢)	5.53	0.23
Ag population	Percent of population with agriculture as main activity	64.58	1.41
OTHER			
Poverty	Proportion of households living below poverty line	0.54	0.003
Population	Total population (1000)	154.73	5.71
Land area	Total land area (1000 sq. km)	2348.73	273.69
Population density	Number of people per sq. km	119.39	1.657
Ethnicity (cf.: Akan)	Proportion of population by ethnicity: (cf.: Akan)		
Ga	Ga	0.02	0.01
Ewe	Ewe	0.04	0.01
Guans	Guans	0.09	0.02
Other	Other	0.46	0.02
Religion (cf.:	Percent of population by religious affiliation: (cf.: Christianity)		

Christian)			
Islam	Islam	18.05	2.23
Traditional	Traditional	7.31	1.32
Other	Other	6.54	.41
Rainfall_average	Annual average amount of rainfall in mm	1,290.64	3.668
Agro-ecology (cf.: coastal zone)	Dummy variable for location of household in agro-ecological zone (comparative base is coastal zone)		
Forest zone	Household located in forest zone	0.43	0.008
Southern savannah	Household located in southern savannah zone	0.10	0.005
Northern savannah	Household located in northern savannah zone	0.33	0.007

Notes: [1] TLU is aggregated using the following weights: cattle (1), donkeys and pigs (0.36), sheep and goats (0.09) and rabbits and poultry (0.01). In 2000, US$1 ≈ GH¢0.55. Total number of observations is 4,013. Sources: Authors' calculation based on: 2003 Core Welfare Indicators Questionnaire (CWIQ) survey (GSS 2004); 2005/06 Ghana Living Standards Survey (GSS 2007); government finance statistics (CAGD 2007); Agriculture Services Sector Investment Programme (MoFA 2007); and Ministry of Road Transport (MoRT 2006).

3.2. Estimation Approaches and Issues

We used a three-stage least squares (3SLS) econometric approach to simultaneously estimate equations (1) through (3), first for the total sample and then separately for the four agro-ecological zones. There are a couple of data and estimation issues to consider when using this approach. First is the estimation of equation (3) within the system, where the unit of observation of the dependent variable is the district, which is different from the other two equations where the unit of observation of the dependent variables is the household. This poses a problem for implementing 3SLS, which requires the same number of observations for each of the dependent variables. One way to handle this in general is to aggregate the household data upwards to the district level, as done in Fan et al. (2004). However, the GLSS5 survey data, unlike the CWIQ survey data, are not representative at the district level because the sampling is based on enumeration areas that are different for the district areas. And so any statistics generated at the district level would not be a reliable estimate characterizing the district. Thus, we estimate equations (1) and (2) jointly and equation (3) separately. The delta method (Oehlert 1992) is then used to estimate the variance and standard errors of the relevant elasticities. Write the general form of the estimated elasticities as:

$$\in = f(\hat{\beta}_A, \hat{\beta}_F, \hat{\beta}_P) \quad (6)$$

Then the variance of the elasticities, using the delta method and the variance-covariance matrix of the coefficients ($\hat{\Sigma}$), can be obtained as:

$$\text{var}(\in) = \left[\left(\frac{\partial f}{\partial \hat{\beta}_A}\right)\left(\frac{\partial f}{\partial \hat{\beta}_F}\right)\left(\frac{\partial f}{\partial \hat{\beta}_P}\right)\right] \cdot \hat{\Sigma} \cdot \left[\left(\frac{\partial f}{\partial \hat{\beta}_A}\right)\left(\frac{\partial f}{\partial \hat{\beta}_F}\right)\left(\frac{\partial f}{\partial \hat{\beta}_P}\right)\right]^T . \quad (7)$$

Another issue to deal with is the identification of equation (1), which we deal with using exclusion restrictions—i.e. excluding some of the explanatory variables (or instruments) used in estimating equation (2) from equation (1), Since using weak instruments could yield more biased estimates than those obtained if the parameters were estimated by an ordinary least squares

(OLS) method (Greene 1993), the desired instruments were selected based on Hansen's (1982) chi-squared test of identification. The utilized instruments include household-level adult and male labor, employment and income strategy.

Multicollinearity also needs to be considered when using a large number of explanatory variables. Severe multicollinearity problems can cause the parameters to be estimated imprecisely—e.g. wrong signs, implausibly large values, and wide variations in magnitudes when the number of observations is changed (Greene 1993). This was not a problem here since the value of the largest variance inflation factor (VIF) associated with any of the explanatory variables in the different equations was 10, which is less than the cut-off point of 20 suggested by Kennedy (1985). The only exception was observed in the estimation of equations (1) and (2) for the coastal agro-ecological zone, where recurrent and developmental agricultural spending (i.e. $PAGINV_d\_recurr$ and $PAGINV_d\_dev't$) had VIF values of 28 and 31, respectively, likely due to the smaller sub-sample of the zone compared with the other three agro-ecological zones. The regression results, however, do not show any anomalies compared with those estimated from the total sample or the other agro-ecological zones.

4. RESULTS AND DISCUSSION

Details of the regression results first using the pooled total sample and then separately for the four agro-ecological zones (coastal, forest, northern savannah and southern savannah) for equations 1 and 2 on agricultural productivity and farm investments, respectively, are presented in Tables 2 and 3 (using aggregate data on public agricultural spending) and Tables 4 and 5 (using the disaggregated data (i.e. separating public agricultural spending into developmental and recurrent expenditures)). Table 6 shows the results for equation 3 on the determinants of public agricultural investments. The marginal effects associated with the different types of public investments are shown in Table 7.

Marginal agricultural productivity effects of public agriculture spending

As the regression results show (Tables 2-5), public spending on the agricultural sector in the recent past years has had significant positive impact on agricultural productivity, either directly or via greater private farm investments and inputs. For all rural areas taken together, the marginal effect is estimated at 0.15 (Table 7). This means that a one percent increase in agricultural public expenditure is associated with a 0.15 percent increase in the value of agricultural production per capita. This overall elasticity compares favorably with estimated elasticities of spending on the sector in other countries, including, for example, the elasticity with respect to agricultural capital expenditure in Rwanda (0.17; Diao et al., 2007) and spending in agricultural research and extension in the U.S. (0.11 to 0.19; Huffman and Evenson, 2006). As expected, the effect associated with the development spending component was much larger (elasticity of 0.54), counteracting the negative effect associated with the recurrent spending component. This result reflects the low government capital-recurrent expenditure ratio in the sector (less that 20 percent), which resonates the fact that simply paying staff salaries, administrative costs and other overheads is unlikely to yield any substantive outcomes. The estimated elasticity associated with development expenditures obtained here is higher than those in the studies cited above as well as those estimated in other studies, e.g. the elasticity with respect to agricultural research in India (0.25; Fan et al., 2000) and agricultural capital expenditure in Africa (0.3; Fan and Rao 2003).

The estimated effect of public spending on agriculture differs substantially across the four agro-ecological zones. The marginal effect of aggregate spending is positive and statistically significant in the forest and southern savannah zones only, with elasticities of 0.45 and 1.30, respectively. The insignificance of aggregate spending in the coastal and northern savannah zones is due to the counteracting negative effects associated with the recurrent spending, except in the southern savannah zone where recurrent expenditure was the sole driver of positive agricultural productivity impact.

Marginal agricultural productivity effects of other public goods and services

As Table 7 also shows, greater access to health services and greater rural roads density were associated with greater productivity. For all rural areas taken together and considering the effect on total agricultural public spending, the elasticities with respect to health and feeder roads density are 0.21 and 0.13, respectively. Formal education, on the other hand, had a negative effect, although mostly insignificant. As Tables 2-5 show, while the effects of health and feeder roads are direct only, the effects of education are both direct and indirect. In fact, households with more educated members were associated with greater private farm investments, although the consequent positive effect on productivity was not enough to override the direct negative effects, which is most likely due to skilled labor (i.e. more educated people) being allocated away from the farm (Jolliffe 2004). The effects of education found here are consistent with those of many previous studies on Latin America or other African countries, but contradict those found in Asia (Jolliffe 2004).[7]

Similar to public spending on agriculture, the marginal effects associated with the other public goods and services differ substantially by agro-ecology. The negative effect of education, for example, is statistically significant in the coastal zone only, which is not surprising since nonfarm employment opportunities or exit options out of agriculture are abundant there compared to the other zones. In fact, the marginal effect of education was positive (although insignificant) in the northern savannah zone, where exit options out of agriculture are least likely, suggesting that more educated farmers also work on the farm. This is supported by the positive and significant direct effect of secondary education or greater on agricultural productivity in the zone (Tables 2 and 3) and is consistent with the findings from Asia (Yang 1997). The positive effect associated with greater access to health services holds everywhere, although it was not statistically significant in the coastal zone, where overall access to health services is much better compared to the other zones. Regarding feeder roads density, the effect was significant and positive in the forest agro-ecological zone only.

Marginal agricultural productivity effects of other factors

Several other factors contribute to the determination of private farm investments and agricultural productivity. The coefficients associated with these factors are consistent in both sign and magnitude whether they are estimated using aggregate agricultural public expenditures (Tables 2 and 3) or with the expenditures separated into developmental and recurrent spending (Tables 4 and 5).

The regression results (Tables 2 and 3) show that private farm investments and inputs have had a significant positive impact on agricultural productivity, with the exception of the

[7] See Jamison and Lau (1982) for a review of the evidence.

coastal and southern savannah agro-ecological zones, where the estimated coefficients were not statistically significant at the 10 percent level. For all rural areas taken together, a one percent increase in the value of farm investments is associated with a 0.12 percent increase in the value of household total agricultural output per capita. As expected, farm size and initial capital stocks in livestock and crop and other agricultural equipment all had positive and significant impacts. Consistent with the earlier finding regarding lower investment among female-headed households, we find that agricultural productivity is lower among such households by about 38 percent on average.[8] Similarly, larger households and households headed by the elderly were associated with lower agricultural productivity. The indirect positive effects of these factors via investments were outweighed by their direct negative effects. Together, these findings suggest that poverty and food insecurity is more likely to be problematic in such households. The forest agro-ecological zone was associated with the greatest value of agricultural productivity on average.

Regarding the determinants of farm investments, farm size, initial livestock assets, and agricultural equipment all have positive and significant impacts on the value of private farm investments and inputs. Gender had mixed impacts. While households headed by women were associated with lower values by about 40 percent on average, those with more male labor were associated with lower values of investments and inputs by about 32 percent on average.[9] Larger households and households headed by older people or with more employed members were associated with greater farm investments. These findings are generally expected given the potential impacts of the factors on labor availability and access to income for financing investments. Households in the forest and southern savannah zones were associated with greater values of farm investments and inputs by about 28 and 18 percent on average, respectively, than their counterparts in the coastal and northern savannah zones.

Determinants of public agricultural spending

The regression results presented in Table 6 show that public agricultural spending tends to be greater in districts with moderate access to public health services (i.e. where a majority of the population is within 15 and 45 minutes of a health center as opposed to less than 15 minutes or 45 minutes or more) and greater road network development. Since greater spending on health and rural roads independently contributes to greater agricultural productivity, the above findings suggest that complementarity between spending on health and rural roads and spending on the agriculture sector. Education achievement composition of the population (a measure of human capital development) did not have any significant impact on public agricultural spending; although districts with more people having completed middle or greater levels of formal education were negatively associated with public agricultural spending.

The expectation that public agricultural spending would be influenced by past performance of the agricultural sector to direct more resources to areas where performance is high did not hold up. The results show a significant negative association between public agricultural spending and past total crop output. Past crop yield or agricultural population had no significant association with public agricultural spending. Similarly, past poverty levels and total population had no significant association with public agricultural spending.

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[8] This is the total effect, which is made up of the direct and indirect effects.

[9] The percentage impact of such binary variables on the dependent variable can be calculated by taking the exponential of the relevant coefficient in Table 2 or 3, since the dependent variable is transformed by logarithm.

Table 2. Three-stage least squares regression estimates of the determinants of agricultural production in Ghana (Equation 1: Ln $AGOUT\_PC_h$)—using aggregate agricultural expenditures

Explanatory variable	Total sample	Agro-ecological zone			
		Coastal	Forest	Southern savannah	Northern savannah
Private farm investments					
Ln $FARMINV_h$	0.117***	-0.121	0.157***	0.042	0.173***
Public investments in:					
Agriculture					
Ln $PAGINV_d\_total$	0.136	-0.263	0.451***	1.271***	-0.066
Education					
Primary	-0.128**	-0.119	-0.094	-0.110	-0.035
Middle	-0.156***	-0.060	-0.203***	0.202	-0.205
Secondary or more	-0.161***	-0.344	-0.148	-0.184	0.253*
Health (cf.: <15 mins)					
Health_15-29 mins	-1.723***	-3.444**	-3.060***	-0.470	-0.944
Health_30-44 mins	-0.166	-0.792	0.685	1.712	-0.758
Health_gt 44 mins	-0.666***	1.008	-0.748**	-1.925***	-0.817***
Ln Rural roads	0.106***	0.227	0.419***	0.104	-0.007
Household characteristics (HHD_XICS_h)					
Ln Household size	-0.807***	-0.446***	-0.966***	-0.728***	-0.831***
Gender of head	0.282***	0.465***	0.270***	0.105	0.301***
Ln Age of head	-0.166***	-0.185	0.053	-0.330**	-0.322***
Adult labor	0.127*	-0.101	0.240***	-0.149	
Income strategy (cf.: subsist. ag.)					
Market crops	0.241***	0.697***	-0.062	-0.229	0.018
Market other agriculture	-0.052	0.594**	-0.323***	0.224	-0.921**
Off-farm	0.010	-0.337	-0.041	0.209	-0.094
Farm characteristics ($FARM\_XICS_h$)					
Ln Farm size	0.053***	0.067***	0.041***	0.051***	0.042***
Ln Livestock assets	0.063***	0.031	0.083***	0.098***	0.063***
Ln Crop equipments	0.177***	0.172***	0.197***	0.231***	0.120***
Ln Other equipments	0.110***	0.097	0.147***	0.047	0.083
District-level factors ($OTHER\_X_d$)					
Population density			-0.382***		-0.021
Rainfall_average					1.940**
Agro-ecology (cf.: coastal zone)					
Forest zone	0.156***				
Southern savannah	0.040				
Northern savannah	0.099				

Year of survey (0=2005, 1=2006)	-0.095***	-0.416***	0.059	-0.241*	-0.078
Intercept	4.000***	7.352***	3.797***	-0.422	-8.014
Model estimation statistics					
Chi-square	1441.020	162.900	999.410	201.250	479.100
R-square	0.278	0.182	0.382	0.342	0.271
Number of observations	4013	571	1729	392	1321
Model identification test (exclusion restriction)					
Hansen's *J* chi-square statistic	2.535	3.672	0.615	1.627	0.803

Notes: See Table 1 for a detailed description of the variables. All continuous variables are transformed by natural logarithm, which is indicated by Ln. *, ** and *** means that the coefficient is statistically significant at the 10 percent, 5 percent or 1 percent level, respectively.

Table 3. Three-stage least squares regression estimates of the determinants of farm investments in Ghana (Equation 2: Ln *FARMINV*$_h$)—using aggregate agricultural expenditures

Explanatory variable	Total sample	Agro-ecological zone			
		Coastal	Forest	Southern savannah	Northern savannah
Public investments in:					
Agriculture					
Ln $PAGINV_d\_total$	0.148*	0.050	-0.028	0.727**	1.559***
Education					
Primary	0.492***	0.761***	0.752***	0.174	0.071
Middle	0.451***	0.775***	0.594***	0.317*	0.139
Secondary or more	0.435***	0.751***	0.648***	0.131	0.176*
Health (cf.: <15 mins)					
Health_15-29 mins	-0.725*	-1.379	-1.203	0.451	-1.998***
Health_30-44 mins	-0.336	-2.936	-0.618	2.416	-0.926**
Health_gt 44 mins	-0.157	0.387	-0.362	0.032	-0.644***
Ln Rural roads	-0.045	-0.236	0.054	-0.126	-0.157**
Household characteristics (HHD_XICS_h)					
Ln Household size	1.587***	1.173***	1.612***	1.584***	1.777***
Gender of head	0.334***	0.507***	0.308***	0.126	0.150**
Ln Age of head	0.332***	0.447***	0.533***	0.044	0.070
Adult labor	0.080	0.044	0.095	-0.335	0.204**
Male labor	-0.381***	-0.443**	-0.423***	0.099	-0.400***
Employment	2.522***	2.083***	2.784***	2.609***	2.168***
Income strategy (cf.: subsist. Ag.)					
Market crops	-0.006	0.045	-0.041	-0.028	-0.082
Market other agriculture	-0.175*	-0.166	-0.375***	-0.546*	0.457
Off-farm	-3.806***	-4.012***	-3.338***	-3.542***	-3.839***
Farm characteristics ($FARM\_XICS_h$)					
Ln Farm size	0.037***	0.053***	0.036***	0.044**	0.021**
Ln Livestock assets	0.012*	0.009	0.011	0.026	0.016*
Ln Crop equipments	0.044***	0.106*	0.050**	0.113**	0.011
Ln Other equipments	0.045**	0.071	0.079*	0.014	0.099***
District-level factors ($OTHER\_X_F$)					
Poverty	0.625***	1.713***	0.231	1.833	
Population density			-0.196***		0.123***
Rainfall_average					1.994***
Agro-ecology (cf.: coastal zone)					
Forest zone	0.230***				
Southern savannah	0.170**				

Northern savannah	-0.100				
Year of survey (0=2005, 1=2006)	-0.013	-0.386***	0.054	0.339***	0.017
Intercept	0.524	0.577	1.785*	-2.280	-19.345***
Model estimation statistics					
Chi-square	8798.370	1023.740	3197.960	837.120	5131.370
R-square	0.687	0.642	0.649	0.681	0.795
Number of observations	4013	571	1729	392	1321

Notes: See Table 1 for a detailed description of the variables. All continuous variables are transformed by natural logarithm, which is indicated by Ln. *, ** and *** means that the coefficient is statistically significant at the 10 percent, 5 percent or 1 percent level, respectively.

Table 4. Three-stage least squares regression estimates of the determinants of agricultural production in Ghana (Equation 1: Ln *AGOUT_PC*$_h$)—using disaggregated agricultural expenditures

Explanatory variable	Total sample	Agro-ecological zone			
		Coastal	Forest	Southern savannah	Northern savannah
Private farm investments					
Ln *FARMINV*$_h$	0.119***	-0.098	0.158***	0.079	0.198***
Public investments in:					
Agriculture					
Ln *PAGINV*$_d$*_dev't*	0.549***	1.993*	0.451**	-0.165	0.473**
Ln *PAGINV*$_d$*_recurr*	-0.244***	-1.430**	0.058	1.275***	-0.325
Education					
Primary	-0.126**	-0.159	-0.096	-0.095	-0.033
Middle	-0.162***	-0.090	-0.208***	0.208	-0.155
Secondary or more	-0.163***	-0.373*	-0.152	-0.192	0.254*
Health (cf.: <15 mins)					
Health_15-29 mins	-1.645***	-3.506**	-3.025***	-0.531	-1.113
Health_30-44 mins	-0.175	-0.527	0.529	1.635	-1.021
Health_gt 44 mins	-0.551***	0.388	-0.604	-2.239***	-0.903***
Ln Rural roads	0.110***	0.171	0.419***	0.103	-0.068
Household characteristics (*HHD_XICS*$_h$)					
Ln Household size	-0.812***	-0.470***	-0.964***	-0.804***	-0.887***
Gender of head	0.281***	0.462***	0.268***	0.110	0.305***
Ln Age of head	-0.158***	-0.186	0.056	-0.324**	-0.318***
Adult labor	0.138*	-0.084	0.241***	-0.161	
Income strategy (cf.: subsist. ag.)					
Market crops	0.214***	0.648***	-0.057	-0.352*	-0.065
Market other agriculture	-0.082	0.478	-0.330***	0.154	-0.937**
Off-farm	0.000	-0.392	-0.036	0.279	-0.025
Farm characteristics (*FARM_XICS*$_h$)					
Ln Farm size	0.052***	0.065***	0.040***	0.046***	0.045***
Ln Livestock assets	0.063***	0.029	0.083***	0.103***	0.063***
Ln Crop equipments	0.174***	0.158***	0.196***	0.238***	0.118***
Ln Other equipments	0.105***	0.113*	0.152***	0.057	0.081
District-level factors (*OTHER_X*$_d$)					
Population density			-0.386***		0.039
Rainfall_average					1.881**
Agro-ecology (cf.: coastal zone)					
Forest zone	0.121***				

Southern savannah	0.049				
Northern savannah	0.105				
Year of survey (0=2005, 1=2006)	-0.097***	-0.523***	0.053	-0.262**	
Intercept	3.608***	4.720***	3.989***	0.634	-8.656
Model estimation statistics					
Chi-square	1462.550	169.570	1002.300	209.110	487.250
R-square	0.281	0.198	0.382	0.350	0.273
Number of observations	4013	571	1729	392	1321
Model identification test					
Hansen's *J* chi-square statistic	4.705*	2.027	0.809	1.440	0.718

Notes: See Table 1 for a detailed description of the variables. All continuous variables are transformed by natural logarithm, which is indicated by Ln. *, ** and *** means that the coefficient is statistically significant at the 10 percent, 5 percent or 1 percent level, respectively.

Table 5. Three-stage least squares regression estimates of the determinants of farm investments in Ghana (Equation 2: Ln *FARMINV*$_h$)—using disaggregated agricultural expenditures

Explanatory variable	Total sample	Agro-ecological zone			
		Coastal	Forest	Southern savannah	Northern savannah
Public investments in:					
Agriculture					
Ln *PAGINV*$_d$*_dev’t*	-0.094	-0.497	0.084	-0.697*	0.607***
Ln *PAGINV*$_d$*_recurr*	0.197*	0.331	-0.095	1.128***	0.975***
Education					
Primary	0.491***	0.762***	0.751***	0.209	0.073
Middle	0.453***	0.772***	0.593***	0.345*	0.155
Secondary or more	0.436***	0.753***	0.646***	0.131	0.177*
Health (cf.: <15 mins)					
Health_15-29 mins	-0.754**	-1.283	-1.201	0.321	-2.032***
Health_30-44 mins	-0.330	-3.496	-0.661	2.785	-0.945**
Health_gt 44 mins	-0.194	0.679	-0.318	-0.513	-0.666***
Ln Rural roads	-0.048	-0.217	0.055	-0.152	-0.175**
Household characteristics (*HHD_XICS*$_h$)					
Ln Household size	1.587***	1.177***	1.613***	1.552***	1.775***
Gender of head	0.335***	0.501***	0.307***	0.150	0.151**
Ln Age of head	0.330***	0.437**	0.534***	0.067	0.072
Adult labor	0.078	0.035	0.095	-0.367	0.207**
Male labor	-0.383***	-0.445**	-0.422***	0.077	-0.396***
Employment	2.518***	2.112***	2.784***	2.757***	2.185***
Income strategy (cf.: subsist. Ag.)					
Market crops	0.001	0.040	-0.038	-0.231	-0.107
Market other agriculture	-0.167*	-0.142	-0.379***	-0.666**	0.450
Off-farm	-3.799***	-4.022***	-3.338***	-3.639***	-3.850***
Farm characteristics (*FARM_XICS*$_h$)					
Ln Farm size	0.037***	0.054***	0.035***	0.037*	0.022**
Ln Livestock assets	0.012*	0.010	0.011	0.035*	0.016*
Ln Crop equipments	0.045***	0.108*	0.049**	0.131***	0.011
Ln Other equipments	0.046***	0.066	0.081**	0.031	0.098***
District-level factors (*OTHER_X*$_F$)					
Poverty	0.657***	1.478**	0.251	2.204	
Population density			-0.198***		0.139***
Rainfall_average					1.941***
Agro-ecology (cf.: coastal zone)					
Forest zone	0.243***				

Southern savannah	0.166**				
Northern savannah	-0.110				
Year of survey (0=2005, 1=2006)	-0.012	-0.344**	0.052	0.334***	0.020
Intercept	0.722*	1.397	1.738**	-1.372	-18.114***
Model estimation statistics					
Chi-square	8802.640	1024.260	3198.420	856.850	5132.480
R-square	0.687	0.642	0.649	0.686	0.795
Number of observations	4013	571	1729	392	1321

Notes: See Table 1 for a detailed description of the variables. All continuous variables are transformed by natural logarithm, which is indicated by Ln. *, ** and *** means that the coefficient is statistically significant at the 10 percent, 5 percent or 1 percent level, respectively.

Table 6. Ordinary least squares regression estimates of the determinants of agricultural public investments in Ghana (Equation 3: Ln $PAGINV_d$)

	Ln $PAGINV_d$_total	Ln $PAGINV_d$_dev't	Ln $PAGINV_d$_recurr
Public investments ($OTHINV_d$) in:			
Education (cf.: none)			
Primary	0.050	0.053	0.045
Middle	-0.195	-0.012	-0.316
Secondary or more	-0.358	-0.303	-0.415
Health (cf.: <15 min)			
Health_15-29 min	0.895 ***	0.678 **	1.014 ***
Health_30-44 min	0.727 *	0.428	0.885 **
Health_gt 44 min	-0.195	-0.173	-0.194
Ln Rural roads	0.193 ***	0.148 ***	0.218 ***
Ag Performance ($AGPERF_d$)			
Ln Crop production	-0.172 ***	-0.099 ***	-0.211 ***
Ln Crop yield	0.060	0.011	0.096
Ag population	-0.001	0.001	-0.002
Other factors ($OTHER\_X_P$)			
Poverty	0.122	0.125	0.120
Ln Population	0.038	0.072	0.018
Ln Land area	0.189 ***	0.145 ***	0.212 ***
Ethnicity (cf.: Akan)			
Ga	0.142	0.171	0.129
Ewe	0.272 ***	0.350 ***	0.237 *
Guans	0.068	0.301 **	-0.052
Other	0.277 ***	0.235 ***	0.294 ***
Religion (cf.: Christian)			
Islam	0.000	-0.002	0.002
Traditional	0.004 *	0.000	0.006 ***
Other	0.003	0.001	0.003
Agro-ecology (cf.: coastal zone)			
Forest zone	0.028	0.003	0.044
Southern savannah	0.119	0.035	0.159 *
Northern savannah	-0.255 *	-0.202	-0.278 *
Intercept	5.098 ***	3.112 ***	5.170 ***
R-square	0.730	0.578	0.740
F-test	9.170 ***	4.650 ***	9.660 ***
Number of observations	102.000	102.000	102.000

Notes: See Table 1 for a detailed description of the variables. All continuous variables are transformed by natural logarithm, which is indicated by Ln. *, ** and *** means that the coefficient is statistically significant at the 10 percent, 5 percent or 1 percent level, respectively.

Table 7. Marginal effects (elasticities) of public investments in Ghana

	Total sample	Agro-ecological zone			
		Coastal	Forest	Southern savanna	Northern savanna
Agriculture					
$PAGINV_d$_total	0.15 *	-0.27	0.45 ***	1.30 ***	0.21
$PAGINV_d$_dev't	0.54 ***	2.04 *	0.46 **	-0.22	0.59 ***
$PAGINV_d$_recurr	-0.22 **	-1.46 **	0.04	1.36 ***	-0.13
Education[1]					
$PAGINV_d$_total	-0.04 ***	-0.06 ***	-0.04	-0.08	0.00
$PAGINV_d$_dev't	-0.04	-0.12	-0.03	0.00	0.00
$PAGINV_d$_recurr	-0.02	0.01	-0.02	-0.10	0.00

Health[1]					
$PAGINV_d$_total	0.21 ***	0.18	0.17 ***	0.10	0.53 ***
$PAGINV_d$_dev't	0.18 ***	0.15	0.17 ***	0.24 ***	0.00 ***
$PAGINV_d$_recurr	0.22 ***	0.26 *	0.18 ***	0.12	0.00 ***
Feeder roads					
$PAGINV_d$_total	0.13 ***	0.20	0.51 ***	0.35 ***	0.01
$PAGINV_d$_dev't	0.18 ***	0.49 **	0.50 ***	0.06	-0.01
$PAGINV_d$_recurr	0.06	-0.13	0.44 ***	0.39 ***	-0.13

Notes: Authors' calculations based on Tables 9-13 and equations and (4), (4') and (9). The elasticities represent percentage change in value of agricultural production per capita due to a one percent increase in the public investment variable. [1] For education and health, the elasticities are x100 and are evaluated the average values of the dependent and public investment variables, and weighted across the different categories, where the weights are the shares of each category in the total. For education, these are: Primary (0.41, 0.41, 0.33, 0.36, 0.62), Middle (0.33, 0.36, 0.42, 0.31, 0.09) and Secondary or more (0.26, 0.24, 0.25, 0.33, 0.29). For health they are: Health_15-29 min (0.24, 0.45, 0.32, 0.17, 0.18), Health_30-44 min (0.22, 0.27, 0.21, 0.23, 0.22) and Health_gt 44 min (0.54, 0.28, 0.47, 0.60, 0.60). The numbers in parenthesis are shares for total sample and the four agroecological zones (coastal, forest, and southern and northern savannah, respectively. For Education, health and Feeder roads, *$PAGINV_d$_total*, *$PAGINV_d$_dev't*, and *$PAGINV_d$_recurr* represent the represent the interaction effect included in the estimation—see equation (4'). *, ** and *** mean that the estimate is statistically significant at the 10 percent, 5 percent or 1 percent level, respectively.

Greater public agricultural spending was associated with districts with: larger total land area and greater proportion of people of Ewe and other ethnic origins (compared to Akan) and with traditional religious affiliation (compared to Christianity). Districts located in the northern savannah agroecological zone were associated with lower public agricultural spending.

Marginal cost of public services and agricultural productivity returns to public spending

To estimate the marginal returns to public spending on agriculture, education, health and rural roads as shown in equations (5) and (5'), information on the unit cost of providing the relevant public capital is needed. This is straight-forward for agriculture, where we use the ratio of the value of agricultural output per capita to the value of agricultural public expenditure per capita. For the other sectors, it is not as simple since, unlike public agricultural spending, we were unable to obtain district-disaggregated data to use directly in the regression analysis. Therefore, we need to estimate these unit costs separately. For education, we need to estimate how much it would cost to raise the proportion of those with at least primary education by one percent. For health and rural roads, we need to estimate how much it would cost to raise by one percent the proportion of households living within 15 minutes of a health facility and build one kilometer of rural road, respectively. These marginal costs can then be divided by their respective marginal effects to obtain the estimated marginal returns.

There are a few ways to estimate such unit costs. One approach is to estimate the average unit cost from past investments, where the accumulated public capital stock is divided by total expenditure over several years. Lack of historical data on public expenditures makes the use of this approach rather difficult. A simpler way is to use the actual cost of building one unit of public capital under present conditions. In this study, we use a variant of the two approaches depending on the availability of data, as in Fan et al. (2004).[10]

[10] The downside of using these different approaches is the difficulty of comparing the resulting returns across the different sectors.

For education, we first calculated the average annual spending on public education using public expenditure data obtained from the Ghana Education Service over the 2002–2005 periods, including both government and donor sources of financing (Table 8). This was then divided by the total number of students in the corresponding education system, which was estimated using the GLSS5 survey data. The estimated annual cost per student was about GH¢ 22.3 in 2000 constant prices, which compares favorably with the annual average unit subsidy of GH¢ 19 (in 2000 constant prices) for primary school students over the 1990-1994 period (Canagarajah and Ye 2001). This was then multiplied by the number of people corresponding to a one percent increase in the proportion of the population that have completed at least primary education, which again was based on the GLSS5 data, to obtain the marginal cost—see Table 9.

Table 8. Public spending on education, health and rural roads in Ghana (2000 GH¢, millions)

Year	Education	Health	Feeder Roads
2000	--	--	7.71
2001	--	87.38	13.66
2002	218.98	132.52	22.40
2003	302.48	190.56	40.82
2004	364.81	269.59	56.32
2005	465.54	349.12	57.83

Notes: Expenditure is from both government and direct donor spending. Sources: Authors' calculation based on data from the Ghana Education service, Ministry of Health, and Ministry of Road Transport.

Table 9. Marginal (one percent increase in) stock and costs of public investments

	Total	Agro-ecological zone			
		Coastal	Forest	Southern savanna	Northern savanna
Education					
Marginal stock (population completed at least primary education)	17,539	3,245	13,696	1,428	1,128
Marginal cost (GH¢)	391,092	72,275	305,061	31,801	25,115
Health					
Marginal stock (households within 15 minutes of a health center)	5,635	1,914	4,635	673	189
Marginal cost (GH¢)	2,221,278	754,423	1,834,957	265,114	74,522
Feeder roads					
Marginal stock (km per sq km)	386	57	180	45	103
Marginal cost (GH¢)	323,398	47,662	151,373	37,983	86,380

Estimating how much it would cost to bring one household within 15 minutes of a health facility is a quite tricky since (increased) expenditures may not lead to improvement in access to or use of health services. Access to and use of health services can improve without any effort to bring the service closer to people. For example, access will improve when people themselves move closer to an existing facility or service or when they invest in ways to reach the facility or service quicker. For example, the 1998 review of the health sector of Ghana cited in Canagarajah and Ye (2001) showed that although immunization outreach sites increased by more than 50 percent, the immunization rate only increased by 13 percent. In Accra, the 80 percent increase in outreach sites yielded no change in the immunization rate. In the Upper-West region, on the other hand, an increase in outreach sites by 50 percent produced an immunization rate increase of

70 percent. Against this background information of caution, we first calculated the change between 1997 and 2003 in the total number of households that lived within 15 minutes of a health facility using the corresponding 1997 and 2003 CWIQ survey data (GSS 1998 and 2004). The total number of households was divided by six to get the average annual change of number of households living within 15 minutes of a health center, which were about 212,400.[11] Then we estimated the average annual cost of providing public health services by the Ministry of Health over the 2001–2005 periods (Table 8). This was then divided by 212,400 to obtain the estimated cost of bringing one household within 15 minutes of a health facility, which was about GH¢ 394. Given that the private sector plays a substantial role in health service provision in Ghana, the above estimated unit cost for improving access to health services is likely an underestimate since the CWIQ survey data did not distinguish between households' access to public versus private health services. The government, for example, finances all higher-level health care (i.e. regional-level hospitals or higher), 95 percent of all health centers, and 44 and 39 percent of lower-level hospitals and clinics, respectively; while the private sector and missionaries together finance 56 and 61 percent of lower-level hospitals and clinics, respectively, and 98 percent of all maternity homes (Canagarajah and Ye 2001). Similar to calculation for the education sector, the estimated unit cost was then multiplied by the number of people corresponding to a one percent increase in the proportion of the population living within 15 minutes of a health center to obtain the marginal cost—see Table 9.

The unit cost of rural roads was estimated using the actual initial cost of building (or grading) one kilometer of feeder road (GH¢ 1,022 (MoRT 2007)) and the average annual maintenance and administrative expenditures of the Department of Feeder Roads of the Ministry of Road Transport over the 2000–2005 period (Table 8). The maintenance and administrative expenditures were divided by the total length of feeder roads in 2004 (about 38,561 km (MoRT 2007)) to obtain the cost of maintaining one kilometer of feeder road. This together with the initial establishment cost gave an estimated unit cost of GH¢ 839 per kilometer, which was multiplied the number of kilometers of road corresponding to a one percent increase in the total length of roads to obtain the marginal cost—see Table 9.

The above unit costs and the marginal effects presented in Table 7 were used to estimate the marginal agricultural productivity returns to the different types of public investments, as shown in equations (5) and (5'). The results are shown in Table 10, again for Ghana as a whole and then separately for the four agro-ecological zones. It is clear that there are substantial returns to most types of public investments, although there are also substantial differences among different types of public investments and across different agro-ecological zones. Taking the country as whole, public spending on agriculture has the highest returns. For the marginal Ghana cedi (GH¢) invested in the agricultural sector, GH¢16.8, in terms of total value of agricultural production, is returned. A marginal Ghana cedi invested in feeder roads returns about GH¢ 5, while a similar investment in improving health services returns just about a hundredth of its value.

[11] This was calculated based on the following data: (a) proportion of households with access to a health facility within 15 minutes of their residence (7.89 percent in 1997 and 30.8 percent in 2003) and the total number of households surveyed (14,510 in 1997 and 49,000 in 2003) (GSS 1998 and 2004); (b) total number of households in Ghana in 1997 and 2003, estimated at 4,533,171 and 5,303,000, based on the respective population of 18.586 and 21.212 million and average household size 4.1 and 4.0 in 1997 and 2003, respectively (World Bank 2007).

Table 10. Marginal agricultural productivity returns to public investments in Ghana

	Total sample	Agro-ecological zone			
		Coastal	Forest	Southern savanna	Northern savanna
Agriculture	16.77 ***	22.52 **	33.14 ***	47.44 **	0.75 ***
Education[1]	-0.12 ***	-0.19	-0.08	0.27	0.05
Health[1]	0.12 ***	0.05	0.06 ***	0.04	1.88 ***
Feeder roads	4.97 ***	8.12	18.59 ***	11.2 ***	0.20

Notes: Authors' calculation based on equations and (5) and (5') using estimated marginal effects and costs (Tables 14 and 15) and estimated unit costs of providing related public goods and services. The values are benefit-cost ratios and represent amount of GH¢ in terms of total value of agricultural production due to a GH¢1 increase in public investment. The values for agriculture are weighted averages of the returns to developmental and recurrent expenditures, using shares of the expenditures in total agricultural expenditures as the weights. The values for education, health and feeder roads are associated with their effect on total public agricultural spending. [1] The values for education and health are x10. *, ** and *** mean that the estimate is statistically significant at the 10 percent, 5 percent and 1 percent levels, respectively.

The finding of positive and substantial marginal returns to public spending on feeder roads is consistent with previous studies. Public investments in infrastructure, especially road development, is often ranked among the top two public spending sources of overall growth and poverty reduction (see e.g. Fan et al. 2000; Fan and Zhang 2002; Mogues et al. 2008). Our findings also mirror results in Uganda, where Fan et al. (2004) found that the marginal returns to public spending on feeder roads in terms of agricultural productivity and poverty reduction were three to four times larger than the returns to public spending on murram and tarmac roads. Again, the negative agricultural productivity returns to education is troubling, and indicates that the formal education system is not benefiting the agriculture sector.[12] This is consistent with some of the findings of Jolliffe's (2004) study on Ghana, which shows that more educated household members are more likely to engage in off-farm work than their less educated counterparts, and that higher levels of formal schooling increase off-farm profit by a much greater amount (more than 100 percent) than it does farm profit. This suggests that more effort leading to more agriculture-relevant knowledge and skills being employed on the farm is needed.

The estimated marginal returns to the different types of public investments differ among the four agro-ecological zones. The marginal returns to agricultural spending are highest in the southern savannah zone, followed by the forest and coastal zones and then the northern savannah zone. Marginal returns to spending on the health sector, on the other hand, are highest in the northern savannah zone, while the marginal returns to spending on rural roads are highest in the forest zone, followed by the southern savannah zone.

Increasing public spending necessarily implies raising taxes now or in the future. And it is common knowledge that taxation alters a society's consumption and production decisions, resulting in a deadweight loss. In sum, the shadow price of a dollar of public fund raised is higher than one dollar because, in addition to the deadweight loss, the government also incurs administrative costs to collect the taxes. These costs, which are not taken into account in our analysis, would reduce the marginal returns. The deadweight loss (i.e. negative effect on production and consumption) for several African countries, for example, has been estimated to range from 1.05 to 1.37 percent of GDP, while the administrative costs of governments to collect taxes is estimated to range from one to four percent of total tax collections (Warlters et al. 2005 cited in Herrera 2007).

[12] Note that we have not considered the non-agricultural productivity returns to public spending, as it is outside the scope of this paper.

5. CONCLUSIONS

Using district- and region-disaggregated Ghana public expenditure data from 2000 to 2006 and household-level agricultural production data from the 2005/06 Ghana Living Standards Survey, this paper estimated the agricultural productivity returns to different types of public spending, a fundamental but scarce knowledge necessary for prioritizing public expenditure resources. Results of the simultaneous equations modeling approach used show that an increase in public spending on the agriculture sector by one percent is associated with a 0.15 percent increase in agricultural productivity (i.e. value of household total agricultural production per capita). The effect associated with the development expenditure component was much larger (elasticity of 0.54), counteracting the negative effect associated with the recurrent spending component. This result reflects the low government capital-recurrent expenditure ratio in sector (less than 20 percent), which resonates the fact that simply paying staff salaries, administrative costs and other overheads is unlikely to yield any substantive growth and development outcomes. Provision of other public goods and services (i.e. rural roads and health services) also had statistically significant impact on agricultural productivity. The elasticities associated with health and rural roads were 0.21 and 0.13, respectively.

These translate into very high economic returns. For the marginal Ghana cedi (GH¢) invested directly in the agricultural sector, GH¢16.8 is returned in terms of increase in total value of agricultural production. The marginal Ghana cedi invested in feeder roads returns about GH¢ 5, while a similar investment in improving health services returns just about a hundredth of its value. Furthermore, the returns differ for the various agro-ecological zones of Ghana. Together, the results suggest that additional public resources spent on the agricultural sector, particularly on development and capital investment activities, will yield the highest payoffs, and targeting different investments to different areas of the country will be critical for maximizing the payoffs.

Formal education, on the other hand, was found to be negatively associated with agricultural productivity, although mostly insignificant. This suggests that the formal education system is not benefiting the agricultural sector. Although the results showed that households with more educated members were associated with greater value of farm investments and inputs in the production process, the consequent positive effect on productivity was not enough to override the direct negative effects due to skilled labor being allocated away from the farm. Thus, more effort leading to more agriculture-relevant knowledge and skills being employed on the farm is needed.

There are a few areas that further research on the topic can contribute to the existing knowledge. While they were discussed in the conceptual framework, this paper was unable to address then empirically due to data constraints, especially lack of time-series, spatial-disaggregated public expenditure data. First, we assumed the unit cost of building public capital in a particular sector was the same in all areas of the country. This assumption is unlikely to be realistic especially for public goods that are provided locally. The unit costs will be different to the extent that local capacities differ. Second, the cost of raising public funds is higher than one, since public spending necessarily implies raising taxes that results in a deadweight loss (associated with alteration of society’s production and consumption decisions) and the government incurs administrative costs to collect the taxes. These costs, when estimated and taken into account, would reduce the returns to public expenditures.

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