ReSAKSS
Regional Strategic Analysis and Knowledge Support System

African Union — NEPAD

Comprehensive Africa Agriculture Development Program (CAADP)

ReSAKSS Working Paper No. 7

June 2008

Growth and Poverty Reduction Impacts of Public Investments in Agriculture and Rural Areas

Assessment Techniques, Tools, and Guide for Practitioners

Sam Benin
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About ReSAKSS

The Regional Strategic Analysis and Knowledge Support System (ReSAKSS) is an Africa-wide network of regional nodes supporting the Common Market of Eastern and Southern Africa (COMESA), the Economic Community of West African States (ECOWAS), and the Southern African Development Community (SADC), in collaboration with the International Food Policy Research Institute (IFPRI) and the Africa-based centers of the Consultative Group on International Agricultural Research (CGIAR), to facilitate the implementation of the AU/NEPAD's Comprehensive Africa Agriculture Development Programme (CAADP).
The ReSAKSS nodes offer high-quality analyses to improve policymaking, track progress, document success, and derive lessons for the implementation of the CAADP agenda.
ReSAKSS is jointly funded by the United States Agency for International Development (USAID), the UK Department for International Development (DFID), and the Swedish International Development Cooperation Agency (SIDA). The nodes are implemented by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI) and the International Water Management Institute (IWMI), in collaboration with regional and national partners.

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The goal of the ReSAKSS Working Paper series is to provide timely access to preliminary research and data analysis results that relate directly to strengthening ongoing discussions and critical commentaries on the future direction of African agriculture and rural development. The series undergoes a standard peer-review process involving one reviewer either from within the ReSAKSS network of partners or from an external organization. It is expected that most of the working papers eventually will be published in some other form and that their content may be revised further.

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SUMMARY

Public expenditure is an important instrument for promoting economic growth and poverty reduction. Given the predominant role of agriculture in the economy of many developing countries, it is not surprising that public expenditure on the agriculture sector and in rural areas is one of the most important government instruments for promoting overall economic growth and reducing mass poverty. But, what kinds of public spending are needed to achieve stated development objectives of growth and poverty reduction? How should public expenditure resources be allocated among different types of public goods and services (e.g. agriculture research and extension, irrigation, roads, other infrastructure, education, health, etc.) and across geographical areas (e.g. high-potential versus lagging regions) to achieve greater or better distributed outcomes and impacts? How should the investments be financed?

Often governments and their development partners have clear principles on how they should, for example, prioritize their scarce resources. For example, allocate resources in favor of those sectors which can make the strongest contributions to accelerating pro-poor growth and human development or shift resources in favor of projects and programs which most clearly contribute to poverty eradication in a cost effective manner. However, what is lacking is the information that can be used to operationalize these principles. While there is an abundance of theories, methods and evidence on the growth and poverty impacts of public investment, due to differences in methodological approaches and data used in assessing the impacts, there is a large variation in the empirical findings of past studies on the magnitude of impacts and, to some extent, on the direction of impacts. Furthermore, there is very little evidence on the impact of public investments in developing countries, particularly in sub-Saharan Africa.

To help fill these knowledge gaps, and particularly help build the capacity for undertaking related public investment analyses, this document lays out a conceptual and empirical framework for a holistic assessment of the economy-wide, growth and poverty reduction impacts of public investments in agriculture and rural areas; and shows how the framework and results of the analysis can be used for budgeting, monitoring and evaluating public investments and poverty reduction strategies to achieve stated development objectives.

INTRODUCTION

The recognition that agriculture and rural development must play a central role in economic growth, poverty reduction, and food and nutrition security improvement is widely accepted, as the cost of disinvesting from the sector during the structural adjustment era had become all too obvious. This is evident in recent intensifying efforts at redirecting resources to agriculture and for rural development as well as commitments to allocate greater resources to these sectors. For example, in 2002 at the Monterrey Conference, rich countries renewed their pledge to increase their development assistance from 0.24% to 0.7% of their GDP (UN 2002). In 2003, African leaders came together under the African Union's New Partnership for Africa's Development (NEPAD) and adopted a Comprehensive Africa Agriculture Development Programme (CAADP), and also decided to allocate 10% of their national budgetary resources to CAADP's implementation (NEPAD 2003). In 2005, the Commission for Africa, chaired by the then UK Prime Minister Tony Blair, called for rich countries to double their aids to Africa and to cancel debts poor countries owe to them (Commission for Africa 2005). President George W. Bush pledged a 50% increase over its $10 billion annual funding for U.S. development and humanitarian assistance, representing a $5 billion annual increase (USAID 2003). Many developing countries have also been adopting the concept of Poverty Reduction Strategy Papers (PRSPs) to outline their strategic plans and earmark financial resources to achieve their national development goals and objectives.

The 2008 World Development Report argues that recent improved performance of the agriculture sector holds promise for using agriculture for development, and urges a concerted action by the international development community to: level the playing field in international trade; provide global public goods, such as technologies for tropical food staples; and help developing countries address climate change and overcome looming health pandemics for plants, animals, and humans (World Bank 2007).

Governments and their development partners want to know whether the resources are sufficient for achieving stated development objectives of economic growth and poverty reduction. In particular, how should the pledged resources be allocated across different sectors of the economy such as agriculture, infrastructure, health and education for efficient and equitable outcomes? And within a particular sector, taking agriculture for example, how should the resources be allocated among research and development, extension, irrigation, farm support, etc? Governments and their development partners often have clear principles on how they should prioritize their

Box 1

Conditions for public spending allocation

(Case of Uganda)

The demands for public expenditure always outstrip the resources which are available to fund them. Therefore, Government [of Uganda] will rigorously prioritize its expenditures and provide taxpayers with value for their money. If public expenditure is to maximize its contribution to the PEAP, it is imperative that three conditions are met:

Inter-sectoral budget allocations be shifted in favor of those sectors which can make the strongest contributions to tackling the core challenges of the PEAP: accelerating pro-poor growth, human development and restoring security and support for regions afflicted by conflict.

Intra-sectoral budget allocations be shifted in favor of projects and programs which most clearly contribute to poverty eradication in a cost effective manner.

Efficiency is improved in all areas of public expenditure, so that better value for money, in terms of the quality and quantity of [public] services, can be achieved with the scarce resources available to Government [of Uganda].

Source: MFPED 2004

scarce public resources—see Box 1 for the case of Uganda. However, the information needed to operationalize the principles is often lacking.

There is an abundance of theories, methods and evidence on the growth, income and poverty impacts of different types of public investment in agriculture and rural areas (see Guild 2000, Anderson et al. 2006, Palmer-Jones and Sen 2007, Paternostro et al. 2007, and Fan 2008 for reviews and collection of various studies). However, the theory and evidence shows that there are several channels through which different types of public investment can affect growth, household incomes and poverty, and that the impacts can be direct or indirect and they can be assessed at several levels (e.g. farm-household, province, sector, national). Due to these considerations, as well as differences in the methodological approaches and data used in assessing the impacts, there is a relatively large variation in the empirical evidence of the impacts, which are mostly assessed at the aggregate level and limits their usefulness in addressing prioritization of resources at more disaggregated, programmatic levels.

The overarching goal of this document is to lay out a conceptual and empirical framework for a holistic assessment of the economy-wide, growth and poverty reduction impacts of public investments, and show how the framework can be used for budgeting, monitoring and evaluating public investments and poverty reduction strategies to achieve stated development objectives.

Policy research questions

There are two sets of policy research questions underlying the fundamental questions raised above that governments, policymakers, development partners, as well as other stakeholders involved with development strategy in Africa are looking for answers. The first set of policy research questions derives from wanting to know lessons associated with past public spending:

- How effective have different types of public investment been to date?
- Have expectations in terms of achieving development objectives been met?
- What factors have shaped the level of impact that has been achieved?
- What are the trade-offs and complementarities, if any, among different types of investment?

The second set of policy research questions derives from being forward looking:

- What are the projected impacts if public investment programs proceed as currently planned?
- Are these projected impacts compatible with the development goals and targets?
- Could greater or better distributed outcomes and impacts be obtained by reconfiguring the investment portfolio?
- What are the new targets that can be set for achieving greater or better distributed outcomes and impacts?
- What are the resources needed to achieve the desired outcomes and impacts?
- How can these investments be financed?

To help address these policy research questions, this document has four specific objectives. The first objective is to analyze the various channels through which different types of public investment in agriculture and rural areas can lead to achieving various development goals and objectives, including higher agricultural productivity, higher rural incomes, and reduced rural poverty. The issues that need to be considered in assessing the impacts are also discussed. These are dealt with in the upcoming section. The second objective, which is dealt with in section 3, is to review different techniques and tools utilized in assessing the impacts of public investments and the how the issues identified in the first objective have been dealt with in previous studies on public investment analysis, as well as the challenges faced in addressing (or failing to address) the issues. How results of studies applying these methods can be used to address the first set of policy research questions raised above is also presented. Noting the shortcoming of previous studies in assessing the impacts of public investments, the third objective is to develop a holistic approach for assessing the *ex-post* and simulating the *ex-ante* economy-wide impacts of public investment to address the above policy research questions, especially the latter. This is done in section 4. The fourth objective, which focuses on indicators and data requirements for public investment analysis, is to identify a set of input, output and outcome indicators that are consistent with the various pathways of impact. This dealt with in section 5. We make concluding remarks and discuss plans for implementing the proposed framework in section 6.

The document is primarily targeted to those involved with planning, implementing and monitoring agricultural and rural development strategies, including: Ministries of Finance, Agriculture, and Local Governments; Departments of Agriculture within Regional Economic Communities, AU/NEPAD, and the donor community concerned with agriculture in Africa. This document will also be useful to researchers and others interested in knowledge on impact assessment of public agricultural and rural investments in general.

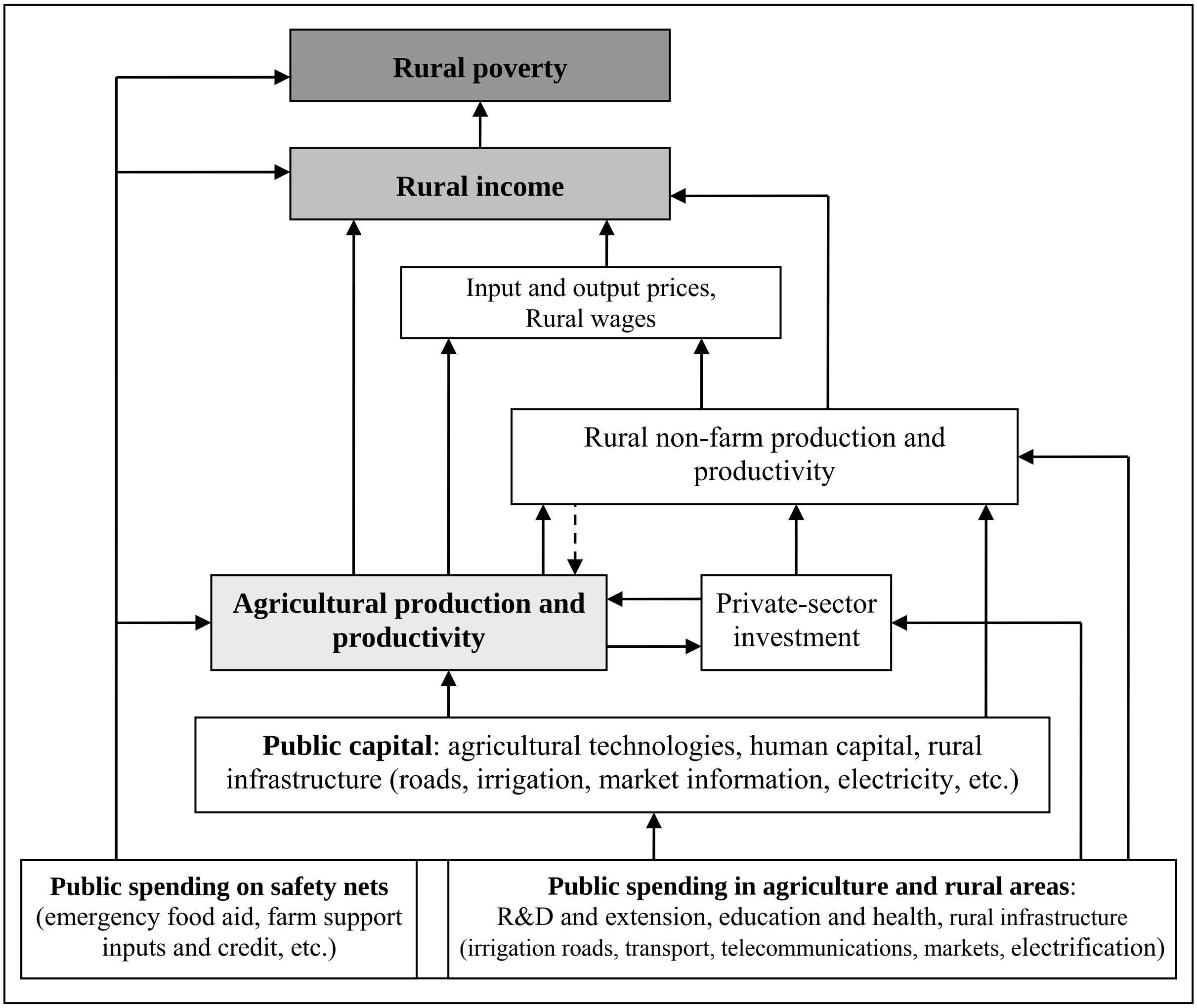
2. HOW PUBLIC INVESTMENT AFFECTS GROWTH AND RURAL POVERTY

There is an abundance of theories, methods and evidence on the growth, income and poverty impacts of different types of public investment in agriculture and rural areas. The literature shows that: i) there are several channels through which different types of public investment can affect agricultural growth, household incomes and poverty; ii) the impacts can be direct or indirect; and, iii) the impacts can be assessed at several levels, beginning from the farm-household level through the district and provincial levels to the sector and national levels.[1] Furthermore, the theory is clear on the direction of impacts, which can be assessed in a variety of ways considering the broader perspective of poverty including its economic, social and environmental dimensions. However, due to these several considerations, as well as differences in the methodological approaches used in assessing the impacts, there is a relatively large variation in the empirical findings in the magnitude of impacts, and to some extent on the direction of impacts. Most of the studies in the past have analyzed only some of the potential pathways of impacts or have used methods that insufficiently controlled for the various conditioning and confounding factors that affect realization of the impacts (Adato et al. 2007). These suggest that a holistic approach for assessing the impacts is needed.

Figure 1 provides a conceptual framework of the potential channels through which various types of public investment in agriculture and rural areas can affect agricultural production, rural income and rural poverty. The various types of public expenditure including spending on agricultural research and development (R&D), extension, education, health, and infrastructure lead to the development of public capital in related activities, which in turn affect agriculture productivity and production. A key underlying assumption linking public capital and agriculture production is that public and private capital are complements (Anderson et al. 2006), so that an increase in the public capital stock raises the productivity of all factors in agricultural production including private capital, which in turn leads to higher farm wages and incomes and poverty reduction.[2] Fan and Pardey (1992) pointed out that omitting public investment, such as agricultural R&D investments for example, as a determinant of agricultural growth biases estimates of the impact of other factors that are included as determinants. Consequently, Fan and others have modeled and estimated the impacts of different types of public investment on agricultural growth and poverty reduction as well as on other development indicators (see Rosegrant and Evenson 1995; Fan et al. 2000, 2004, 2005; Fan and Rao 2003; Fan and Zhang 2004; Huffman and Evenson 2006). By raising the productivity of all factors of production, public investment can also crowd in private capital investment for agricultural development as well as for non-farm rural development (e.g. in food processing and marketing, transportation and trade, restaurant services, electronic repairs shops) and for urban industrial and service development (see Barro 1990; Hart 1998). The development of the non-farm rural sector can have multiplier effects if it expands the market opportunities for farmers and creates off-farm employment opportunities. The latter is particularly important for absorbing the excess labor and other factors of production that arises as a result of the increased agricultural productivity.

[1] See Anderson et al. (2006), Palmer-Jones and Sen (2007), Paternostro et al. (2007), and Fan (2008) for reviews and collection of studies.

[2] The notion that growth in public capital is an endogenous process (or an outcome of growth in income rather than a cause of it) is debatable and an empirical issue (see Ansari et al. 1997; Zhang and Fan 2004).



Source: Adapted from Fan 2008.

Figure 1. Growth and poverty-reduction pathways of public investments

In addition to their agricultural productivity impacts, public investment in rural areas directly creates non-farm rural employment opportunities, thereby directly improving rural wages and incomes and reducing rural poverty. Investment in safety nets (such as emergency food aid and farm support programs) directly supports the incomes and consumption of specific socio-economic groups, especially those that are unable to participate at all or equally in the growth process (including the aged, pregnant women, children, disabled persons, and internally displaced persons). Such direct transfers can also contribute indirectly to the growth and poverty-reduction process by raising the productivity of those target groups through investments in their human capital including education, skills, health, and nutrition (Schultz 1982). However, recipients of such transfers may alter their farm labor supply, which may negatively impact agriculture production, or their consumption and savings choices such that the net income gain is less than the amount of the transfers (van de Walle 2003). There are also indirect price effects of transfers, particularly arising from subsidies to producers or suppliers for restricting or encouraging production and supply of particular agricultural inputs and commodities. However, because of the market-distorting characteristics, such transfers can crowd out private investment in agriculture.

Another key impact pathway derives from market development and integration arising from reduced transportation and transactions costs with increased public investment in roads, transport and telecommunications, and market infrastructure. Together with the increased production discussed above, reduction in transportation and transactions cost lead to reduced input and food prices and causes real incomes to rise, especially incomes of households that are net buyers of food.[3] Transactions cost is very important, as whether or not markets are thin or fail depend on them (Sadoulet and de Janvry 1995). In the grain trade in Ethiopia, for example, Gabre-Madhin (2001) shows that the transactions cost, which is associated with search for a trading partner and represented by the opportunity cost of labor and capital invested in the search, can be as high as a fifth of the total grain marketing cost.

Contrary to early classical thinking, which viewed agriculture as a low-productivity, traditional sector that primarily contributed to development of a nation by providing food and employment, increase in real incomes in rural areas provides market opportunities for urban industrial and service development, through increased derived demand for urban-manufactured goods and services. This feedback linkage is critical for development of the economy as a whole, especially where export opportunities are not sufficient to allow urban industries to achieve competitive efficiency in foreign markets through economies of scale.[4]

The sources of financing public spending (or of government revenue), although not shown in Figure 1, have important implications for private sector investment and overall growth and poverty-reduction through multiplier effects. Basically, government revenue derives from domestic sources (taxes and borrowing) and foreign sources (grants and loans). Internally, even without a change in the existing tax rates, e.g. income tax, a rise in rural income and consumption as discussed above will lead to a rise in government revenues and, therefore, potential increases in public spending.[5] Governments can also increase the tax rates in order to increase their revenues, which can have some negative total investment (or crowding-out) effects. For example, in response to higher taxes households can adjust their savings downwards in order to maintain their current consumption levels, leading to a reduction in savings that are available for investment in both rural and urban areas. The reduction in savings will tend to raise domestic interest rates and may crowd out private investment. An increase in government borrowing from domestic banks can also have similar effects. To the extent that public investments are financed from external sources, however, it will tend to appreciate the real foreign exchange rate and in turn reduce the competitiveness of the tradable sectors and economic growth (see Thurlow and Wobst 2004). In addition to these macroeconomic effects, revenue generation modalities can moderate or amplify the potential poverty reduction impact of public investment through the distributional consequences of tax regimes. For example, public investments may contribute less to improving incomes of the poor if they are financed from taxes that are strongly regressive, or levied on income sources that the poor predominantly rely on, without greater benefits from their use of public goods and services that are financed with the taxes.

In the discussion so far (and as illustrated in Figure 1), we have not differentiated the impacts of one type of public investment from other types, although we know or can expect, for example, that the impacts of investment in agricultural research would not necessarily be the same as those of investment in roads. We have not yet discussed the conditioning and confounding factors that affect realization of the outcomes and impacts of public investments. These are

[3] The decline in (food) prices has powerful real income effects, and the welfare benefits are large when spread across all consumers, even if some producers end up being worse off.

[4] See Diao et al. (2007) for further discussion.

[5] See footnote 1.

discussed later on. In what follows, we discuss how each of the major different types of public investment in agriculture and rural areas may affect agricultural production and productivity, rural incomes and rural poverty at various levels. These are testable hypotheses, and so the existence, direction and magnitude of any effect become empirical issues.

2.1. IMPACT PATHWAYS FOR SPECIFIC PUBLIC SPENDING

Agricultural research, extension, and support services

Public investment in agricultural research leads to the development of improved technologies for raising agricultural productivity and production and for sustainable use of natural resources.[6] It also leads to the development of improved post-harvest technologies for reducing post-harvest losses and improving product quality to attract price premiums. To reap the benefits of the technologies, however, farmers have to first acquire and use them appropriately. Investment in agriculture extension develops systems through which the technologies can be extended to and adopted or adapted by farmers, and several studies have shown the positive impacts of such investments on agricultural productivity and incomes (Alston et al. 2000; Evenson et al. 1999). Typically, extension creates awareness of the technologies and develops or strengthens the know-how and skills of producers in using those technologies. Through awareness creation, extension also can raise the ability of farm households to demand technologies and further advisory services that meet their specific needs. By broadening extension to advisory services on agriculture-related and other rural development issues in general, investment in extension can also have direct impacts on nutrition, health, population control, etc (Birner et al. 2006). Similar to investment in extension and advisory services in general, public investment in veterinary services, pest control services, produce inspection and grading services, etc. can enhance the adoption of improved technologies (including post-harvest technologies), help raise agricultural productivity and production, help reduce post-harvest losses, and help improve product quality. Investment in produce inspection and grading services contributes to market development, which is discussed later on.

Irrigation

The evidence of the positive impact of public investment in irrigation on agricultural productivity and production is immense, especially in the case of Asia as compared to sub-Saharan Africa (see Spencer 1994). Public investment in irrigation is known to contribute to raising agricultural productivity beyond its value as an input (i.e. relaxing moisture constraints and improving year-round cultivation) by raising productivity of other factors of production, especially improved seeds and chemical fertilizers. Aside from the productivity impacts, construction of irrigation dams for example can have direct welfare and environmental impacts by contributing to watershed management (flood control, drainage, etc.). However, poorly managed irrigation projects can have negative effects by becoming breeding grounds for human disease vectors and parasites (e.g. mosquitoes) as well as for animals (e.g. worms and ticks). The problem of increased salinity for crop production is also important.

Rural roads

There are several pathways associated with infrastructure development in general and investment in rural roads in particular, and the evidence here too is substantial (see (see Guild 2000; Fan et al. 2000 and 2004). Firstly, public investment in rural roads leading to improvement

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[6] 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).

in the rural road network (i.e. density and condition) reduces transportation and transactions costs and can improve access to input and output markets. This can lead to lower agricultural input prices and higher farm gate prices, which together leads to higher farm incomes. With reduced input prices, farmers can increase the amount of purchased inputs used (especially improved seeds and fertilizers), which leads to increased production. Secondly, improvements in rural roads improves physical access and reduces transportation cost to other services (extension, schools, health centers, financial institutions, telecommunications, etc), leading to related impacts discussed above or to be discussed later on. Thirdly, improvement in rural roads that link urban areas opens up non-farm employment opportunities (encouraging migration), which in turn raises rural wages and remittances, and, consequently, incomes. The likely negative impact of remittances on labor supply, and consequently, agricultural production is similar to that associated with targeted transfers, which is discussed later on. Fourthly, improvement in rural roads crowds in private investment in transportation and other related services (see below), further reducing transportation and transactions cost and contributing to the aforementioned impacts through multiplier effects.

Rural transport and telecommunications

Public investment leading to improvement in public transport services (road, rail, water, air) and telecommunications services (e.g. telephones, post office, market information) also contributes to reduction in transportation and transactions costs and impacts as discussed under investment in roads. Public investment in transport and telecommunications may also crowd in private sector investment in related services (especially market information services), further reducing transactions cost and reinforcing the impacts.

Markets

Here, it is useful to distinguish between physical infrastructure and market-related services (e.g. information on prices, produce inspection and grading). Similar to the effects of public investment in rural roads, transport and telecommunications, public investment in market development can lead lower transactions cost, which in turn can lead to lower agricultural input prices and higher farm gate prices (Kherallah et al. 2002). As already mentioned, investment in produce inspection and grading helps improve product quality that can attract price premiums and lead to higher incomes for farmers. Public investment in market development also can crowd in private investment in related services (especially market information system), further reducing transactions cost and contributing to the impacts as discussed previously.

Rural electrification

The primary impact pathway of public investment in rural electrification is crowding in of private investment in agro-industrial processing and, thus, providing expanded market opportunities for farm produce and creating off-farm employment opportunities, which together leads to higher farm gate prices and higher rural wages, respectively (Fan et a. 2002). Improvement in rural electrification also can crowd in private sector investment in irrigation development (e.g. irrigation pumps) as well as in cottage industries for farm inputs (e.g. fertilizers) and appropriate technologies; potentially reducing the cost of farm inputs and equipment, raising agricultural productivity, and raising rural incomes.

Agricultural and rural education

The link between human capital, economic growth and poverty reduction has long been established (Schultz 1982), and evidence on the positive impacts of education is immense (see e.g. World Bank 2001; Fan et al. 2002).[7] Public investment in rural education will potentially lead to an increase in the stock of human capital and raise labor productivity, whether on the farm, within the rural labor force, or in the household, which in turn will raise wages and incomes. Investment in education also complements investment in agricultural R&D and extension, as educated farmers are better positioned to adopt (as well as influence their colleagues to adopt) improved production and natural resources management (NRM) technologies, leading to increased agricultural productivity and sustainable use of natural resources and the environment. The notion behind this is that technologies tend to be highly complex, knowledge intensive, and location specific, and so they require knowledge and skills for successful adoption. Targeted investment in the education of girls, for example, has been shown to yield one of the highest payoffs in economic development in general; as better educated women have lower fertility rates (Schultz 1994; Sen 1999) and are associated with greater investment in children in terms of children's education, nutrition and health (Kassouf and Senauer 1996; Smith et al. 2003; Quisumbing and Maluccio 2003; Quisumbing 2003). Improvement in rural education also encourages migration. With better education, however, the employment opportunities of migrants are better, leading to higher-paying jobs and greater migrant remittances. Public investment in rural education such as the building of schools in rural areas can also crowd in private sector investment in related services (e.g. hostels, internet cafes, stationery stores, etc), reinforcing the above impacts and contributing to overall growth in rural incomes and poverty reduction.

Rural health

The productivity impacts of human health are similar to those of education, as public investment in health contributes to human capital development. Health problems (HIV/AIDS, tuberculosis) and other debilitating illnesses (e.g. malaria) have major negative economic effects, including loss of work days and wages, decline in productivity, medical costs, and burden of family care. At an aggregate level, Tompa (2002) argues that individuals with longer life expectancy may invest more in the education of younger generations as they tend to receive greater returns from their investment, and they may also be motivated to save more for their retirement, which together leads to greater accumulation of physical capital. Similarly, investment in provision of health services leading to improvement in the survival and health of young children may provide incentives for reduced fertility, which may result in increased labor-force participation. Health problems often are exacerbated by lack of safe drinking water, poor sanitation, and poor management of irrigation projects, among others. Thus, public investment in these areas will reinforce the above impacts.

Safety nets and targeted transfers

These can be classified into two broad categories: i) safety-net programs (e.g. emergency food aid, school-feeding) targeting specific disadvantaged groups (including the poor, aged, pregnant women, children, and disabled persons) that are unable to participate in and/or benefit from the growth process; and ii) farm support programs or subsidies to producers or suppliers with the aim of restricting or encouraging the production and supply of particular agricultural inputs and commodities. The former helps to distribute more of the gains from economic growth to those disadvantaged groups. Thus, public spending on such programs can contribute directly to raising incomes and consumption and reducing poverty, as well as indirectly by raising productivity through investments in human capital (e.g. education, skills, health, and nutrition). However, the notion that recipients of such transfers may alter their labor supply or spending

[7] At the individual household level, however, it is important to note that education can have negative impact on agricultural production, where education promotes off-farm employment opportunities. The argument also holds for road development and other public investments that promote exit options out of agriculture.

and savings choices (van de Walle 2003) may undermine the expected outcomes of such programs, as the net gain may be less than the amount of the transfers. The second type of transfers (i.e. agriculture subsidies) can have substantial indirect price effects, and they also tend to benefit large-scale or commercial farmers. Due to its market distortion characteristics, however, agriculture subsidies have recently regained recognition as a policy instrument in development strategy, renewing the debate on several issues, including: i) how to introduce and make them sustainable; and ii) what should and should not be subsidized so as to not distort market forces.

2.2. CONDITIONING AND INFLUENTIAL FACTORS

There are several conditioning and confounding factors that affect the investment decision as well as realization of the outputs and outcomes of public investments. Therefore, these factors need to be taken into account for a holistic assessment of the impacts of public investments in agriculture and rural areas. We only focus on some of the key factors; for example, how much of its resources the government spends on a specific activity or project depends not only on the total resources available to the government, but on political economy, institutional and governance factors (see Birner and Resnick 2005 and Resnick and Birner 2005 for reviews). Governance, for example, is one factor that has attracted particular attention during the last decade regarding the efficacy of public spending or the relationship between the amount spent and actual public goods and services provided.

Recall that achieving the benefits of public investments hinges on the complementarity between public capital and private capital. Therefore, policies that create an enabling environment for private entrepreneurship, or market-distorting characteristics, are critical. In addition to tracking the amount of private capital investments, the above policies can be monitored through indicators associated with taxation, interest rates, foreign exchange rates, industrial protection, etc.

Because of forward and backward linkages between agricultural and non-agricultural sectors, it is important to track factors associated with the latter. Generally, development of the non-farm rural sector can have substantial multiplier effects on the overall economy if it expands the market opportunities for farmers and creates off-farm employment opportunities, which is particularly important for absorbing the excess labor and other factors of production that arises as a result of the increased agricultural productivity. This is contrary to early classical thinking that viewed agriculture as a low-productivity, traditional sector that primarily contributed to development of a nation by providing food and employment. Increase in real incomes in rural areas provides market opportunities for urban industrial and service development, through increased derived demand for urban-manufactured goods and services. Indicators associated with employment, rural wages, agriculture-non agriculture terms of trade are important.

Other important conditional factors are those associated with integration of the economy into global markets, since foreign competition and markets can shape the prospects for agricultural transformation. Here, monitoring trade policies in both domestic and high-income countries is important, as evidence shows that a combination of poor policies and institutional failures in Africa and developed-country policies limiting market access has reduced investment incentives and growth opportunities in African agriculture (World Bank 2007; Anderson et al. 2006; Binswanger and Townsend 2000). In particular, import tariffs, farm support and export subsidies granted to farmers in many countries of the Organization for Economic Co-operation and Development (OECD) tend to boost production in those countries, depress world prices, and reduce the scope for import competition in developing countries. Although it has been argued that such policies can benefit developing countries that are net importers of agricultural products from developed countries by providing access to the subsidized commodities at lower prices, the evidence is limited. Developing countries may also use high tariffs to protect domestic production—the small country argument. Thus, it will be important to monitor import and export tariffs and quotas, Sanitary and Phyto-Sanitary (SPS) requirements, international prices, exchange rates, etc.

Other conditioning and/or exogenous factors to monitor at various levels of the input-to-impact pathways in Figure 1 include resource endowments, natural disasters, and conflict, which have been critical factors in explaining the poor performance in African agriculture development (Binswanger and Townsend 2000).

2.3. SUMMARY AND IMPLICATIONS

From the discussion so far, several conclusions with implications for assessing the impacts of different types of public investments in agriculture and rural areas can be drawn:

Different types of public investment have different pathways of impact, suggesting need for public spending data that is disaggregated by: sector (e.g. agriculture, education, health, infrastructure, etc.); sub-sector (e.g. for agriculture: crops, livestock, fishery, forestry, NRM, etc.); function (e.g. for agriculture: research, extension, irrigation, farm support, etc.); economic (recurrent vs. development); and space (rural/urban, region, district, etc.).

Different types of public investment share common pathways, affect or are affected by other types of public investment, suggesting that it may be difficult to attribute impact to a single type of public investment and so:

Substitutability and complementarity among investments is important;

Sequencing of investments is also important.

The impacts of public investments can be assessed at the micro, sector or macro level, suggesting need for related spatially disaggregated data, and integrated analytical and empirical framework to assess the full economy-wide impacts.

Ignoring spatial spillover may lead to biased estimation of impacts;

Assessing impacts at the micro-level only ignores any effects due to change in higher-level factors such as prices, wages, interest rates, exchange rates, etc;

Assessing impacts at the meso- or macro-level only ignores income distribution and equity considerations.

There are feedback-impact loops, suggesting causality (endogeneity) issues need to be taken into account in the empirical assessment of the impacts.

For any type of public investment, there are several pathways of impact. All of these are unlikely to be of equal significance, suggesting need (but challenge) for identifying major pathways along which indicators can be identified for monitoring progress.

For any single impact pathway, there are several conditioning (exogenous) factors affecting realization of outcomes and impacts along that pathway, suggesting that data on those exogenous factors are also needed, and should be disaggregated sectorally and spatially as above in order to assess unbiased impacts.

So far, we have made no distinction between public *investment* and public *expenditure*. Public investment is that part of public expenditure that adds to the public capital stock (e.g. agricultural research facilities, irrigation dams and canals, roads, electricity grids, schools, hospitals, etc), which typically corresponds to *capital* or *development* expenditure in national accounts, as opposed to (*re*)*current* expenditure. *Recurrent* expenditure typically includes salaries for employees, overheads, administration and operational cost for delivery of public goods and services. While it makes sense to examine the impact of total public expenditure, it is useful to distinguish between the different components, as the significance and realization of their relative impacts is likely to be different. From here on, we make the distinction, using *public expenditure* to mean the total public spending and *public investment* to mean expenditure that adds to the public capital stock only. However, it is important to note that individual public investment projects (e.g. an irrigation project) often include large current expenditure components, data on which may be difficult to disaggregate.

In the next section, we review various methods and tools employed in assessing the impacts of public investments, highlighting their respective strengths and weaknesses. As you will soon see, the review is not meant to be exhaustive in terms of being detailed for each of the different methods and tools. Rather, the objective is to bring together the various methods and tools that are typically found in different strands of the literature or used in different disciplines and highlighting their key features in complementing each other.

3. ESTIMATING NET BENEFITS OF PUBLIC INVESTMENT PROJECTS: REVIEW OF METHODS

Cost-benefit analysis

The standard technique for assessing the merits of public investment projects is cost-benefit analysis (CBA).[8] The essential steps in undertaking CBA of a project involve identifying all the people in the society likely to be affected directly and indirectly by the project, and then measuring the net benefit (i.e. benefits minus costs) of the project on each person in current money value terms. A project is said to be justified if the weighted sum of the net benefits over all the relevant people (or net present value (NPV)) is greater than zero (Dasgupta and Pierce 1972). When comparing alternative investment projects, the rule is to select the project with the highest positive NPV. Without going through the mathematical foundations of CBA, the NPV is given by:[9]

$$NPV = \sum_{t}^{T} \frac{B_t - C_t}{(1+r)^t}, \qquad \ldots\ldots\ldots 1$$

where B_t and C_t are benefits and costs in time period t, respectively, r is the discount rate, and T is the time horizon or life span of the project within which the costs are incurred and benefits accrue. Key challenges in applying CBA include: i) attribution of change in the outcome indicator of interest to the project and identification of all costs and benefits of the project; and, ii) discounting and weighting to capture the relative importance of the project's net benefits to different members of society (including those who have not yet been born).

The issues of attribution and identification of the cost and benefits are taken up later. The issue of discounting arises because costs and benefits are often incurred and realized, respectively, at different time periods, and so a positive discount rate is suggested. However, since the effect of the discount rate is that benefits and costs incurred into the future have lower present values, the choice of a particular discount rate becomes critical. As the discount rate rises, the time bias also increases, making projects with benefits occurring in the future more unattractive while those with future harmful effects also occurring in the future seem less problematic. There are equally compelling arguments for a zero and for a positive discount rate. Arguments for a zero rate are based on ethical grounds. Suppose that individuals are required to make inter-generational allocation decisions that will affect them from a position in which they cannot be sure about the way the decision will affect them (i.e. individuals do not know what generation they will be drawn into or whether they will be poor or affluent), then the rational decision will be one in which all costs and benefits occurring within any time period are equally weighted, suggesting a zero discount rate. On the other hand, since capital is productive and there is a demand for investment funds, then a zero discount rate becomes inefficient; else consumption will remain at the subsistence level and never rise above it.[10] It is agreed that the social discount rate should be less than the financial (or market) interest rate and so rates between 2.5 and 8 percent are commonly used.

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[8] Analysis of the internal rate of return (IRR) is a variant of CBA.

[9] See Dasgupta and Pierce (1972), Hanley and Spash (1993) and Munda (1996) for the conceptual and mathematical foundations of CBA.

[10] See Benin and de Frahan (2000) for further discussion of the debate.

Discounting is an aspect of weighting costs and benefits across generations. However, deciding whether and how to differentially weight net benefits accruing to different households is also an issue, with compelling arguments for assigning, for example, little or no weights to individuals that are well off. For example, the use of head-count poverty ratio as a social welfare measure implies that marginal net benefits of any public investment program accruing to the non-poor (i.e. those individuals living above the poverty line) are assigned a zero social welfare value. Rather than applying different social welfare weights, it is argued that the most efficient way for achieving distributional objectives of public investment programs is through the use of taxes and transfers to the target individuals, assuming the taxes and transfers did not affect the behavior of the donors and recipients (Anderson et al. 2006). With the assumption being unrealistic, or at least to some extent, meaning that all of the distributional objectives of public investment programs cannot be achieved through fiscal policy alone, net benefits of public investment programs may be weighted according to the level of consumption of the individual to whom the net benefits accrue, with weights favoring those with relatively lower consumption (see Deaton (1997) for further discussion).

Since most public investment projects impact the environment, other important challenges in undertaking CBA include: i) valuation of non-market goods and services; ii) how to model the complex relationships between policies and the environment; iii) how to deal with irreversible and uncertain environmental impacts; and, iv) whether or not undertaking CBA can lead to sustainable development.[11] When public investment projects impact the environment, other project appraisal methods come into play. These include cost-effectiveness analysis (CEA), environmental impact assessment (EIA), scenario analysis (SA), and risk effectiveness analysis (REA). However, only CBA and CEA are effective for decision making, and while CEA is used for selecting among alternative projects only, CBA has the advantage of deciding whether a project must be undertaken or not. The other methods are non-monetary and, largely, are components of CBA.

The foregoing implies that CBA is typically an *ex-ante* analysis, which involves prediction of the consequences of a policy or public investment project. However, irrespective of whether a policy or project has already been implemented or not, or whether all the net benefits associated with the policy or project have been realized or not, CBA is still applicable. An important aspect though is basing the analysis on information of what (some of) the net benefits of the project have been in the past. This is done by undertaking an *ex-post* analysis, which involves measurement of actual consequences of the policy or public investment project by comparing the observed state (i.e. state of world with the policy or project) with a hypothetical alternative (i.e. state of world without the policy or project). This is the focus of the upcoming sub-sections, which look at how the costs and benefits of public investment projects can be estimated after such projects have already taken place or have been implemented.

3.1. ESTIMATING THE COSTS

Estimating the costs of a public investment project seems straightforward, and in many cases involves the costs associated with capital items, salaries and operations to complete the project. This information can be obtained from public records as government spending in the form of grants, loans, subsidies or compensation given for the provision of public goods and services such as roads, public schools, or public hospitals. These can be provided either directly by

[11] See Benin and de Frahan (2000) for a review of these issues and other issues.

public service agencies or indirectly by financing private agencies to provide the public goods and services.[12]

The building of a school or a road, for example, may involve damage to the environment such as drainage of a wetland or clearing of forest areas whose costs include loss of flood control benefits and loss of habitat for endangered species, respectively. Other examples of negative effects of public investment projects can be found with irrigation projects that become breeding grounds for human disease vectors and parasites (e.g. mosquitoes) as well as for animals (e.g. worms and ticks), thereby reducing productivity, raising health cost, and reducing welfare in general. Such indirect costs (i.e. loss of current and future benefits from the wetland or forest or reduction in production) should be included in the analysis by adding them to the direct costs associated with capital items, salaries and operations to complete the project. Estimating such indirect costs, especially those that impact the environment is covered under valuation of non-market goods and services in the next section.

Another indirect cost that is sometimes ignored in public investment analysis is the cost of raising public funds. This is because public spending necessarily implies raising taxes, now or in the future. It well known that taxation alters society's consumption and production decisions, such that both the composition and levels of production and consumption end up being different than they would be in the absence of taxation. Also, the government incurs administrative costs to collect taxes, and there are compliance costs that private agents incur to meet their tax obligations. In sum, each one dollar of public funds raised by the government costs more than one dollar to society. Herrera (2008) reviews many aspects of the cost of raising public funds. For example, the administrative costs of governments to collect taxes is estimated to range from 1 to 4 percent of total tax collections, while the deadweight loss (i.e. negative effect on production and consumption) is estimated to range from 1 to 3 percent of GDP, with between developed and developing countries. Thus the cost of raising public funds should also be included in the analysis by adding them to the direct costs associated with capital items, salaries and operations to complete the project.

Seemingly straightforward, estimating the direct costs of many public investment projects can be challenging when records on actual spending are not available or not disaggregated in a useful manner, either spatially (e.g. region, province, district, etc.), functionally (e.g. agriculture R&D, agriculture extension, irrigation, type of road, etc.), economically (i.e. development vs. recurrent expenditure), or over time. Secondly, information on transformation of actual expenditure (or investment flows) into public capital or public goods and services is of interest, since it is the public capital or public goods and services that combine with private capital investments to produce benefits to the society. This is the unit cost of public capital or cost of building one unit of public capital. With regard to public spending in agriculture R&D, for example, the information of interest can be the cost of developing a crop variety with some desirable yield or pest-resistant characteristic. Regarding education, it can be the cost of educating a child in the rural area to attain primary education.[13]

To estimate this cost, let us begin with the standard capital formation equations:

$$PC_t = PC_{t-1}(1-\tau) + I_t, \qquad \ldots\ldots\ldots 2$$

[12] At this point we make no distinction between sources of financing public investments, which may include domestic taxes or borrowing or overseas development assistance (ODA) in the form of grants or loans.

[13] Indicators associated with various public expenditure outputs and outcomes are discussed further in Section 6.

$$PC_t = \sum_{q=1}^{t} I_q (1-\tau)^{t-q} + \frac{I_0}{(\tau + r)}, \qquad \text{.........3}$$

where *PC* is the stock of public capital, I_t and I_0 are the gross capital formation in year *t* and the initial period, respectively, τ is the depreciation rate, and *r* is the interest rate. PC_t can be interpreted also as *accumulated* public investment outcome, and there are a number of ways to estimate its unit cost. An easy and quick way is to use the actual cost of building one additional unit of the public capital, say one km of a particular type or class of road, under present conditions. A second approach is to estimate the average unit cost from past investments by dividing the public capital stock by total investments (see Fan et al. 2004a). However, because of the time lag between actual investments and creation of public capital, time series data on the investments are required. Such time series data is often difficult to obtain in developing countries. With adequate time series data available on public investment (*PI*), however, a more rigorous approach for obtaining a proxy for the unit cost is to econometrically estimate equation 3 to obtain the marginal cost or cost of building an additional unit of public capital. This is the approach used in the Fan et al. studies in India and China (e.g. Fan et al. 2000; Fan et al. 2002), by first regressing the stock variable or public capital (*PC*)[14] on the lagged values of public investment (*PI*) according to:

$$PC_t = g(PI_t, PI_{t-1}, PI_{t-2}, ..., PI_{t-N}, Z^{PC} \mid \delta) + \mu_t, \qquad \text{.........4}$$

where Z^{PC} is vector of other factors affecting public capital formation and δ are the parameters to be estimated, which describe the relationship between investment flows and other factors and public capital stock. Totally differentiating equation 4 with respect to *PI* gives the marginal effect of public investment on the public capital stock:

$$\frac{dPC_t}{dPI} = \sum_{k=0}^{N} \frac{dPC_t}{dPI_{t-k}}. \qquad \text{.........4'}$$

If equation 4 is estimated in log form, then equation 4' can also be interpreted as an elasticity, i.e. percentage change in public capital due to a one percent change in public investment or *capital–investment elasticity* (ε_{PI}^{PC}). The cost of an additional unit of public capital (or marginal cost) can then be estimated by multiplying the elasticity by the total investment (*PI*), which can then be simply compared with the benefit associated with an additional unit of the public capital (or marginal benefit) to determine the benefit-cost ratio or return on investment. Estimating the benefits of public investments is discussed next. Due to lack of adequate time series data on actual public investments, disaggregated by type of spending and across space, there are very few studies that have used this approach. The dataset used in the Fan et al. studies in India and China are rather exceptional, with public investments and related data spanning more than 25 years. Data are also disaggregated at sub-national level: at the state level in the case of India

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[14] Further discussion on indicators of public capital stock is presented in section 6. In some cases too, data on the stock variable, *PC*, themselves may not be available. Fan et al. (2004a) show how such variables may be constructed using a weighted summation of lagged expenditures, $\overline{PC_t} = \sum_{k=0}^{N} \varpi_{t-k} PI_{t-k}$, where $\overline{PC}$ is the constructed stock variable and ϖ is the *a priori* specified set of weights.

and at the provincial level in the case of China. Not surprisingly, many studies have estimated equation 4 without accounting for the lagged effects, an important issue that is dealt with later on. Table 1 shows a sample of estimated marginal effect (or elasticity) of public investment on public capital stock for different types of public investment in different countries.

Table 1. Marginal effect of public investments on public capital stock in agriculture and rural areas

Public investment spending (*PI*) on:	Indicator of public capital (*PC*)	Elasticity	Time lag (years)	Remarks (country, source)
Irrigation	Crop area irrigated (%)	0.87	8	Rural India (Fan et al. 2000)
Roads	Road density (km/1000Km^2)	0.23	7	
Education	Illiteracy rate (%)	0.07	11	
Electrification	Villages electrified (%)	0.07	7	
Irrigation	Crop area irrigated (%)	0.25	14	Rural China (Fan et al. 2002)
Roads	Road density (km/1000Km^2)	0.47	17	
Telecommunications	Number of telephones per 1000 residents	0.30		
Education	Average years of schooling of adults 15 years or more	0.34	16	
Electrification	Electricity consumption per capita	0.25	12	
Roads	Road density (km/1000 persons)	1.74	0	Ethiopia (Mogues et al. 2007)
Education	Primary enrollment rate (%)	0.24	0	
Health	Distance to nearest health facility (km)	–0.12	0	

Notes: Elasticity is the percentage change in public capital (*PC*) due to a one percent change in public investment (*PI*) (see equation 5). The cost of an additional unit of public capital (or marginal cost) can be estimated by multiplying the elasticity by the total investment (*PI*). The time lag is the number of years that the investment was estimated to have impact, after the year in which the investment was made.

3.2. ESTIMATING THE BENEFITS

Based on neoclassical welfare economics, benefits are considered to be improvements in individuals' welfare, which are typically captured by changes in real income and its distribution or changes in prices and quantities of goods and services purchased in markets. In the development arena, however, benefits can be defined more broadly to include other aspects of well-being such as poverty, hunger, nutrition, health, education, etc. as implied by the Millennium Development Goals. As with estimating the cost of public investment projects, there are a number of ways to estimate the benefits, ranging from very simple measures of attribution, to moderately complex methods such as economic surplus approach and benefit incidence analysis, and then to more rigorous methods by way of advanced econometric analysis and controlling for conditioning and confounding factors.

Simple difference method

A simple or "back-of-the-envelope" method of obtaining the benefit of for example an agricultural extension programme or irrigation project, involves calculating the difference in the indicator of interest, say average crop income per household per year, between beneficiaries and non-beneficiaries of the project. The net benefit of the project can then be obtained by dividing this difference in crop income by the average cost of providing the extension or irrigation to each of the beneficiary households per year. The main disadvantage in using this approach in estimating the benefits of public investment projects is neglecting spillover effects (or impacts of the program on non-participants). For example, information provided by the extension program may be shared with and used by those who are not participating in the program, causing changes in crop income or other outcomes for non-participants as well as for participants. Thus, comparing outcomes of program participants and non-participants will underestimate the impacts of the program. Another drawback is that other factors that may have contributed either positively or negatively to the observed outcome are ignored, leading to underestimation or overestimation of the impacts.

Economic surplus approach

The simple difference method is a simplification of the economic surplus approach, which, in the case of agricultural R&D for example, can be applied based on change in agricultural productivity associated with a new technology. As depicted in Figure 2, let the curves *DD*' and S_0S_0' represent the demand and initial supply functions of the relevant agricultural products, respectively. The corresponding initial equilibrium price and quantity are Pr_0 and Q_0. The effects of agricultural R&D (e.g. adopting improved technologies), captured as improvement in agricultural productivity, can be expressed as a per unit reduction in production costs, *H*, and modeled as a parallel shift down in the supply function to S_1S_1'. Assuming demand remains unchanged, this technology-induced supply shift leads to an increase in production and consumption from Q_0 to Q_1 (the change is measured by $\Delta Q = Q_1 – Q_0$). The market price drops from Pr_0 to Pr_1 ($\Delta P = Pr_0 – Pr_1$).

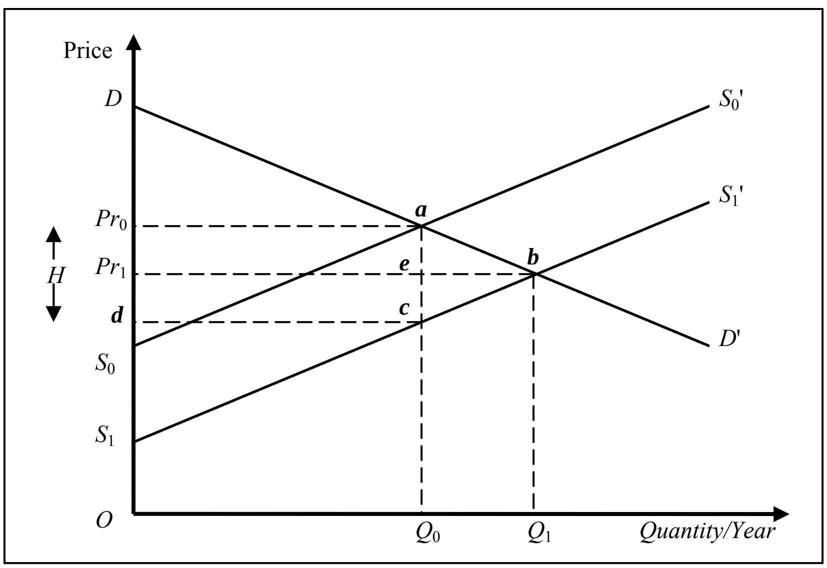

Figure 2. Economic surplus associated with productivity change

Consumers are better off because of the reduced output price and increased consumption. Producers also are better off if the positive effect associated with the increase in production and decrease in per unit cost of production outweighs the negative effect associated with the decrease in output price.[15] The total economic surplus or total benefit to consumers and

[15] This outcome depends on the elasticity of demand, where the benefit to producers increases as the demand curve becomes flatter (or more elastic) and declines as the demand curve becomes steeper (or more inelastic).

producers associated with the change is equal to the area S_0abS_1, which is approximated by the area Pr_0abcd, where Pr_0abPr_1 is consumer surplus associated with the technological change and Pr_1bcd is the producer surplus. The change in the per unit cost of production multiplied by the initial quantity, i.e. $H \times Q_0$, is often used as an approximation for measuring the total economic surplus or benefit of the public investment project, which can then be compared to the actual cost of the project to obtain the net benefit of the project (e.g. see Benin and You 2007). Here too, spillover effects and factors that may have contributed to the observed outcome are ignored.

Benefit incidence analysis

Another technique for measuring the benefits of public investment programs is the benefit incidence analysis (Demery 2003), which basically shows who is benefiting (and by how much) from public services and how public spending affects the welfare of different socio-economic groups or individual households. This is done by combining the unit cost of providing the service with information of use of the service. The benefit incidence of total public spending imputed to group *j* (BI_j) is given by:

$$BI_j = Y_j \frac{PI}{Y}, \qquad \ldots\ldots\ldots 5$$

where Y_j is the number of individuals in group *j* benefiting from (or using) the public good or service, and *Y* is the total number of individuals in the target population. Note that PI/Y is the unit cost of the public good or service. The benefit incidence can be compared across different groups (and geographic locations) to assess the efficiency of transferring income to various groups within the target population—this is the strength of the technique. The benefit incidence can be looked at for different levels of the same type of service. To education as an example, the benefit incidence of total public education spending imputed to group *j* (BI_j) over different levels of education *i* (e.g. primary, secondary, and tertiary) can be obtained by:

$$BI_j = \sum_{i=1}^{N} Y_{ij} \frac{PI_i}{Y_i}, \qquad \ldots\ldots\ldots 5'$$

where Y_{ij} is the primary, secondary, or tertiary enrollments from group *j*, Y_{ij} is the total primary, secondary, or tertiary enrollments, and PI_i/Y_i is the unit cost of providing primary, secondary, or tertiary public education. Without reliable cost data, the benefit incidence can be reduced to measuring the distribution of use of the service: $BI_j = Y_j / Y$ and $BI_j = \sum_n Y_{ij} / Y_i$ for equations 5 and 5', respectively. The analysis can be extended to examine the effect (or marginal incidence analysis) of changes in public investment over time as well as control for household and/or government behavior and how they are constrained in making choices (van de Walle 2003).

One of the main drawbacks with this technique is that it can only be applied to public investments that are ‘assignable’ or ‘chargeable’ to households such as programs that deal with transfers or subsidies (education, health, farm support, etc.). Since most public spending is nonrival in nature, the use of benefit incidence analysis is limited. Also, impact is focused on current income or consumption as a direct outcome of transfers or subsidies, without necessarily looking at the long-term effects; e.g. of school enrollment on productivity or income.

Conjoint analysis

Due to the non-market or public good or nonrival nature of public spending, their benefits to society have to be inferred from consumer behavior regarding consumption of related goods and services. This is an extension of the revealed preference theory (Samuelson 1938; Varian 1992), which essentially posits that the preferences of consumers for non-market, public goods and services can be revealed by their demand for related items. This is where conjoint analyses, also called multi-attribute compositional models, become useful. These include the hedonic pricing and travel cost methods services (see Freeman 1993 for further discussion of various methods).

Hedonic pricing:

The hedonic method is based on the notion that individuals choose the level of consumption of local public goods through their choice of a jurisdiction to reside in, so that the housing market functions also as a market for the purchase of local public goods. The assumption here is that the value of the house can be decomposed into the value of private goods (i.e. size of plot, number of bedrooms, etc.) and the value of the public goods (e.g. quality of public schools and health centers, quality of public parks and recreation centers, distance to the city center, etc.). The values or benefits for both private and public goods are analyzed in a hedonic regression equation, which treats the private and public goods (or bundles of attributes) separately and estimates prices for each of them.

Travel cost method:

As the name suggests, this method is based on the cost of travel (i.e. physical travel cost, opportunity cost of time, etc.) to visit a recreational site for example. The basic premise here is that the time and travel cost expenses that people incur to visit a recreational site represent the ‘price’ of access to the site. Thus, peoples’ willingness to pay to use a public good can be estimated based on the number of trips that they make at different travel costs, which is analogous to estimating peoples’ willingness to pay for a marketed good based on the quantity demanded at different prices. To apply the method, information is needed from a sample of users of the good, split into zones depending on the distance traveled or origin of travel to the site. The information includes the average distance traveled, average travel cost, and visit rate (i.e. number of visitors from a given zone divided by the population of that zone) to the site from each zone. The visit rate from zone j (VR_j) is regressed against travel cost from zone j (TC_j) to estimate the demand for the site.

$$VR_j = g\,(TC_j, Z^{VR} \mid \acute{\upsilon}); \qquad \text{.........6}$$

where Z^{VR} is a vector of other factors affecting visit rate and $\acute{\upsilon}$ are the parameters to be estimated. The demand curve is essentially the total population of visitors from each zone for different levels of cost or ‘price’. The area under the curve is the willingness to pay for the site which can be used for benefit cost analysis. In practice, the estimated total population of visitors from each zone multiplied by the average price and summed over all the zones can be used as a proxy for the value of the benefits.

This method, which is typically used for valuing recreational sites, is also useful when estimating the indirect cost of public investment projects, say building of a road, that involve damage to the environment such as drainage of a wetland or clearing of open spaces that are habitats for wildlife and recreational sites. The main disadvantage for using this method is that it ignores the preferences of those who value the site, but for some reasons would not visit or use it. For example, some individuals or organizations may make donations to other individuals or organizations that are involved in acquiring such open spaces or advocacy to preserve them and yet they may never visit those sites. Therefore, while their preferences are reflected through their donations, etc. they are not captured in the information obtained from the sample of visitors to the site that is used in the travel cost estimation. This reflects the concept of nonuse values, whose measurement is discussed next.

Contingent valuation analysis

The contingent valuation is the main technique employed in measuring benefits and costs of public investment projects that impact the environment. Actually, it is the only method available for estimating nonuse values (Freeman 1993). In the context of this document, its usefulness comes when estimating the indirect cost of agricultural and rural public investment projects that involve damage to the environment such as drainage of a wetland or clearing of open spaces that are habitats for wildlife and recreational sites. Basically, contingent valuation relies on describing a hypothetical situation to the target sample and asking them to state their willingness to pay (WTP) for a desirable change to occur or for an undesirable change to not occur.

First proposed in theory by Ciriacy-Wantrup (1945), Contingent valuations became widespread following their use in a quantitative assessment of damages related to the Exxon Valdez oil spill. Despite its widespread use, many economists question the use of stated preference to determine WTP for a good, preferring to rely on people's revealed preferences in binding market transactions. The criticisms were indeed valid, as early contingent valuation surveys were often open-ended questions to elicit WTP or willingness to accept (WTA) compensation for a change in the status quo, potentially suffering from a number of shortcomings, including strategic behavior, protest answers, response bias and respondents ignoring income constraints. In addition, some survey results seemed to indicate people were expressing a general preference for environmental spending in their answers, described as the embedding effect (Mitchell and Carson 1989). In response to the criticisms, a panel of high profile economists (chaired by Nobel Prize laureates Kenneth Arrow and Robert Solow) was convened under the auspices of the National Oceanic and Atmospheric Administration (NOAA) in 1993 to hear evidence from expert economists. The panel then put forward a number of recommendations on the design and control of contingent valuation method including among others: i) use of personal interviews as opposed to telephones or mail methods; ii) designing surveys in a yes or no referendum format on a specific WTP/WTA amount; providing detailed information on the resource in question; iii) and careful explanation of income effects (Arrow et al. 1995). Although widely used in the developed countries, contingent valuation is only beginning to gain ground in developing countries in general and sub-Saharan Africa in particular. As with the conjoint analysis, regression modeling estimation of individual respondent decision behavior is needed to obtain the WTP or WTA values.[16]

[16] A recent application of contingent valuation in valuing agricultural public spending is valuation of extension benefits in Kenya by Gautam (2000).

3.3. NET BENEFITS

From the foregoing discussion, we have seen that establishing cause-effect relationships between a public spending and the relevant welfare indicator of interest is very critical for obtaining accurate measurement of the net benefits of any public investment project. Establishing cause-effect relationships can be done using regression methods. Following from the conceptual framework that was presented section 2, let the various cause-effect relationships between public capital and welfare be expressed according to the following two general equations:

$$P = g^{P}(Y, Z^{P} \mid \varphi) \ , \qquad \ldots\ldots\ldots 6$$

$$Y^{i} = g^{Y}(Y^{j}, PC_{s}, Z^{Y} \mid \beta)\,, \quad \forall\ i \neq j, \qquad \ldots\ldots\ldots 7$$

where *P* represents the set of outcome indicators (e.g. poverty, inequality) and *Y* the set of intermediate outcome indicators (e.g. income, agricultural productivity, non-farm employment, wages, prices, etc). *Z* is a vector of other factors that affect the left-hand side variables, and φ and *β* are vectors of parameters representing the relationship between the individual right-hand side (explanatory) variables and the left-hand side (endogenous) variables. Note that a specific level of analysis is not implied at this stage. The superscripts "*i*" and "*j*" in equation 7 are used on *Y* to imply endogeneity of different types of intermediate outcomes, as discussed in section 2. Also, the subscript "*s*" is used loosely to denote disaggregation of public spending by sector, sub-sector, space (province, district), gender, etc. To avoid notational complexity, we have left out the time notation that was included in equation 4 and earlier equations. From the above relationships, the benefit associated with an additional unit of public capital (or marginal effect) can be obtained by totally differentiating equations 6 and 7 with respect to public capital to give:

$$\frac{dP}{dPC_{s}} = \sum_{i}\sum_{s}\left[\frac{dP}{dY^{i}}\frac{dY^{i}}{dPC_{s}}\right]. \qquad \ldots\ldots\ldots 8$$

Abstracting from the general definitions of *P* and *Y* given above, equation 8 can be interpreted as the poverty-reduction impact of an additional unit of public capital, say of having a crop variety with some desirable yield or pest-resistant characteristic or of educating a child to attain primary education, to continue with earlier examples. To use the concept of elasticity, rewrite equation 8 as:

$$\frac{\partial P}{\partial PC_{s}} = \sum_{i}\sum_{s}\left[\frac{\partial P}{\partial Y^{i}}\frac{\partial Y^{i}}{\partial PC_{s}}\right]. \qquad \ldots\ldots\ldots 8'$$

where $\partial x = \Delta x / x$.[17] The first term in the brackets can be interpreted as the '*poverty–growth elasticity*' (ε_Y^P) and the second term as the '*growth–capital elasticity*' (ε_{PC}^Y).[18] Unlike estimating the cost of public capital, however, there are several studies that have estimated the benefits associated with public capital in terms of the effect of public capital stock on a range of outcome variables including consumption, agricultural productivity, marketed surplus, wages, employment, etc. Any attempt at a review here will be futile. Many of these studies are however introduced in the next section where we discuss alternative econometric estimation approaches on measuring the net benefits of public investment projects.

By combining the estimation of equations 4, 6 and 7, the marginal effect of public investment in a particular activity *s* on poverty or '*poverty–investment elasticity*' can be obtained by:

$$\varepsilon_{PI_s}^P \equiv \frac{\partial P}{\partial PI_s} = \sum_i \sum_s \left[\frac{\partial P}{\partial Y^i} \frac{\partial Y^i}{\partial PC_s} \frac{\partial PC_s}{\partial PI_s} \right]. \qquad \text{.........9}$$

Multiplying equation 9 by the ratio of the number of poor people to total public investment will give the marginal net benefit of the public investment project in terms of the number of people lifted out of poverty due to spending an additional unit amount of money on the project.

3.4. ECONOMETRIC ANALYSIS

The discussion from the previous sub-sections suggests that a systems approach to estimating equations 4, 6 and 7 would be ideal for capturing the various impact pathways for public spending, which is in line with the conceptual framework shown in Figure 1. There are various empirical challenges with the systems approach and, more specifically, with using a simultaneous-equations method (the challenges will be discussed in detail in section 3.4.2). Consequently, most studies have opted for a single-equation approach instead.

There are at least two disadvantages with doing this. First, as seen in equation 6 for example, many of the determinants of poverty, such as productivity growth, prices, and wages are generated from the same economic process as poverty. Similarly, the decision to invest in a particular sector or sub-sector may be influenced by the performance of the same sector or sub-sector, respectively. In other words, these variables, i.e. determinants of poverty and investment decision to are also endogenous in the system.[19] Ignoring these endogeneity characteristics leads to biased estimates of the effects or net benefits of public investments (Greene 1993). To avoid the endogeneity problem, a reduced-form, single equation of poverty is often estimated by instrumenting for the potentially endogenous explanatory variables or estimating a reduced-form model. In general, the reduced-form specification eliminates the potential for endogeneity bias altogether and allows estimation of the total impacts of the exogenous explanatory variables on the dependent variable. However, finding appropriate instruments can be challenging, since one needs to find variables (at least one for each explanatory endogenous variable) that are

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[17] Note that elasticity is a dimensionless variant of slope and is measured as the percentage change in the dependent variable due to a one percent change in the independent variable. The '*poverty-growth elasticity*', for example, is given by: $\partial P / \partial Y = (\Delta P / P)/(\Delta Y / Y) = (Y / P) * (dP / dY)$.

[18] Following the definition of *Y* in equation 7, the *growth effects* can be assessed in terms of income, agricultural productivity, employment, wages, etc.

[19] The endogeneity issue is discussed in detail later.

correlated with the endogenous explanatory variables being instrumented (e.g. productivity growth, prices, wages, public investment) but not correlated with the dependent variable (e.g. poverty). But if appropriate instruments can be found, then it is possible to explicitly endogenize the policy variables by incorporating equations that capture their determination in the structural model (see Fan et al. 2000, 2003). Mogues et al. (2007), for example, use this approach by taking advantage of provincial governments' budget constraints, and of the assumed lack of direct effect of administrative spending (e.g. on the judiciary, parliament, etc.) on outcomes in economic sectors such as health, education, agriculture, etc.. If time series are available, lagged variables can be used as instruments—this is discussed in detail later on. When poor instruments are used, it is often the case that statistical significance of the resulting estimated parameters or elasticities is low. Instrumental variables approach is particularly useful when the intermediate effects of public investment (see Figure 1) are not of interest to the research.

But we have seen from Figure 1 and subsequent discussion that several of the variables that affect poverty do so through multiple channels. For example, improved rural infrastructure reduces rural poverty not only through growth in agricultural production but also through reduced input prices and improved wages and opportunities for nonfarm employment. Thus, by using a reduced-form, single-equation approach, the different intermediate effects that are important for addressing the policy research questions raised in the introduction cannot be analyzed. From the policy viewpoint, changes in public spending are not linked one-to-one with changes in outcomes, and so relying on reduced-form estimates to make recommendations about whether and how to increase or decrease public spending can be misleading.

There are other different challenges depending on the level of analysis of the impacts, which can be done at several levels, beginning from the micro (e.g. farm-household, village) level through the meso (e.g. district, provincial, sector) level to the macro (national or economy-wide) level.

3.4.1. Micro-level econometric analysis

Public investment analyses at the micro level are especially useful for assessing income distribution or inequality effects of public spending. Through carefully designed and implemented surveys, the impacts of individual public investment projects or broader sector-specific public investments can be analyzed at a highly disaggregated level (e.g. farm, household or village). In fact, with nationally representative household survey data becoming more available and reliable, such microeconometric approach has become very common for policy analysis. However, since data on public investments (*PI*) or public capital (*PC*) does not vary at this level or by the unit of the analysis (i.e. farm, household or village), the effect of public investments is captured by including in the regression(s) variables that measure the household's access to particular public goods and services in a variety of ways. To take the example of roads, some of the measures or indicators of access to public goods and services used include: distance or walking time taken from the household to the nearest type of road; whether or not the household lives within *x* km of a particular class of road; or whether or not the household lives in a community that has a particular class of road. For an individual public investment project, on the other hand, whether or not the household is a beneficiary of the goods and services produced from the project is commonly included as the variable for impact assessment.[20] The variables are measured as such in order to obtain heterogeneity across the units of analysis in their access to or use of public infrastructure and services, which is a necessary requirement for econometric estimation. There is an overwhelmingly large number of studies using this approach that contribute to the body of knowledge on the benefits of different

[20] Later on we will look at problems with this technique of program evaluation.

types of public goods and services on agricultural productivity, household incomes and poverty. Analyzing the impact of say farmland area under improved technologies, farmland area under irrigation, or access to extension on agricultural productivity also contributes to the body of knowledge on the benefits of public investment in agriculture research, irrigation, and extension, respectively. The estimated coefficients on these variables represent the marginal effects (or marginal benefits) of the relevant public goods and services, e.g. reducing distance or walking time taken from the household to nearest road by one unit. These can then be averaged or aggregated over the relevant number of farms, households or villages, and then compared with the appropriate cost of the project or investment to obtain the net benefit.

At this level of analysis, however, the cost of increasing access to a public good or service by a marginal unit, e.g. cost of reducing distance to the nearest road by one kilometer, cannot be estimated. Also, modeling and estimating relationships associated with the economy-wide factors (e.g. wages and prices), as represented in equation 6, quickly become highly complex. Typically, these variables do not vary at the farm or household level and rarely vary at the village level, making their econometric estimation unreliable or impossible, which leads to the estimation of single, reduced-form equations and associated problems, as discussed earlier.

3.4.2. Meso-level econometric analysis

This level of analysis is more suitable for assessing the effects of inter- and intra-sectoral public expenditure allocation, i.e. public spending across economic sectors such as agriculture, education, health, and infrastructure, and within sectors, which to take agriculture for example includes research, extension, irrigation, farm support subsidies, etc. As the unit of analysis here is higher (e.g. district or province), and available sector-specific public investment data also more likely to be disaggregated at the same level, the effects of different types of public investment on the economy-wide variables such as employment, wages and prices are better and more reliably analyzed. By including district- or province-specific indicators in the analysis, the spatial distribution of growth and poverty-reduction can also be evaluated.

The classic literature on the analysis of different types of public investments at this level of disaggregation comprises those by Fan and others (see Fan et al. 2000, 2004a, 2005; Fan and Rao 2003; Fan and Zhang 2004, Fan 2008). To address the endogeneity issue raised earlier, Fan and others have developed a simultaneous-equations model mimicking a rural economy of the conceptual framework presented in Figure 1, where government spending is the driving force behind agricultural productivity growth and rural poverty reduction, controlling for other factors. In their model: rural poverty is a function of agricultural productivity, nonfarm employment and wages, and terms of trade (agricultural prices relative to nonagricultural prices); agricultural productivity is a function of government investment in agricultural R&D and public capital stocks of irrigation, power, education, and rural roads; rural wages and nonfarm employment are functions of agricultural productivity and public capital stock such as roads, education and electricity; formation of capital stocks in education, irrigation, roads, and other types of public capitals as a function of different government expenditures; and agricultural prices are modeled as functions of agricultural productivity. The returns to or marginal effect of public investment in terms of growth and poverty reduction, for example, are calculated by totally differentiating the system of equations with respect to each public investment variable, as shown in equation 9 above.

As pointed out earlier, the data used by Fan and others in the case studies of India and China are rather exceptional in terms of sub-national disaggregation. Without such a luxury, data from nationally representative household surveys can be used to aggregate household data values upwards to the desired unit of analysis, e.g. district, assuming the data are representative at that level. The data values can also be averaged across the sample within the desired unit of analysis. One challenge emerges from the need to have the level of disaggregation of public investments (PI) and public capital (PC) data correspond to the level of the information on the other variables. Another challenge lies in correctly specifying all the structural equations in the system, as the bias from any one incorrectly specified equation will affect the estimated coefficients in the entire system of equations. Since the level of analysis is higher, income distribution issues at the household level cannot be analyzed. Generally, without sector- or subsector-disaggregated data, the model cannot assess sectoral or sub-sectoral distribution of growth since the indirect effects, via changes in relative prices of goods and services, cannot be modeled and estimated.

An issue that has not been dealt with at this level of analysis is evaluating public spending at administrative levels (e.g. federal or central) higher than the unit of analysis (i.e. district or province). Given that spending at the federal or central level will unlikely be distributed proportionally to district- or province-specific spending, there is likely to be a bias in the estimated effects of public spending at the district or provincial level when public spending at the federal or central level is ignored. This issue is less of a problem for the types of public investment that are primarily undertaken by sub-national tiers of government. However, if one wanted to assess the total effects of spending in sectors where the central government has the primary responsibility for investments, e.g. defense and scientific R&D, then this meso-level analysis alone cannot be used. A macro-econometric model, which requires a much longer time series of data for estimation, may be needed. Otherwise, as in the case of some applicable sectors, one has to first make some assumptions about how such federal or central government spending is distributed across districts or provinces and use that information to disaggregate the relevant spending. In the case of R&D for example, information on how technology is diffused in the system can be used to construct a variable that is a function of the distance from the center or point of investment to the various provinces or districts, which can then be included as an explanatory variable in the regression analysis.

3.4.3. Macro-level econometric analysis

The effects of public spending can also be estimated at the national level, where different types of public investment and related data are often available. Without a relatively long time series data, however, variability in the data values over time may not be large enough to warrant a reliable econometric estimation. With a relatively short time series data, low degrees of freedom is likely to become an issue, but may be eased by utilizing a cross-country approach, where the unobserved cross-country heterogeneity can be controlled for by estimating a fixed effects model, i.e. including country-specific dummy variables in the regression equations. Such an approach is extremely useful for public investment analysis in developing countries where time series data are rarely available over a long period of time. Data problems are discussed further in the upcoming sub-section. There are several papers that have used cross-country panel data to analyze the effects of different types of public investments on growth and poverty reduction (see e.g.: Canning 1999; Fan and Rao 2003; Mosley and Suleiman 2007).

The main critique with the cross-country approach is the policy relevance of the conclusions drawn, since the parameter estimates are restricted to be identical across countries (Brock and Durlauf 2001). As it is unrealistic to assume that all the countries included in the analysis are on the same international production frontier for example, including country-specific dummy variables to capture cross-country heterogeneity, as mentioned above, addresses some aspects of the problem. The problem can further be reduced if the data allows identification and estimation for groups of countries with common structural and productivity-growth characteristics. Nevertheless, given data constraints for carrying out separate country-specific public investment analysis, cross-country data analysis can provide basic evidence that can be used to assess policy and public spending scenarios in the individual countries.

3.4.4. Econometric estimation issues

Endogeneity (attribution, attrition and selection bias)

The main challenge with estimating the benefits irrespective of the approach used is attributing change in the indicator of interest to the particular public investment project that is being evaluated. In the economic program evaluation literature, particular concern has focused on biases resulting from non-random selection or assignment of program participants to particular "treatments".[21] Taking the example of attributing the effect of agriculture extension on crop income, let Y_i^{ext} represent the crop income of farmer *i* in the extension program (*EXT*) and Y_i^{noext} the crop income of farmer *i* not in the extension program. Then, holding all other influential factors (*X*) constant, the impact of agriculture extension on crop income of farmers participating in the agriculture extension program (i.e. average treatment effect on the treated (ATET)) is given by:

$$ATET_i = E(Y_i^{ext} - Y_i^{noext} \mid X_i, EXT_i = 1), \qquad \ldots\ldots\ldots 10$$

where $E(Y_i^{noext} \mid X_i, EXT_i = 1)$ is the crop income that participating farmer *i* (i.e. EXT_i=1)[22] would have obtained had he or she not participated in the program, conditional upon other influential factors, including observable characteristics and inputs by farmer *i* (X_i). The basic problem of attribution is that the counterfactual $(Y_i^{noext} \mid X_i, EXT_i = 1)$ is not observable since farmer *i* is assumed to be participating in the program. By randomly assigning households to receive or not to receive agriculture extension services, an unbiased estimate of $(Y_i^{noext} \mid X_i, EXT_i = 1)$ is possible, since random assignment assures that the distribution of unobserved and observed characteristics of households in the program are the same as those not in the program. However, such randomized social experiments are confronted with a number of ethical issues as well as practical and methodological problems. We will pick up the discussion on experiments again later.

Other problems arise with sample attrition and selection bias. Sample attrition, refers to respondents being lost from the evaluation sample for whatever reason, including lack of interest in participating and migration, which can cause sample selection bias in the remaining sample. Selection bias can also result from non-random program placement (e.g. programs may be chosen to operate in locations or with communities that are more or less able to benefit from the program than the underlying population for which program impacts are sought) or non-random choice of participation (e.g., households that are more able to benefit from a program may self-select into the program) (see Maddala 1983). Continuing with the agriculture extension and crop income example, the impact to be analyzed is modeled as:

$$Y_i = X_i'\gamma^x + \gamma^{ext} EXT_i + \mu, \qquad \ldots\ldots\ldots 11$$

where the impact of extension on crop income is measured by the estimate of γ^{ext}. However, the dummy variable, *EXT*, for participating in the extension program cannot be treated as exogenous if there is selection bias in which case the estimation is performed using the

[21] See Birner et al. (2006) for a review of the problem and suggested techniques for addressing it.

[22] As opposed to *EXT*=0 meaning non-participation.

treatment effect model, where *EXT* is first modeled and estimated as a probit, and then the results (i.e. predicted values of EXT_i) are used in the estimation of *Y* (Maddala 1983).

As in the case of most policy interventions and on placement of individual investment projects in general, the decision to invest in one sector or region may itself be affected by the level of development of that sector. If, for example, educational services are relatively well developed in one province of a country, a strong equity focus in investment policy would imply the tendency to spend less per capita on education in this province compared to other provinces. In turn, efficiency-oriented policy may lead to greater resource allocation to a sector where its performance is already high. An example may be where factors that drive agricultural productivity positively also are factors that would contribute to increased returns in investments in agriculture.

An aspect of potential endogeneity bias, especially for the meso-level analysis, arises from the effect of cross-section differences in investments of sub-national governments, where better developed provinces are generally better equipped to mobilize more resources for investment programs by generating their own revenue through taxes and other sources. In this case, we may observe greater investments or outcomes in better developed provinces. Such potential programme placement effects are less relevant when analyzing effects of public investments at the same level that decision on revenue mobilization and allocation occurs. In sum, to the extent that there is potential simultaneity in the investment decision and realization of outcomes, the direction of the possibly ensuing bias cannot be conclusively determined. At the same time, one cannot necessarily assume that the various possible counteracting effects of development outcomes on investment allocation will cancel each other out. There exist a range of different approaches, both through *a priori* programme design, as well as through the application of *ex post* statistical methods, to address selection and other biases in program evaluations, and these are widely documented (e.g. Maddala 1983). Here, we will make selective reference to approaches in light of their applicability and usefulness in public investment analysis.

Randomized experimental design, which is considered the “gold standard” among the *a priori* approaches, has been frequently employed in the case of specific public interventions and programmes, such as cash transfers administered to households randomly selected from an eligible pool of households (see e.g. Coady and Harris 2004; Skoufias 2005). Application of such a design is rarely possible, both technically and politically, when one wants to assess the impact not of an individual public investment program, but of overall public spending on a sector or sub-sector, and even less feasible when the relative impact of different types of investment is of interest. For example, to determine the contribution of public investments in rural roads to changes in poverty levels, it is practically impossible to encourage a government to randomly select communities from a pool of eligible communities throughout the country to be the only beneficiaries of rural roads investments; and more so where there is a certain degree of decentralized decision making on such investments. Similarly, in the case of public spending on agricultural R&D, the feasibility of a randomize experiment is even more limited due to strong externalities.

Unlike the intentional randomization of policy design as described above, there are some instances in which researchers can take advantage of “natural experiments”, including circumstances such as the imposition of certain laws, regulations, and other mechanisms that create a variation in the policy intervention of interest that would plausibly render placement of this policy exogenous (see Meyer 1995 for detailed discussion). The presence of natural experiments has not been frequently exploited in public investment analysis and, where this approach is used, it is mostly in developed country contexts (e.g. Dye and McGuire 1997).

A commonly used quasi-experimental method is propensity score matching (PSM) method in which a matching criterion is used in selecting ex-post program beneficiaries and non-beneficiaries who are as similar as possible in terms of observable characteristics that are expected to affect participation in the program as well as the realization of outcomes.[23] The difference in observed outcomes between the two matched groups can be interpreted as the impact of the program on the beneficiaries (Smith and Todd 2005). In practice, the PSM method matches the project beneficiaries with comparable non-beneficiaries using a propensity score, which is the estimated probability of being included in the program. Only beneficiaries and non-beneficiaries that have comparable propensity scores are used to estimate the impacts (see equation 10). Since beneficiaries and non-beneficiaries that do not have comparable propensity scores are dropped from the analysis, problems associated with insufficient sample sizes and lack of representativeness at the level at which the results would like to be generalized become important. Combining this with the double-difference (DD) estimator to compare changes in outcome measures (i.e. change from before to after the program) between program participants and non-participants, has the added advantage of netting out the effects of any factors (whether observable or unobservable) that have fixed (or time-invariant) and additive impacts on the outcome indicator.

The difference approach is another way of dealing with the endogeneity of public investment decisions by using changes in the values of the variables over time rather than their levels. For example, Fan et al. (2000) use the difference approach and argue that if the (omitted) features affecting public investments are fixed over time (e.g. agro-climatic conditions), then a significant source of endogeneity will be omitted. This would apply not only to endogeneity resulting from omitted variables, but also from simultaneous effects, as long as expenditure decisions are driven by levels, but not changes, in hypothesized outcomes. Differencing, however, may remove the long-term effect of public investments whose benefits often materialize with a lag (Hsiao 1986), which is a temporal feature that has been used to address the programme placement effect. Several studies use either backward lags of the investment variables (e.g. Mogues et al. 2007; various papers by Fan and others) or forward lags of the outcome variable (e.g. Devarajan et al. 1996), suggesting that unless policy makers adjust spending decisions on the basis of anticipated outcomes in years ahead, the use of lags should at least somewhat delimit simultaneity bias.

Spatial correlation and spillover effects

The existence of spending interactions among decentralized (or sub-national) governments complicates a public investment analysis, since externalities arise when the spending or tax setting decisions of a given sub-national government has positive or negative consequences on the fiscal choices of other sub-national governments. This is due mostly to mobility and information asymmetries among private agents and local government officials and politicians. From the competitive standpoint, 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. For example, Case et al. (1993) and Figlio et al. (1999) found that per capita public expenditures of neighboring states in the United States are positively correlated. Such spatial correlation is a source of endogeneity and heteroskedasticity (Kelejian and Prucha 1998). Spatial spillover effects also complicate specification of the counterfactual discussed previously, that is, selection of a comparison group

[23] This method is referred to as a “quasi-experimental” method because it seeks to mimic the approach of experiments in identifying similar “treatment” and “control” groups. However, since the comparison groups identified in PSM are not selected by random assignment, they may differ in unobserved characteristics, even though they are matched in terms of observable characteristics.

to be used to measure the impact of the public investment project. Spatial information is needed to model and address these issues using dynamic programming (Agenor and Neanidis 2006) and spatial econometrics (Anselin 1988; Kelejian and Robinson, 1993).

Lagged effects

A critical issue in policy impact analysis is that the effects of public investment commonly materialize with a lag rather than contemporaneously. The length of this lag will depend on the performance indicator with respect to which the effect of public investment is being assessed. For example, public investment in the road sector can be expected to improve road density within a shorter time span than public investment in the education sector would be expected to increase the adult literacy rate. This is because the literacy performance of young children benefiting from better educational services today will be captured in the adult literacy rate only after they have become adults, usually 15 years and older. Furthermore, the lag with which spending may result in sector-specific outcome indicators can be expected to differ within a given sector. For example, the primary enrollment rate is likely to respond sooner to greater resource allocation to the education sector, than the literacy rate, for reasons analogous to the above.

When considered, this issue of lags has been treated in different ways in the literature. Others too have ignored the issue. For example, Collier et al. (2002), who use public expenditure data at the national level to compute unit costs of increasing the quality and quantity of health services, do not account for the potential span between intervention and outcome. Often, expenditure data limitations appear to have necessitated this approach, as with Fan et al. (2004, 2005) that similarly used the unit cost approach. Gomanee et al. (2003) determine the effect of social sector spending on human development by regressing the human development index on contemporaneous social sector expenditure. While the approach used in this study is in contrast to the unit cost approach, both regression estimation controlling for non-expenditure influences on the outcome of interest, the possibility of lagged effects is not explored.

Other studies have accounted for the lag between investment and outcomes, although different approaches have been used. For example, Devarajan et al. (1996), which explores the growth effects of public spending, accounts for investment lags by using a 5-year moving average of agricultural growth as the dependent variable. In the Fan et al. (2000, 2002) papers, the specification of the investment equations not only allows for lagged effects, but permits a parameterization of the individual effects of spending at different time intervals (i.e. effect of current vs. past spending). Furthermore, the lag period is allowed to vary across the different investment categories (see Table 1). Zhang and Fan (2004) also address the lag issue in a similar free-form fashion. Such an unconstrained optimal lag length determination, however, may not be possible due to data as well as estimation constraints. According to Holtz-Eakin et al. (1988), the lag length should be less than one-third of the total time span of the data, else the covariance matrix cannot be correctly estimated due to over-identification problems. The free-form approach can also overburden the data in the sense of estimating too many parameters, which potentially can lead to severe multicollinearity problems that can bias the estimates of the parameters (Greene 1993; Evenson 2001). In recent studies by Malla and Gray (2005) and Huffman and Evenson (2006), they include a specific lag of the public investment or public capital variable only.

To empirically determine the appropriate lag structure, the Akaike information criterion (AIC) and adjusted-R^2 are commonly used (see Greene 1993). The optimal length of the lag is determined when the adjusted-R^2 reaches a maximum. The AIC works in a similar fashion by rewarding goodness of fit and penalizing loss of degrees of freedom, and optimal length of the lag is determined when the value reaches a minimum. Practically, one can start by specifying an arbitrarily long lag length (say one-third of the total time length as suggested by Holtz-Eakin et al. (1988)) and then allow the model to determine the “optimal” length, as done by Zhang and Fan (2004).

Data problems

A fundamental challenge for policy analysis in developing countries in general, and for public investment analysis in particular, is in getting sufficient data. Major problems include: i) difficulties in operationalizing and measuring appropriate indicators of inputs, outputs and outcomes; ii) issues of data comparability (especially when different survey instruments are used at different points in time or for different sub-samples); iii) missing observations; and others, which often lead to larger biases than some of the estimation problems discussed above. Overcoming these difficulties have become urgent given recent surge of interest in tracking government expenditure in both economic (agriculture and infrastructure) and social (education and health) sectors regarding implementation of PRSPs and following the CAADP initiative and Maputo Declaration by African leaders to allocate 10 percent of their national budgetary resources to agriculture (NEPAD 2003, 2005). We take up issue of indicators later in section 5, where we propose a set of key indicators that is relevant for monitoring and evaluating various types of public investment in agriculture and rural areas.

From the review of the methods and issues to deal with, it is clear that a variety of data types would be needed for a holistic assessment of the impacts of different types of public spending in agriculture and rural. For example, data from both experimental and non-experimental sources would be required. Experimental data are mainly for situations where preferences of the target group (i.e. expected to be affected by public spending) would not otherwise be observed in the normal market place as in valuation of nonuse values. Experimental data (or data from pilot projects) are also critical for addressing program placement effects related endogeneity issues. The data may be in the form of time-series data (collected over discrete intervals of time), cross-section data (collected over sample units in a particular time period) or panel data (collected across the same sample units over time). They may be at different levels of aggregation, such as on individual economic decision-making units such as individuals, households, firms or villages (micro data) or from pooling over the individual economic decision-making units at the local, district, province or national level. The data may also represent flow (outcome measured over a period of time) or a stock (outcome measured at a particular period in time), and they may be quantitative or qualitative (see Hill et al. 1997 for further discussion).

The data can be obtained from several sources. For example, public spending data can be obtained from financial statistics of central governments (line ministries and accountant general’s office), various local governments, in-country donor agencies, and from international agencies (e.g. IMF’s government financial statistics and the World Bank’s world development indicators (WDI)). Data on spending outcomes and other indicators can be obtained from secondary sources (e.g. national statistical reports, annual reports of line ministries, local governments, international public databases (FAOSTAT, WDI, etc.) and primary sources (e.g. service delivery surveys, living standards surveys, core welfare indicators surveys, consumption and budget surveys, agricultural censuses, demographic and health surveys, etc.). These sources are explored further when we discuss specific indicators and data requirement in section 5.

3.4.5. Effectiveness and efficiency of past public spending

So far we have looked at how the net benefits associated with different types of public spending in agriculture and rural areas can be assessed, the different techniques and tools that can be employed, the sorts of issues arising with using the different techniques and tools, and how the issues may be taken care of. Now we are in a position to look at how we can use results of the analysis to address the first set of policy research questions raised in chapter 2, which derives from the need to learn from past public investment:

> How effective have different types of public investment been to date?
> Have expectations (development objectives) been met?
> What factors have shaped the level of impact that has been achieved?
> What are the trade-offs and complementarities, if any, among different types of investment?

The first question on how different types of public investment have been effective can be answered by comparing the estimated net benefit (or benefit per unit of amount of public spending) across competing sectors, programs, projects, etc. With respect to government sectoral allocation in terms of poverty-reduction, for example, the net benefit (e.g. number of poor people lifted out of poverty per unit amount spent) can be compared across the various sectors (e.g. agriculture, education, health, roads, communication, etc.). Depending on the level of disaggregation of the underlying data and subsequent results, the comparison can be extended to look at the separate effects of public spending within a particular sector: e.g. agriculture (R&D vs. extension vs. irrigation vs. farm support subsidies, etc.); roads (asphalt vs. gravel vs. feeder roads); education (primary vs. secondary vs. tertiary education); health (primary health care targeting pregnant women and infants vs. HIV/AIDS vs. other debilitating diseases). The widely-cited studies by Fan and others deal with comparisons across sectors and sub-sectors. For example, the study by Fan et al. (2004b) on rural China (shows that, in terms of the number of poor people lifted out of poverty, a dollar spent in education has been the most effective, followed by a dollar spent in agricultural R&D, roads, electrification, communications and then irrigation. Similar comparisons using econometric analysis and including other sectors and sub-sectors, as well as in terms of raising agricultural productivity growth, have been done in India (Fan et al. 2000; Jha et al. 2001), Thailand (Fan et al. 2004c), Uganda (Fan et al. 2004a), Tanzania (Fan et al. 2005), Ethiopia (Mogues et al. 2007), and cross-country (Dollar and Kraay 2002; Fan and Rao 2003).[24] In their study on Uganda for example, Fan and his co-authors show that government spending on feeder roads was nearly three times as efficient as spending on murram (gravel) roads and four times as efficient as spending on tarmac roads in terms of the number of poor people lifted out of poverty per dollar invested in each of these types of road. More research looking at the effectiveness of such intra-sectoral allocation is needed. With data permitting, the analysis can also be extended to look at the effectiveness of other aspects of spending, including: spending targeting specific demographic groups; central vs. decentralized spending; recurrent vs. development spending; etc.

The second question as to whether expectations have been met is relatively straight-forward, but it does imply that there is a stated target and costing to achieve the target that the econometric results can be compared with. The estimated net benefits can be compared with the stated development objectives, taking the planned spending versus the actual amount invested into account.

This leads naturally to the third question on the factors that have shaped the level of impact, irrespective of whether the expectations have been met or not. This can be determined by analyzing the sign, magnitude and statistical significance of the parameters associated with all the non-expenditure variables included in the regressions. These are represented by the vector Z in equations 4, 6 and 7, which may include agro-ecological conditions, demographics,

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[24] See Anderson et al. (2006), Palmer-Jones and Sen (2007), Paternostro et al. (2007), and Fan (2008) for reviews of the evidence and collection of studies

institutional and political structures, etc. By transferring the estimated parameters onto a schematic diagram similar to Figure 1, one can easily visualize how each level of impact has been achieved via the various pathways and relative magnitudes in doing so (see Fan et al. 1999 for an example). Recall that one of the key pathways of impact is the crowding-in (or crowding-out) of private capital investment. With available data on private investments, it is possible to analyze such effects as done by Malla and Gray (2005) regarding agricultural R&D.

The question dealing with trade-offs and complementarities among different types of public spending can be answered in a variety of ways. Regarding inter-sectoral allocation of public investments for example, this can be done by modeling the outcome of one sector as a function of investment or outcomes of other sectors. A typical example is the complementarity between education spending and other public spending; for example investment in education and investment in agricultural R&D and extension. The notion is that agricultural technologies tend to be highly complex, knowledge intensive, and location specific, and so they require knowledge and skills for success (see e.g. Shultz 1982; van de Walle 1996). Another example is the road and transport sector which is normally considered as a service sector to the other sectors. Therefore, one can model the outcomes of other sectors (e.g. agriculture, education, health) as a function of road investments or outcomes via a transportation or transactions cost equation. As we will see later on in section 5 on the discussion of indicators, several of the outcome indicators relating to social services, for example, are expressed in terms of access (i.e. distance, travel time, or travel cost) to the nearest service or facility, which implicitly incorporates the notion of road and transport development. Obtaining the relevant elasticity can be used to infer the tradeoff or complementarity. In addition to the above method, interaction terms among the relevant investments or spending variables can be included in the regression model. A positive sign of the estimated coefficient associated with such variables indicates complementarity, while a negative sign indicates tradeoffs or substitution. The use of interaction terms, however, can introduce severe multicollinearity and cause the regression parameters to be estimated imprecisely; meaning wrong signs, implausibly large values, and wide variations in magnitudes when the number of observations is changed, among others (Greene 1993).

The second set of policy research questions that were raised in the introduction are forward-looking and can also be addressed using results from the *ex-post* analysis in follow-up simulations. For example, the estimated parameters can be used in an econometric prediction model to simulate the effect of changes in public investments. Since the parameters are fixed in the simulations, they are not affected by changes in investment or other factors, which is a scenario that seems realistic in the short run only. Public investments are rarely undertaken with a short term perspective only. Also, spillover effects on prices, wages and employment or availability of inputs and outputs in the entire economy, environmental externalities, as well as the responses of other programs to the presence of a particular investment program, cannot be ignored. Even for individual investment projects that are implemented over a relatively short period of time, because of the relatively large total outlays, which typically span several sectors, the spillover and other effects cannot be ignored. Programs financed by the Millennium Challenge Corporation (MCC) are typical examples. To take the case of Ghana for illustration, it is expected to receive $547 million MCC grant over five years, of which 44 percent is expected to be spent on agriculture development, 26 percent on transport development, 18 percent on and rural services development such as education, water and sanitation, and electricity, with the remaining 12 percent going to program management, monitoring and evaluation.[25] In these situations, use of economy-wide modeling techniques becomes inevitable.

[25] See www.mcc.gov/countries/csr/Ghana for further details.

This is the topic of the next sub-section, where we briefly look at basics of simulation modeling methods and their applications. Then in section 4, we propose an integrated approach for assessing the net benefits of public investments that can help address both sets of policy research questions in a more comprehensive manner.

3.5. SIMULATION MODELING TECHNIQUES AND APPLICATIONS

Unlike econometric methods that focus on *ex post* analysis and the estimation of the relationship between one (dependent) variable and a set of other (explanatory) variables to determine how change in the explanatory variable affects the dependent variable, simulation modeling methods in general focus on *ex ante* analysis by applying microeconomic theories (e.g. maximization theory) to systematically solve the values of the variables from within an allowed set. A set of parameters is necessary for any simulation model, and some of these parameters are often drawn from results of relationships that have been econometrically estimated independent of the simulation models. We now review different modeling techniques and their applications for public investment analysis.

3.5.1. Partial equilibrium modeling and linkages with public investment analysis

Based on the producer's and consumer's surplus approach presented earlier (see Figure 2), Alston et al. (1995b) and Wood et al. (2000) have developed a partial equilibrium simulation model called the Dynamic Research EvAluation for Management (DREAM) model, together with a computer program for the model, to measure the economic returns to investment in commodity-oriented research under a range of market conditions.[26] The model allows for price and technology spillover effects across space due to adoption of productivity-enhancing technologies or practices produced from the research in an innovating area that is different from the area where the impacts are being assessed. DREAM has been used is many studies to evaluate the economic impacts of agricultural (R&D). Recently, Omamo et al. (2006) used DREAM and other tools to evaluate potential investment opportunities for increasing both agricultural and overall economic growth within Eastern and Central Africa, encouraging a wide variety of agricultural production to match the diversity of national demands and capacities, and promoting regional cooperation in agricultural development. The cost of investments needed for developing and promoting the technologies was not included, however. Recently, Benin and You (2007) used DREAM to estimate the economic returns (benefit-cost ratio) of the government of Uganda's investment in research to develop disease-resistant clonal coffee varieties and replace aging coffee trees and those affected by coffee wilt disease. DREAM is limited to evaluating investments in agricultural R&D.

Another simulation modeling application based on the economic surplus approach that provides a framework for analyzing the impact of various types of public investment is the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by IFPRI. IMPACT generally offers a methodology for analyzing alternative scenarios for global, regional and national food security issues, i.e. food demand, supply, and trade (see Rosegrant et al. 2001). IMPACT covers 36 countries and regions and accounts for about 16 commodity groups. Being a partial equilibrium model, household incomes are exogenous, and hence, the model is unable to capture the feedback effects of productivity and prices on households' incomes. IMPACT has been used in several important research projects to examine the linkage between the production of key food commodities and food demand and security at regional and global levels. In terms of public investment analysis, the studies by Rosegrant et al. (1995; 2001), in which the effect of public investment and other factors on food security and nutrition status were

[26] DREAM can be freely downloaded at http://www.ifpri.org/dream.htm.

analyzed, stand out. Ultimately, the utility of IMPACT in helping to address the forward-looking set of policy research questions that were raised in chapter 2 will depend on how public investment is modeled. Basically, since this model relies on parameters from econometric estimations, the main challenge lies with formulation of public investment in the food demand, supply and trade functions of the various countries or how the elasticities obtained from econometric estimation should be captured at different levels in the model.

In another partial equilibrium application, Warr (2003) simulates the effects of hypothetical reallocations and changes in the overall size of public spending and financing, deriving the effects on both poverty incidence and inequality. For example, Warr simulates the effects of hypothetical reallocations of the total tax burden away from taxes falling heavily on the poor and towards those falling predominantly on the rich. The results show that increased spending on education, health, and agriculture reduces poverty, while higher share of spending on transportation increases poverty.

3.5.2. General equilibrium models and linkages with public investment analysis

Increasingly, computable general equilibrium (CGE) models are being used in analyzing impacts of public investments (see e.g.: Jung and Thorbecke 2003; Thurlow et al. 2007; Lofgren and Robinson 2008). CGE models are useful tools to capture economy-wide linkages, such as cross-sectoral linkages, linkages between households income (and hence demand) and production, and linkages between factor supply and demand and, hence, production. Many variables such as income, wages and returns to land, prices, government revenue, etc. that are treated as exogenous in partial equilibrium simulation models or in econometric models, become endogenous in a CGE model. CGE models use social accounting matrices (SAMs) as their most important source of data, and a SAM is often developed with data and information from a specific year. Although the data that are used in a SAM are often very comprehensive and combines data drawn from a wide range of different sources (including national accounts, government budget information, household and industrial surveys, and balance of payments), they generally cannot describe changes or trends that are observed in time series data. Therefore, many of the parameters used in a CGE model, such as elasticities for production and trade functions, have to be drawn from other studies in which these parameters are econometrically estimated. While the production elasticities (either as coefficients related to total factor productivity (TFP) or specific factor productivity (e.g. labor, land or capital)) in a CGE model are exogenously given, they can be linked to an econometric model such that the impacts of public investment can be analyzed within a general equilibrium framework by taking into account the effects of costs (e.g. increased government spending) and benefits (e.g. increased productivity) in an economy-wide setup. Figure 3 gives an overview of the linkages between public investment and economic activities in a CGE model, which unlike Figure 1, shows how the effects of public spending filters through the entire economy.

As Figure 3 shows, the central agent in the CGE model regarding public spending is the government, who interacts with the rest of the economy and institutions in many ways. The government generates income from different types of tax revenues and from foreign sources. The impacts of changes in public investment on the economy can be simulated in the model through either reallocation of government budget across activities or increases in total government spending (i.e. more of the same activities). There are direct and indirect impacts to consider. The direct impacts are captured not only at macro-economic level, such as the balanced government account, foreign account (if international inflows were involved) or capital account, but also at sector and household levels if the increased spending is to be financed through increased tax income. Such direct economy-wide impacts of changes in public spending can be simulated without relying on any parameters that are estimated from econometric analysis. However, the indirect impacts of changes in public investment on the economy in a CGE model, i.e. the impact due to improvement in productivity at sector or factor levels associated with increased public goods and services, have to be simulated with a combination of parameters that are exogenous in a typical CGE model. Using estimated elasticities that are drawn from other studies, public spending is simultaneously modeled as a determinant and outcome of public goods and services, which in turn augment productivity coefficients for sectors or factors. As such, the total impacts of public investments, including the effects of increased public spending and public goods and services, are captured simultaneously through economy-wide interactions in a CGE model. The question of prioritizing public investments across space or evaluating the impacts of public investments across space (e.g. province or region) differential can also be analyzed in a CGE model by incorporating spatial differences in production technologies and institutional characteristics.

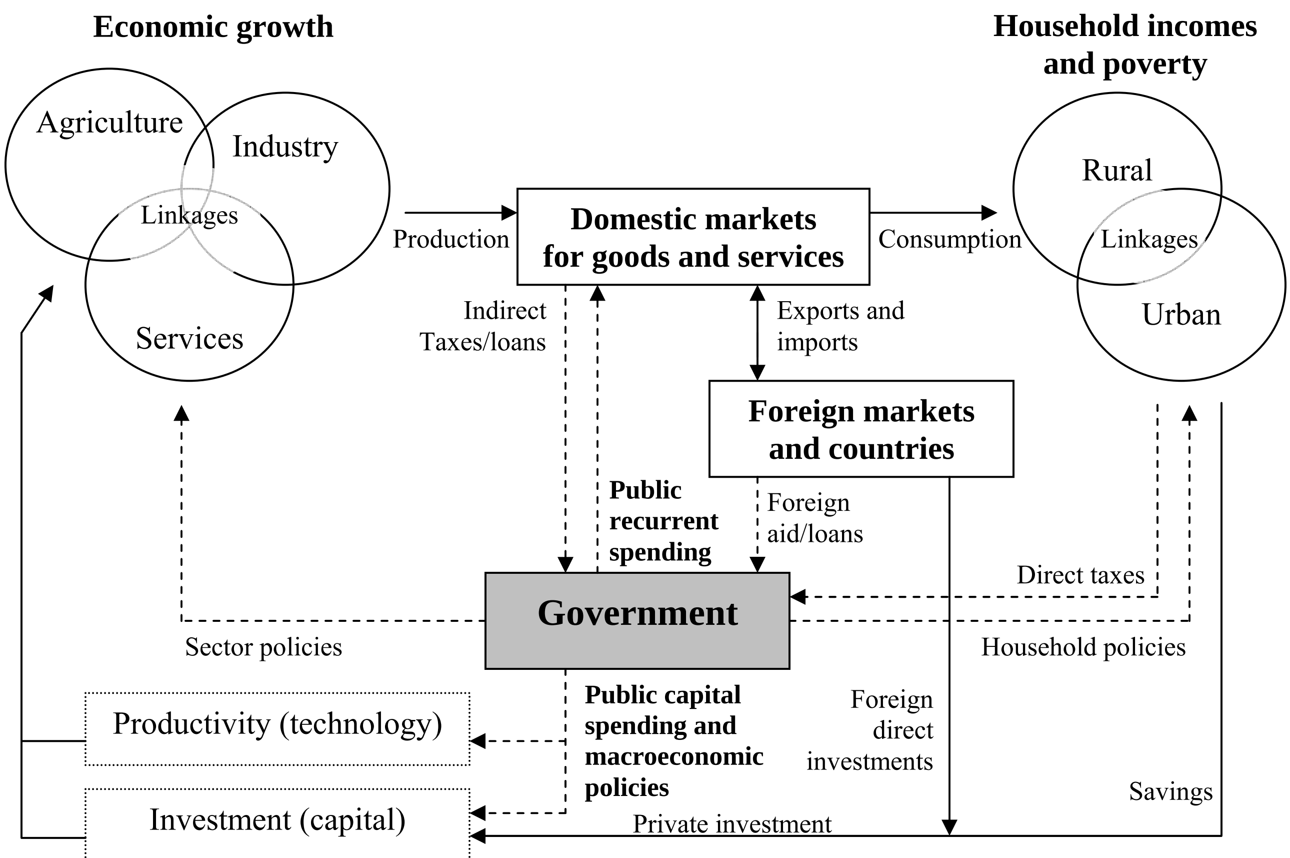

Figure 3. Economy-wide linkages of public spending in a CGE model.

While a CGE model is generally used to simulate the economic impact of aggregate public investment, it can be developed to examine the potential benefits of individual public investment projects. For example, Coady and Harris (2004) use a CGE model to evaluate the impact of targeted cash transfers to poor rural households in Mexico, a social safety net program called PROGRESA. Nin Pratt et al. (2005) also use a CGE model to evaluate the benefits and costs of compliance of sanitary regulations in livestock markets in Ethiopia.

In typical CGE models, however, income distribution and inequality issues can only be analyzed at the aggregate household level or at the regional level. In trying to address this shortcoming, a CGE model (or any other type of economy-wide simulation model such as economy-wide multimarket model (e.g. Diao et al. 2007)) is often linked to a microsimulation model in which household survey data is fully employed to capture the impact of public investment on each individual household in the sample through their participation in sector production activities or their demand for different commodities. Such economy-wide model-microsimulation model analysis has been done, for example, for Ethiopia (Diao and Nin Pratt 2007), Ghana (Breisinger et al. 2007), Uganda (Diao et al. 2007), and Zambia (Thurlow and Wobst 2004). With such linkages, the poverty impacts of public investment can be analyzed *ex ante* and standard poverty measures (such as headcount poverty rate) can be reported at national and regional levels, as well as for rural and urban areas.

As the evaluation of economy-wide impacts of public investment in a CGE model rely critically on elasticities drawn from econometric estimations,[27] and there exists a key inconsistency between CGE models and econometric models (i.e. most of econometric estimations are conducted within a partial equilibrium framework in which some explanatory (exogenous) variables are endogenous in a CGE model), the results of CGE models need to be interpreted with caution. Another challenge in linking econometric estimation with CGE modeling analysis lies with the different levels of aggregation across sectors, households or activities. In a typical econometric public investment analysis, the impact of public investment on agriculture production, for example, is usually estimated at the sector level, i.e. for all agriculture combined rather than at the sub-sector level (e.g. crops, livestock, fisheries, forestry) and rarely at the commodity level (e.g. cereals, export crops, etc.), which tend to be the level of disaggregation in a CGE model. This is because public investment data, as well as data on many of the other factors affecting agriculture production required for regression analysis, cannot be disaggregated at that level. Thus, to transfer the elasticities that are econometrically estimated for a relatively aggregate sector into the commodity production activities included in a CGE model, bold assumptions about the distribution of the impacts of public investments across sub-sectors and commodities have to be made. Addressing these challenges indicates the direction of future efforts in analyzing the impacts of different types of public investments in an economy-wide setting.

In the next section, we discuss a methodological approach that integrates econometric analysis and general equilibrium modeling to address the two sets of policy research questions that were raised in the introduction in a more comprehensive manner.

[27] Challenges in estimating the public expenditure elasticities have already been dealt with under the sections on econometric estimation.

4. LINKING MICRO, SECTOR AND ECONOMY-WIDE MODELING FOR PUBLIC INVESTMENT ANALYSIS

4.1. THE CGE MODEL AND ECONOMY-WIDE LINKAGES

Following up on the brief introduction in the preceding section, CGE models consist of a set of mathematical equations that describes the behavior of and linkages between the various economic agents in a country's economy, including producers, households, enterprises, and governments. Equilibrium conditions ensure that total production equals total consumption, and total factor demand equals total supply. Macroeconomic "closures" set rules for the government, the current account of the balance of payments and the savings and investments to balance. These equations are then utilized with data in a process called calibration to ensure that the structure and behavior of the model captures the unique characteristics of the country's economy in a given year. The dynamic aspect of the models is governed by updating equations in a recursive fashion, where between-period updating often includes changes in population and technology. While this between-period updating is done exogenously, other dynamics such as the availability of capital from one period to the next is determined endogenously.

In building the model for public investment analysis, the challenge is to link production and economic growth (the left side of Figure 3) with household incomes and poverty (the right side of Figure 3).[28] Unlike typical macroeconomic models, the model will be more detailed in its treatment of how economic growth is generated because it usually includes many disaggregated sectors (such as different sub-sectors of agriculture, industry and service sectors of the economy). Also, the model can capture spatial differences in production technologies by including regional economic activities. These disaggregations are important for understanding the subsector-specific and regional-specific technologies used by individual producers (e.g. their factor inputs and productivity) as well the linkages among sectors (e.g. cross-sector demand for intermediate goods or backward and forward production linkages). This sectoral detail allows for the assessment of sector-specific public investments that go beyond the targeted sector, i.e. it captures the indirect effects. For example, public investments in a hydropower dam does not only directly benefit the energy sector, but also generates growth in other sectors through for example demand for construction materials, local services such as restaurants, and irrigation for agricultural production.

Economic growth on the supply side is achieved by exploiting factors of production such as labor, land, and other capital assets, whose demand is modeled as a function of public investments. Economic growth on the supply side is also achieved by increasing the productivity of the factors to produce goods and services, which again is modeled as a function of public investments. How these factors are used and what kinds of factors are employed for production varies from sector to sector. The model can take these details into account by including many disaggregated factors (drawing on household, industrial, and labor surveys). For example, the model can differentiate between different types of factors: labor (e.g. skilled vs. unskilled, male vs. female); capital (agricultural vs. nonagricultural); etc. Such distinctions are important because, while employment may generate factor returns, it is important to know the distribution of factor or asset endowments across households in the country to know how the returns or benefits would be distributed. For example, some households do not have access to land and, therefore, are less likely to benefit from investments that improve returns to land. Other households may not have skilled labor and therefore are less likely to directly benefit from public investments that mainly generate demand for skill-intensive activities (such as biotechnology).

[28] See Diao et al. (2007) for detail description of the composition of various general equilibrium simulation models.

The implications are that different *factor-investment elasticities* are required for the disaggregated factors used in the different sectors, sub-sectors or commodities. Similarly, different *productivity-investment elasticities* are required for the different sectors, sub-sectors or commodities included in the model.

Consumption linkages are generated because households spend their factor incomes on commodities. Expenditure patterns of households depend on their asset endowments, as well as their demographic, geographic, and economic conditions. The model captures these consumption patterns and the associated backward linkages in the economy. Also, the model can account for other linkages between households, especially rural and urban households, such as migration and remittances. For example, public investments in a hydropower dam, to continue with the earlier example, can generate incomes for certain households through earnings from construction, irrigation, and other dam-related activities. Households spend this income on other sectors output, such as food, textiles and other consumption items. For other households, the dam might decrease incomes by inundation of agricultural land or loss of income from fishing, which in turn will lead to a reduction of household expenditures.

Integration of the economy into global markets, in terms of both goods and services, and international capital is important since international trade has important implications not only because trade policies are a key policy instrument for industrialization but also because foreign competition and markets can shape the country's prospects for economic transformation. The model captures the effects of trade by allowing producers to supply both domestic and foreign markets. Domestic producers face import competition, where the Armington assumption allows for imperfect substitutability between imports and domestically produced goods. Apart from changes in trade policies, the model is also able to assess the impact of changes in country's terms-of-trade on growth and poverty. Taking these interactions with international markets into account is important for public investment analysis. Consider again the same large-scale investment in a hydropower dam. The impacts on growth and poverty in the country as discussed earlier will also depend on the import intensity of the capital goods used for construction. Given that many developing countries do only have limited domestic production of goods like machinery, and other high-tech inputs, these goods will have to be imported and do not lead to domestic linkage or multiplier effects. At the same time, these imports can lead to a deterioration of the trade balance and if the imports have to be financed by foreign debt, the current account deteriorates. This can lead to a depreciation of the exchange rate and increase the cost of imports, etc.

The model also captures many of the primary functions and constraints of the government (shown by the dotted lines in the Figure 3). The government receives revenue from taxes (such as producer, value-added, income, and trade taxes), as well as from foreign grants and loans. The government spends this income on salaries for state employees, provision of public goods and services, and social transfers to households. Therefore, the model can capture at the same time the benefit-side or spending effects of public investments and the cost-side or financing effects (via taxes, loans, and grants).

The poverty impacts of public investments in the model are captured by linking the economy-wide (or macro) simulation model to a household (or micro) simulation model as discussed earlier (see discussion under section 3.5.2). Together, these features make the overall model a powerful tool for analyzing the economy-wide effects of different types of public investments while ensuring consistency between macroeconomic and poverty-reduction strategies. The main challenge in the empirical implementation lies with obtaining the *productivity-investment* and *factor-investment* elasticities at the level of disaggregation of factors, sectors, sub-sectors, and commodities that are used in the model.

4.2. ESTIMATING PARAMETERS FOR THE CGE MODEL

In the preceding discussion on the CGE model, we have seen that the elasticities need to be estimated at a highly disaggregated level that is associated with different sectors (agriculture, industry and services), sub-sectors (e.g. for agriculture: crops, livestock, fishery, forestry), commodities (e.g. maize, cassava, milk, meat, fish, etc.), and factors of production (e.g. land, labor, capital). In a typical CGE model, these effects are modeled through the objective production function with constant elasticity of substitution (CES) of the following form:

$$Q_{a,t} = \eta_a * \left(\left(\sum_{f \subset F} \theta_{f,a} * F_{f,a,t} \right)^{-\rho_a} \right)^{-\frac{1}{\rho_a}}, \qquad \ldots\ldots\ldots 12$$

where $Q_{a,t}$ is the quantity of aggregate output of activity *a* in time *t*, *F* is the quantity of factor *f* used in activity *a* in time *t*, *θ* is the factor share parameter in activity *a*, and ρ is the factor transformation elasticity in activity *a*. Here, activity, *a*, is used loosely to represent sector (agriculture, industry and services), or sub-sector (e.g. for agriculture: crops, livestock, fishery, etc.) or individual commodity (e.g. for agriculture: maize, rice, cassava, cattle, etc.) production activities. There are two sources of growth (i.e. change in $Q_{a,t}$ over time), of which the first derives from accumulation of the factors *f* and their productivity. The second source, which is measured by *η*, derives from changes in total output that cannot be explained by changes in the factors *f* used in the production. This second part is referred to as technological change or total factor productivity (TFP) or what is commonly known as the Solow residual (see Romer 2000). To explain these two sources of growth further, consider a Cobb-Douglas production function of the following form, where the factors of production *f* are made up of private capital (human or physical), *K*, and labor force, *L*.[29]

$$Q_{a,t} = \eta_{a,t} * K_{a,t}^{\alpha} * L_{a,t}^{1-\alpha} \qquad \ldots\ldots\ldots 13$$

Differentiating $Q_{a,t}$ with respect to *t* gives

$$\dot{Q}_a = \frac{\partial Q_{a,t}}{\partial \eta_{a,t}} \dot{\eta}_a + \frac{\partial Q_{a,t}}{\partial K_{a,t}} \dot{K}_a + \frac{\partial Q_{a,t}}{\partial L_{a,t}} \dot{L}_a; \text{ where } \dot{x} = \partial x / \partial t \qquad \ldots\ldots\ldots 14$$

Using the results $\partial Q / \partial \eta = Q / \eta$, $\partial Q / \partial K = \alpha Q / K$ and $\partial Q / \partial L = (1 - \alpha) Q / L$ in equation 14, and dividing the resulting equation through by Q, we obtain:

$$\frac{\dot{Q}_a}{Q_{a,t}} = \frac{\dot{\eta}_a}{\eta_{a,t}} + \alpha \frac{\dot{K}_a}{K_{a,t}} + (1-\alpha) \frac{\dot{L}_a}{L_{a,t}} \qquad \ldots\ldots\ldots 15$$

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[29] The Cobb-Douglas production function is a special case of the CES form.

where the first term on the right hand side measures the source of growth deriving from TFP, while the other terms together measure the source of growth deriving from accumulation of the factors and their productivity. Therefore, the parameters required for the CGE model can be estimated from econometric analysis of how various types of public investments in agriculture and rural areas, *s*, affect TFP (i.e. direct effects) as well as the factor demands (i.e. indirect effects) used in a particular activity, *a*. These econometric relationships can be represented as:

$$\eta_{a,t} = g^{\eta}(PC_{s,t}, Z_t^{\eta} \mid \psi), \qquad \text{.........16}$$

$$K_{a,t} = g^{K}(PC_{s,t}, Z_t^{K} \mid \omega^{K}), \qquad \text{.........17a}$$

$$L_{a,t} = g^{L}(PC_{s,t}, Z_t^{L} \mid \omega^{L}), \qquad \text{.........17b}$$

$$PC_{s,t} = g^{PC}(PI_{s,t}, PI_{s,t-1}, PI_{s,t-2}, ..., PI_{s,t-N}; PI_{-s,t}, Z_t^{PC} \mid \delta), \qquad \text{.........18}$$

where ψ , ω and δ are vectors of parameters to be estimated that represent the relationship between the individual right-hand side (explanatory) variables and the left-hand side (endogenous) variables. Here, subscript *s* is used to represent different types of public investment, say research, extension, irrigation, or input subsidy, while $PI_{-s,t}$ is used to capture complementarity and tradeoffs among different types of public investments. Note that equation 18 is similar to equation 4. These equations capture the underlying hypotheses that public and private capital are complements, and that an increase in the public capital stock raises the productivity of all factors of production (equation 16), and that by raising the productivity of all factors, public capital crowds-in private capital investments (equation 17a). Equation 16 falls within the typical literature on TFP decomposition analysis where TFP (or TFP growth) is estimated as a function of the public capital stock (*PC*)[30] in agriculture R&D, human capital development, infrastructure development, etc., as well as other factors, Z^{η} (see e.g. Johnson and Evenson 2000; Evenson 2001; Zhang and Fan 2004; Huffman and Evenson 2006). Z^{η} includes variables such as climate, institutions, organization of production and resource allocation, economies of scale, and input quality, etc. (see e.g. Hayami 2001). Typically, the variables should not directly relate to the factors or their productivity. To take climate for example, a year with unusually good weather (precipitation, temperature, etc.) will tend to result in higher output, because bad weather hinders agricultural output. Thus, weather, which does not directly relate to the factors or their productivity, is considered a TFP variable. Following from equation 15, it is obvious that estimating only the TFP effects of public investments captures part of the total effects. Equations 17a and 17b, which capture the crowding-in (or crowding-out) effects of public capital, are the factor demands. Here, Z^K and Z^L will include variables on interest rates, prices, wage rates, property rights, population growth, etc. Research in this area includes studies examining the effects of public research expenditure on private research expenditure (e.g.: David et al. 2000; Malla and Gray 2005).

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[30] Indicators of different types of public capital stock, how they can be measured, and data requirements are discussed in section 5.

As done previously, the vector of elasticities quantifying the effects of different types of public investment on TFP and factors of production can be respectively obtained by:

$$\varepsilon_{PI}^{\eta} \equiv \frac{\partial \eta_{a,t}}{\partial PI_{s,t-k}} = \sum_{s} \left[\frac{\partial \eta_{a,t}}{\partial PC_{s,t}} \frac{\partial PC_{s,t}}{\partial PI_{s,t-k}} \right], \qquad \text{.........19}$$

$$\varepsilon_{PI}^{K} \equiv \frac{\partial K_{a,t}}{\partial PI_{s,t-k}} = \sum_{s} \left[\frac{\partial K_{a,t}}{\partial PC_{s,t}} \frac{\partial PC_{s,t}}{\partial PI_{s,t-k}} \right], \qquad \text{.........20a}$$

$$\varepsilon_{PI}^{L} \equiv \frac{\partial L_{a,t}}{\partial PI_{s,t-k}} = \sum_{s} \left[\frac{\partial L_{a,t}}{\partial PC_{s,t}} \frac{\partial PC_{s,t}}{\partial PI_{s,t-k}} \right], \qquad \text{.........20b}$$

where ε_{PI}^{η} and ε_{PI}^{K} and ε_{PI}^{L} are the vectors of *TFP-investment* elasticities and *factor-investment* elasticities, respectively, and $\partial x = \Delta x / x$.[31] The second term in the brackets of the TFP-investment elasticity equation, which is the same as the second term in the brackets of the factor-investment elasticity equations, $\partial PC_{s,t} / \partial PI_{s,t-k}$, as we saw earlier in equation 5, represents the marginal effect or of transforming actual investments into public capital or public goods and services. Also be referred to as the *capital-investment* elasticity, it measures an aspect of the efficiency of public spending and estimates for various types of public capital in different geographic areas were shown in Table 1.[32] The first term in the brackets of the TFP-investment elasticity equation, $\partial \eta_{a,t} / \partial PC_{s,t}$, is comparable to parameters estimated in the typical literature on the determinants of TFP and can be referred to as *TFP-capital* elasticity. Examples of these estimates in different geographic areas are shown in Table 2, which also includes examples of the overall effects, $\partial \eta_{a,t} / \partial PI_{s,t}$, or *TFP-investment* elasticities. While the examples reveal that public capital and public investment boosts agricultural development through TFP,[33] the level of impact depends on the type of public capital and public investment being evaluated.

[31] See footnote 17.

[32] When compared across space, these give a measure of the relative efficiency of spending of decentralized governments in the provision of public goods and services, for example. Satisfaction by users of those public goods and services may be needed to capture the full measure of relative efficiency, however.

[33] Measuring TFP across sectors and sub-sectors is usually difficult because of data constraints and technical dependencies that limit the ability to allocate factors and inputs across sectors and sub-sectors. The most common approach used in quantifying TFP is the growth accounting technique or the Törnqvist-Theil index (). A second technique is econometric estimation of the aggregate production function, typically of the Cobb-Douglas type as shown in equation 13 (see e.g.: Johnson and Evenson 2000; Huffman and Evenson 2006). Assumption of the production process, e.g. constant returns to scale, is required to use this method. Another approach, which is especially useful in light of price data limitations, is an adaptation of the directional efficiency measure or the Malmquist index, pioneered by Caves et al. (1982) and based on distance functions, where the index can be estimated using data envelopment analysis (DEA) (Färe et al. 1994). The Malmquist index, which is a non-parametric approach, has been especially popular since it does not entail assumptions about economic behavior (profit maximization or cost minimization) and, therefore, does not require prices for its estimation; see Nin-Pratt et al. (2007), for example, for application.

Table 2. Effect of public capital and public investment on Agriculture TFP

Indicator of public capital (PC)	Elasticity	Time lag (years)	Notes
Agricultural extension (staff per 1000 farms)	0.063; 0.059; 0.041	3	India (Rosegrant and Evenson 1995). The estimates for the periods 1956-66, 1967-77 and 1978-87, respectively
Agricultural research (number of scientists per ha of arable land)	0.027	0	LDCs (Johnson and Evenson 2000)
Road density (km/1000km^2)	0.042	3	India (Zhang and Fan 2004)
Road density (km/1000km^2)	0.242	8	India (Fan et al. 2000)
Indicator of public investment (PI)			
Agricultural research (expenditure)	0.131–0.189	35	USA (Huffman and Evenson 2006).
Agricultural extension (expenditure)	0.110–0.156	4	
Agricultural research (expenditure)	0.066; 0.053; 0.049	27	India (Rosegrant and Evenson 1995). The estimates for the periods 1956-66, 1967-77 and 1978-87, respectively
Agricultural research and development (expenditure)	0.255	13	India (Fan et al. 2000)
Soil and water conservation (expenditures)	0.013	3	

LDCs mean least developing countries. Elasticity is the percentage change in TFP due to a one percent change in public capital (*PC*) or public investment (*PI*). The time lag is the number of years that the investment was estimated to have impact, after the year in which the investment was made.

Table 3. Crowding-in and crowding-out effect of public capital on private capital

Indicator of private capital or investment	Indicator of public capital (*PC*) or public investment (*PI*)	Elasticity	Time lag (years)	Notes
Private applied research (expenditures)	Public applied research (expenditures)	0.25–0.28	1	USA (Malla and Gray 2005). Analysis at industry level.
Private applied research (expenditures)	Public basic research (expenditures)	0.20–0.22	5	
Private R&D (expenditures)	Government subsidy (expenditures)	0.10	0	Ireland (Görg and Strobl 2006). Analysis at firm/plant level.
	Square of government subsidy (expenditures)	–0.03	0	
Crop area under private irrigation (%)	Total government irrigation (expenditures)	0.08	11	India (Fan et al. 2000). Analysis at state level.
Crop area under private irrigation (%)	Crop area under public irrigation (%)	0.92	0	

Elasticity is the percentage change in private capital or private investment due to a one percent change in public capital (*PC*) or public investment (*PI*). The time lag is the number of years that the investment was estimated to have impact, after the year in which the investment was made.

Related to equations 20a and 20b, Table 3 offers examples of elasticities depicting crowding-in (or crowding-out) effects of public investments on private investments. The evidence shows substantial crowding-in effects at the aggregate level, while the study by Görg and Strobl (2006) also shows some crowding-out effects at the firm level to be associated with large multinational firms. The difficulty underlying this type of analysis, especially in developing countries, is the lack of data on private sector capital investments at the meso or sector level. However, with the abundance of national household and sector-wide surveys, it is possible to analyze these relationships at the household level by examining the effects of access to various public goods and services (e.g. roads, extension, markets, irrigation, schools, hospitals, etc.) on household capital assets or investments in land improvement (e.g. soil and water conservation structures), improved production technologies (fertilizer, hybrid seeds, cross-bred cattle, etc.), agriculture machinery (e.g. tractors, ploughs, fishing nets, outboard motors, etc.), other productive assets (e.g. trees, livestock, etc.), and human capital (e.g. education, primary or preventive health care, etc.). The literature on agricultural household models (led by: Singh et al. 1986; de Janvry et al. 1991), adoption of agriculture technologies (led by: Feder et al. 1985; Feder and Umali 1993), and induced innovation in agriculture (led by: Boserup 1965; Hayami and Ruttan 1985) provide conceptual and empirical approaches for modeling and estimating such relationships.

As you would anticipate, most of the examples shown above, which capture the range of existing estimates of *productivity-investment* and *factor-investment* elasticities, are not particularly suitable for the model since they are not adequately disaggregated (see discussion in section 3.5.2). Let us take a relatively simple disaggregated CGE model for illustrative purposes and assume: ten agricultural sub-sectors (i.e. maize, cassava, other staple crops, vegetable crops, export crops, other crops, beef, other livestock products, fishery, and forestry); six factors of production (e.g. 2 types each of labor, land, and other capital assets); and four regions (e.g. north, south, east and west). Assume further that we are interested in examining the effects of six different types of public investments (e.g. research and extension, irrigation, farm support subsidies, rural roads, education, and health). This means that, for each of the ten agricultural sub-sectors we would require 144 (i.e. 6 factors times 4 regions times 6 investments) *productivity-investment* elasticities, and 24 (i.e. 4 regions times 6 investments) *factor-investment* elasticities for each of the six factor of production; for a total of 1,584 estimated elasticities.[34] This means estimating a system of 40 regional-disaggregated agricultural sub-sector equations (as shown in equation 16) and 24 regional-disaggregated factor demand equations (as shown in equation 17), in addition to several other equations on public capital formation (as shown in equation 18) and on public investment allocation decision to deal with the endogeneity issues. It is clear that the data required for estimating these parameters will be a major constraining factor.[35] In practice though, not all of the parameters will need to be estimated and so the data requirements will depend on the policy research questions. For example, not all production activities are undertaken everywhere due to agro-ecological constraints or profitability concerns. But even if the data were available, computational requirements may be problematic.

It is therefore not surprising that there have been very few attempts to analyze the economy-wide impacts of public investments along the lines proposed above. The studies by Lofgren and Robinson (2008) and Thurlow et al. (2007) are leaders in the field in this regard. Both studies rely on prior econometric estimates of linkages between TFP growth and different types of

[34] Note that the technical coefficients of the production function (equation 12) in a CGE model are derived from the SAM.

[35] We discuss the data requirements later in chapter 5.

public spending (i.e. aggregate *productivity-investment* elasticities) to simulate the impact on growth and poverty in a DCGE framework. Lofgren and Robinson (2008) use econometric estimates from Fan and Rao (2003) to simulate the impacts for an archetype SSA country. Their baseline simulation, i.e. continuation of past trends in factor accumulation and TFP growth, shows modest growth and little change in poverty. Results of other simulations indicate that economic performance can be improved significantly when government resources are reallocated from unproductive areas to different target areas, with the most positive over-all effects being realized when agriculture is targeted. Thurlow et al. (2007) use econometric estimates from Fan et al. (2004) to simulate the impacts for Kenya and estimate the investments needed to achieve specific growth and poverty reduction targets. Besides using aggregate *productivity-investment* elasticities, both studies do not explicitly model public spending in the factor accumulation and demand process (i.e. explicitly including prior *factor-investment* elasticities as conceptualized above).

It is clear that estimating the *productivity-investment* and *factor-investment* elasticities at a lower level of disaggregation than is normally done is critical for implementing the proposed framework. Overcoming this calls for combining data and analysis at different levels. For example, equations 16 and 17 can be estimated using data from national household surveys (e.g. living standards and measurement surveys) with detail farm production data, in terms land, labor, capital, and input (seed, feed, fertilizer, pesticides, etc) use by production activity, and access to and use of various public services. Since households engage in the production of multiple agricultural activities, but not all, and also may not use all factors and inputs, some level of aggregation will be needed.[36] U nit values can be used to aggregate production across products within the household. Alternatively, and depending the level of representativeness of the survey data, farm and household data can be aggregated upwards to obtain non-zero values for all production activities and factors of production. Equation 18 can be estimated using district-level disaggregated expenditures, where central and other higher-level data can be disaggregated to the district by using some assumed distribution index (see e.g. Fan et al. 2004). Aggregating (or disaggregating) the data to a level that provides non-zero information across the units of analysis is very important, especially for estimating a system of equations, which requires the same number of observations for each variable in the regression analysis.

4.3. EX-ANTE IMPACTS AND PUBLIC SPENDING REQUIREMENTS AND FINANCING

Having seen how the CGE model for public investment analysis can be set up and how the necessary parameters can be estimated, we are now in a position to look at how the simulation results can be used to address the second set of policy research questions that derive from being forward looking:

What are the projected impacts if public investment programs proceed as currently planned?
Are these projected impacts compatible with the development goals and targets?
Could greater or better distributed outcomes and impacts be obtained by reconfiguring the investment portfolio?
What are the new targets that can be set for achieving greater or better distributed outcomes and impacts?
What are the resources needed to achieve the desired outcomes and impacts?
How can these investments be financed?

[36] Having a CGE model with a higher level of aggregation than is normally done is also very important.

The first question dealing with the projected impacts assuming that public investments proceed as planned are simulated in what is commonly referred to as "business-as-usual" scenario. Here, GDP per capita, household consumption, poverty rate, and several other indicators (e.g. quantity of exports and imports, prices, consumption or expenditures of all agents, etc.) are solved for over a period of time (e.g. 15 years), assuming that the economy continues to grow into the future as it has been in the past. Addressing the second question on whether the projected impacts (i.e. business-as-usual results) are compatible with development goals and targets that have been set, e.g. achieving 6 percent agricultural growth by a certain year and halving poverty by 2015, is straightforward. The business-as-usual results can be compared with these targets.

Addressing the remaining questions is where the strength of the modeling exercise comes into play. Could greater or better distributed outcomes and impacts be obtained by reconfiguring the investment portfolio? Here, the assumption is that total public investment continues to grow as in the past. However, different scenarios can be simulated by changing the budget allocation across various types of investment, for example, shifting investment spending from one sector to the other (e.g. from education to agriculture) or shifting investment spending from one sub-sector to the other but within the same sector (e.g. from agriculture subsidies to irrigation). The set of scenarios is virtually limitless. The results of these scenarios can then be compared to those of the business-as-usual. Even if the business-as-usual results are compatible with the set targets, resource reallocation simulations can still be carried out to isolate inefficiencies in the economy, i.e. whether greater outcomes than the targets can be obtained by reallocating investment resources. The value of the indicators associated with outcomes of the desirable simulations can then be used as guidelines in setting new targets to address the fourth question.

Alternatively, the model can be simulated to solve for various sub-sector growth rates that can lead to achieving some desired targets, again say 6 percent agricultural growth by a certain year and halve poverty by 2015, assuming the business-as-usual outcomes are lower than these. Similarly, sub-sector growth targets that are often listed in actual strategy documents of countries can be used for the simulation and then compare the simulated outcomes with the stated objectives and targets. This is another critical value-addition of the modeling exercise by bringing some consistency among different sub-sector strategies in achieving common national goals and objectives. Following these types of scenarios, the next question can be answered by using the resulting government revenue and investments to quantify the resources required to support the desired outcomes.[37] How to finance the investments, and their implications, can be addressed by comparing the outcomes of simulating alternative financing arrangements (taxes, loans, etc.) to achieve the desired outcomes.

Although we have used growth and poverty as the main development outcome indicators, there are several outcomes of the model (e.g. prices and wages, imports and exports, balance of

[37] Note that the amount of public agriculture expenditure required to achieve a particular target, e.g. agricultural growth rate (θ_{ag}), can be estimated directly using the econometric results by estimating the annual growth rate in public agriculture expenditure ($\dot{E}_{agexp}$) needed to achieve the agricultural growth rate. This is given by:

$$\dot{E}_{ag\exp} = \frac{\theta_{ag} - (\varepsilon_{nag\exp} * \dot{E}_{nag\exp} * s_{nag})}{[\varepsilon_{ag\exp} + (\varepsilon_{nag\exp} * \phi_{nag,ag})] * s_{ag}}$$

where: ε_{agexp} *productivity-agricultural investment* elasticity; ε_{nagexp} is *productivity-non-agricultural investment* elasticity; $\dot{E}_{nagexp}$ is annual growth rate in non-agriculture expenditure; $_{nag,ag}$ is the multiplier effect or linkage (i.e. trade-offs and complementarities) between agriculture and non-agriculture expenditure; and s_{ag} and s_{nag} are shares of agriculture and non-agriculture in GDP, respectively. See Fan et al. (2008) for details.

payments, etc.) that need to be considered when analyzing the results of alternative public investment scenarios or options. The integrated framework will be applied in several countries where independent work on econometric analysis of public investments and general equilibrium modeling is on-going or planned by IFPRI and its collaborators. The countries include Ghana, Ethiopia, Kenya, Malawi, Madagascar, Mozambique, Nigeria, Sudan, Uganda, and Zambia.

5. DATA REQUIREMENTS

In this section, we describe key indicators and data that are needed for assessing the economy-wide, growth and poverty-reduction impacts of public investments in agriculture and rural areas. An expanded set of indicators, their detailed description and potential data sources are provided in the Annex. The indicators and data can be categorized into five groups: i) inputs or actual public investment outlays; ii) outputs or public capital and investment spending outcomes; iii) intermediate outcomes; iv) impacts; and v) conditioning and exogenous factors.

5.1. PUBLIC INVESTMENTS IN AGRICULTURE AND RURAL AREAS

Following the internationally recognized Classification of Functions of Government (COFOG) (IMF 2001), public investments refer to government outlay in the form of grants, loans, subsidies or compensation for the provision of public goods and services in the area of agriculture, education, health, infrastructure, research and development, social protection and defense, classified as capital or development expenditure, as opposed to recurrent expenditure. The public goods and services can be provided directly through public service agencies or indirectly by financing private agencies to provide them.

Following the CAADP initiative and the Maputo Declaration by African leaders to allocate 10% of their national budgetary resources to agriculture (NEPAD 2003), concern over what constitutes agriculture and, therefore, agriculture spending has arisen. In response, the AU under NEPAD has initiated an agriculture expenditure tracking system to monitor progress of the 10 percent commitment (NEPAD 2005). The indicators to be tracked are expenditures on both recurrent and capital items separately for the crops and livestock (or agriculture), fisheries, and forestry, aggregated across various functions including research, extension, irrigation, subsidies, etc. Unlike in the case of the IMF, hunting is excluded from this broad classification of agriculture. Also, the issue of whether 10% of national budget is an appropriate indicator as opposed to 10% or some other percentage of GDP for example has also come up. These issues will not be debated here.

In line with the objectives of this paper, we define agriculture to cover all activities pertaining to the production of crops, livestock, fishery, hunting and forestry. The most important issue for assessing the impacts is the nature of disaggregation, which should be according to function, such as research, extension, irrigation, subsidies, etc. The underlying rationale being that agriculture productivity growth, as we have seen, is driven by technological change which is primarily embodied in the genetic material of plants and animals or other productive technologies. In order to realize the benefits of technological change in crop production for example, farmers have to use planting material that embody the latest technology, in addition to complementary technologies and agronomic practices. For this to happen, foremost, there is need to invest in research for the development (or adaptation) of those technologies and practices that are profitable under conditions in which farmers operate. Then, there is need to: make the technologies available to farmers by, for example, investing in infrastructure development; improve the skills of existing farmers in using the technologies and becoming innovative by investing in training and extension, as well as those of potential farmers by investing in the education and health of the general populace, especially those in rural areas; and invest in irrigation development and provision of agriculture protection services. Farmers may also need to be helped to acquire the technologies through farm support or credit programs, for example. Therefore, public investment data on agriculture should be disaggregated by function as given in Table 4. Details regarding other desirable levels of disaggregation, accompanying information for a comprehensive analysis, and potential sources of data are described in the Annex 1.

Table 4. Agriculture Activities

Activity	Definition
Agriculture research	Research and experimental development activities leading or contributing to the development of technologies, information or techniques associated with the raising of plants and livestock, including fisheries
Agriculture extension, advisory, and veterinary services	Activities related to the provision to farmers (including fishery and forest operators and hunters) of: extension and advisory services; pest and disease control services; and forest fire-fighting and fire prevention services, etc.
Irrigation development	Activities related to the provision of irrigation, flood control and drainage services to farmers
Agriculture market and marketing infrastructure and services	Programs or schemes to provide agriculture market information and commodity inspection and grading services to stabilize or improve farm prices and improve agricultural trade in both domestic and international markets
Agriculture education	Provision of basic education and other learning activities to improve the capacity and skills of farmers to: understand and utilize available technologies, information and techniques for raising plants and livestock, including fisheries; and innovate techniques associated with the raising of plants and livestock, including fisheries
Agriculture credit and finance	Provision of credit and financial services to enhance the capability of farmers to acquire and use available technologies, information and techniques associated with the raising of plants and livestock, including fisheries
Agriculture subsidies	Direct support activities that restrict or encourage farmers to produce particular commodities or use particular inputs

Source: Adapted from NEPAD (2005)

Given that agriculture is the largest sector in many developing countries, in terms of its shares in GDP and employment, it is not surprising that agriculture expenditure should be and is one of the most important government instruments for promoting economic growth and alleviating poverty. However, since the majority of the poor lives in rural areas and depends on agriculture for their livelihood, expenditure on infrastructure and social services in rural areas is a complementary government instrument for promoting economic growth and alleviating poverty. Thus, obtaining information on public investment in rural areas, including investments in education, health, and infrastructure (e.g. roads, telecommunications, energy), is critical for the analysis. Details of indicators on these and their data requirements and potential sources are also described in the Annex 1.

5.2. PUBLIC CAPITAL AND INVESTMENT OUTCOMES

Public capital refer to the physical manifestation of the actual public investment outlays in terms of the capital stock, which mainly reflects the supply of public goods and services, while the outcomes refer to the access or use of those capital items by the population. To the extent possible, the information should be: (a) disaggregated by rural/urban; (b) disaggregated sub-nationally, ideally region/province and district; and (c) obtained for as many years as possible.

Some of the desirable indicators are discussed below. Typically, only one indicator is required for each type of investment and so we use "**or**" to indicate some order of priority where applicable. However, correlation coefficients between the investment and capital or outcome indicators may be used to rank suitability of alternative indicators, since the objective is to have indicators that are a realization of the underlying investments.

Agriculture research: number of technologies developed in research institutions or by public agriculture research scientists **or** number of public agriculture research scientists to farmer ratio

Agriculture extension: public extension system coverage (e.g. number of extension officers per unit of agricultural area or target population **or** number and type of extension visits received by households per month or year).

Irrigation: length of physical structures (e.g. canals) **or** capacity of reservoirs or dams in terms of irrigable area.

Education: public education system coverage (e.g. number and types of public schools or classrooms or teachers per 1000 people in relevant education group) **and** composition of education attainment of the population (e.g. percent of population classified by different level of skills **or** adult literacy rate **or** primary school completion or enrollment rate).

Health: public health system coverage (e.g. number of public hospitals or hospital beds or doctors or health service personnel per 1000 people **or** proportion of population receiving public primary health care) **and** average number of productive days in a month or year lost due to health problems per person or household.

Roads and transportation: road density (e.g. total length of various types of road per unit area or population) **or** access to roads (e.g. percent of population within *x* km of nearest type of road) **or** access to public transportation (e.g. percent of population within *x* km of nearest type of public transportation) **and** road condition mix **and** average time and cost per kilometer to travel to key service centers (e.g. hospital, place of work, school, etc.).

Telecommunications: percent of population within *x* distance or time of nearest public telecommunication service (e.g. public phone, post office, etc.) **or** percent of population using different types of public telecommunication services

Electricity: per capita electricity production **or** percent of population with electricity **and** average number of days in a month or year without electricity coverage.

Drinking water supply: percent of population within *x* distance or time to public potable drinking water supply source.

5.3. INTERMEDIATE OUTCOME INDICATORS

The indicators here are meant to capture manifestation of the complementarity between public and private investments as well as the crowding-in (or crowding-out) effects of public investments on private investments. To the extent possible, the information should be: (a) disaggregated by rural/urban; (b) disaggregated sub-nationally, ideally region/province and district; and (c) obtained for as many years as possible. Here too, we use "**or**" to indicate the order of priority where applicable.

Agriculture

- Production/output by agriculture sub-sector (crops, livestock, fisheries, forestry, hunting)
- Price index and wages by sub-sector
- Total agriculture land area (or total cropland or total arable land) and labor employed by sub-sector
- Agriculture land area under irrigation and improved technologies (seeds/breeds, fertilizers, pesticides) by sub-sector
- Value of private investments in agriculture research, extension, land improvement (e.g. SWC, trees, irrigation, wells), machinery and equipment (e.g. tractors, ploughs, canoes, outboard motors), etc. by sub-sector

Non-agriculture

- Labor (percentage of total labor force engaged in non-farm employment in rural sector)
- Price index and wages by sector (manufacturing, industry)
- Value of private investments in sector (transport and communications, health, education, etc.)

5.4. IMPACT INDICATORS

These indicators capture the country's development objectives and goals, which typically include household income, poverty, and food security. The appropriate indicators and data include:

- GDP per growth by sector
- Household income per capita
- Poverty rate and inequality
- Hunger (child malnourishment, wasting, and infant mortality)

Here too, the information should be: (a) disaggregated by rural/urban; (b) disaggregated sub-nationally, ideally region/province and district; and (c) obtained for as many years as possible.

5.5. OTHER INDICATORS AND DATA

Other indicators that capture the agro-climatic landscape as well as business environment are also important, including:

- Population (total, urban/rural, male/female, age distribution) with sub-national disaggregation
- Amount of rainfall with sub-national disaggregation

Foreign trade data on exports and imports: value and quantity, disaggregated by commodity
Import tariff and export tax data, disaggregated by commodity
Tax data: sales taxes (such as VAT), excise taxes (disaggregated by commodity), etc.
Governance

Although the indicators described here in this section seem straightforward, they are in most cases not readily available or not available at the level of disaggregation desired. However, many of the indicators can be constructed from national survey and census data. Therefore, raw data from such surveys needed. These include:

National household surveys on production, consumption, and expenditure
Agricultural household surveys or census
Industrial or firm survey, including small business and informal sector surveys

6. CONCLUSIONS

Public investment is an important instrument for promoting economic growth and poverty reduction. Given the predominant role of agriculture in the economy of many developing countries, in terms of its contribution to GDP and employment, and the fact that the majority of the poor lives in rural areas and depends on agriculture for their livelihood, it is not surprising that public investment in agriculture and rural areas is one of the most important government instrument for promoting overall economic growth and reducing mass poverty. But, what kinds of public investments are needed to achieve stated development objectives of growth and poverty reduction? How should public investment resources be allocated among different types of public goods and services (e.g. agriculture research and extension, irrigation, roads, other infrastructure, education, health, etc.) and across geographical areas (e.g. high-potential versus lagging regions) to achieve greater or better distributed outcomes and impacts? How should the investments be financed? Governments and policymakers in development countries, their development partners and other stakeholders involved with development strategy have been grappling with these fundamental questions for many years. Often governments, policy makers and their development partners have clear principles on how they should prioritize their scarce resources. For example, allocate resources in favor of those sectors which can make the strongest contributions to accelerating pro-poor growth and human development or shift resources in favor of projects and programs which most clearly contribute to poverty eradication in a cost effective manner. However, what is lacking is the information that can be used to operationalize these principles.

Although there is an abundance of theories, methods and evidence on the growth and poverty impacts of public investment, due to differences in methodological approaches and data used in assessing the impacts, there is a large variation in the empirical findings of past studies on the magnitude of impacts and, to some extent, on the direction of impacts. Most of the studies in the past have analyzed only some of the potential pathways of impact or have used methods and data that insufficiently controlled for the various confounding factors. Furthermore, there is very little evidence on the impact of public investments in developing countries, particularly in sub-Saharan Africa.

To help fill these knowledge gaps, and particularly help build the capacity to undertake the underlying analyses, this document first examined the conceptual framework within which different types of public investment in agriculture and rural areas can affect growth and poverty reduction; noting that public investments affect growth and poverty through many channels and the impacts can be assessed at various (household, sector, national) levels, and that there are several conditioning and influential factors for realization of the outcomes at any level. Then, we reviewed different methodological approaches that are used in assessing the impacts, strengths and weaknesses of the different approaches, and issues to consider in assessing the impacts, especially regarding endogeneity of the investment decision and time lag between actual investment outlay and realization of impact. We then presented a holistic framework for assessing the *ex post* and simulating the *ex ante* economy-wide impacts (i.e. net benefits) of different types of public investment in agriculture and rural areas. This framework combines econometric analysis and general equilibrium simulation modeling, taking into account different pathways through which different types of public investment can affect agricultural growth and poverty, direct and indirect impacts, and different levels of impacts. Most importantly, it lays out the specific elasticities that need to be econometrically estimated for the general equilibrium model. The data requirements for doing these were presented by identifying a set of input, output, and outcome indicators that are consistent with the different pathways and levels of impact that can be used in monitoring and assessing the impacts of different types of public investment in agriculture and rural areas.

The proposed integrated framework will be applied in several countries where independent work on econometric analysis of public investments and general equilibrium modeling is on-going or planned by IFPRI and its collaborators. The countries include Ghana, Ethiopia, Kenya, Malawi, Madagascar, Mozambique, Nigeria, Sudan, Uganda, and Zambia.

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ANNEXES

Annex 1. Public investments in agriculture and rural areas

Indicator	Definition	Data/Methodology	Disaggregation[1]	Accompanying information	Suggested sources[2]
1.1. Agricultural research, extension and support services					
Public investment on agricultural research and technology development	Grants, loans or subsidies given by the government to support research and experimental development related to agriculture undertaken by government agencies, research institutes and universities	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Sub-sector (crops, livestock, forestry, fisheries) Region/province, district Sources of financing	Description of NARS and policy on agricultural R&D Number of scientists by level of training, gender, area of research Number of major technologies released with brief descriptions (name of variety/breed, release year, potential average yields)	Ministries: Finance, Agriculture; NARS office;
Public investment on agriculture extension and services	Operation or support given by the government of extension and advisory services to farmers, including fishery and forest operators; pest and disease control services; and forest fire-fighting and fire prevention	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Sub-sector (crops, livestock, forestry, fisheries) Region/province, district Sources of financing	Description of extension system Number of extension agents by gender, level of training Population receiving extension, number and type of visits per month or year received	Ministries: Finance, Agriculture; NARS office;
Public expenditure on agriculture subsidies	Compensation, grants, or subsidies given by the government to support agricultural activities for restricting or encouraging output of a particular commodity, or for allowing land to remain uncultivated, or for	Amount of actual spending (not budget) on transfers, capital items, salaries, and operations	Commodity Sources of financing	Description of subsidies Population receiving by gender	Ministries: Finance, Agriculture

	encouraging use of a particular input				
Public expenditure on agricultural credit and finance	Loans (cash or in-kind) given by the government to rural households to support agricultural activities	Amount of actual spending (not budget) on loans, capital items, salaries, and operations	Sub-sector (crops, livestock, forestry, fisheries) Region/province, district Sources of financing	Description of credit scheme, modalities for recovery, and success Population receiving by gender	Ministries: Finance, Agriculture
1.2. Irrigation					
Public investment on irrigation development	Grants, loans or subsidies given by the government to support the construction or operation of irrigation, flood control, and drainage systems	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Region/province, district Sources of financing	Irrigation potential and development strategy	Ministries: Finance, Agriculture; NARS office;
1.3. Roads					
Public investment on roads	Grants, loans or subsidies given by the government to support the construction, maintenance or operation of roads	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Road classification Region/province, district Urban/Rural Sources of financing	Rural roads development strategy	Ministries: Finance, Roads & Transport;
1.4. Transportation and telecommunications					
Public investment on transport and telecommunications	Grants, loans or subsidies given by the government to support the construction and maintenance of transport and telecommunications facilities and provision of related services to households	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Sub-sector (road, water, rail, air) Region/province, district Rural/Urban Sources of financing	Transport and telecommunications development strategy	Ministries: Finance, Roads, Transport, telecom;
1.5. Markets					
Public investment on markets, marketing infrastructure and services	Grants, loans or subsidies given by the government to support the construction or operation of agricultural markets; programs or schemes to provide agricultural market information to rural households, or stabilize or improve farm	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Type (physical infrastructure, information, etc.) Region/province, district	Markets and agro-processing development strategy Brief description of marketing system for major exports and food staples	Ministries: Finance, Agriculture, Trade;

	prices; operation or support of agriculture commodity inspection and grading services		Sources of financing		
1.6. Electrification					
Public investment on electrification	Grants, loans or subsidies given by the government to support the construction and maintenance of electricity plants and provision of electricity to households	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Region/province, district Rural/Urban Sources of financing	Rural electrification development strategy Main sources of electricity and energy production mix	Ministries: Finance, Energy;
1.7. Education					
Public investment on education	Grants, loans or subsidies given by the government to support the construction, maintenance or operation of schools in rural areas for basic education, including programs targeting agriculture	Amount of actual spending (not budget) on capital items, salaries, and operations	Region/province, district Rural/Urban Sources of financing	Education policy Type and number of public schools Number of teachers by type of school, gender, level of qualification	Ministries: Finance, Education;
1.8. Health					
Public investment on health	Grants, loans or subsidies given by the government to support the construction, maintenance or operation of health institutions and providing health care to households	Amount of actual spending (not budget) on capital items, salaries, and operations	Expenditure (capital, recurrent) Type (Primary, other) Region/province, district Rural/Urban Sources of financing	Public health care policy Type and number of public health care institutions Number of public health care practitioners (doctors, nurses, etc) by gender	Ministries: Finance, Health;
1.9. Other targeted transfers					
Public expenditure on other transfers	Value of spending by the government on cash transfers, emergency food aid and other transfers to disadvantaged groups (poor, women and children, disabled, etc)	Amount of actual spending (not budget) on transfers, capital items, salaries, and operations	Region/province, district Rural/Urban Social groups Sources of financing	Policy on social exclusion	Ministry of Finance; Disaster prevention org;

Notes: [1] Disaggregation by district applies to lowest level of fiscal and administrative decentralization; Disaggregation by sector/sub-sector is according to Classification of Functions of Government (COFOG) (IMF 2001). [2] NHS and DHS refer to national household and demographic and health survey, respectively.

Annex 2. Public capital, investment outcomes and sectoral performance indicators

Indicator	Definition	Data/Methodology	Disaggregation[1]	Accompanying information	Suggested sources[2]
2.1. Agricultural research, extension and support services					
Number of technologies developed			Public/private Sub-sector focus (crops, livestock, forestry, fishery)	List of technologies produced and associated productivity gains	Ministry of Agriculture; NARS office; Universities; Multinational agencies
Agriculture research scientists to farmer ratio	Number of agriculture research scientists per 1000 farmers	Number of agriculture research scientists Number of farmers	Public/private Sub-sector focus (crops, livestock, forestry, fishery) Region/province, district Level of training (BS, MS, PhD, etc.) Gender		Ministry of Agriculture; NARS office; Universities; Multinational agencies
Agriculture extension coverage	Number of agriculture extension agents per 1000 farmers	Number of agriculture extension agents Number of farmers	Public/private Sub-sector focus (crops, livestock, forestry, fishery) Region/province, district Level of training of agents (BS, Diploma, etc) Gender of agents	Description of extension system Percent of farmers receiving agriculture extension Average number of extension visits per month or year received per farmer	Ministry of Agriculture; NARS office; NGOs; Multinational agencies
2.2. Irrigation					
Irrigation development	Percent of agricultural land under irrigation, including area under crops, pastures, and agro-forestry	Total length of infrastructure (e.g. canals) Irrigation capacity or hectares of total irrigable area Hectares of agricultural land that is irrigated	Public/private Sub-sector (crops, livestock, forestry) Region/province, district	Types of irrigation systems and shares in total area irrigated Major crops under irrigation and shares in total area irrigated	Ministry of Agriculture; NARS office; NGOs

		Hectares of total agricultural land			
2.3. Roads					
Road density	Total length of road per unit of land area or population	Total length (km) of road network Total land area (km^2) Total population	Region/province, district Urban/Rural Road classification (tarred, murram, gravel, feeder)	Population within 2 km of each class of road Average distance (or walking time taken) to nearest class of road Road safety	Ministry of Roads & Transport;
Road condition mix	Quality of state of roads according to good, fair and poor	Total length (km) of road network Condition per section	Region/province, district Urban/Rural Road classification		Ministry of Roads & Transport;
2.4. Transportation and telecommunications					
Access to telecommunication services	Population with access to post offices, telephones	Number of people within 2 km of post office Number of people with telephones (fixed or mobile) Total population	Region/province, district Rural/Urban		Ministry of Telecom;
2.5. Markets					
Access to markets	Population with access to markets	Number of people within 2 km of market Travel time to nearest market Total population	Region/province, district Rural/Urban	Constraints to agricultural marketing	Ministries: Agriculture, Trade;
Marketed surplus	Share of post-harvest losses and marketed surplus	Volume/value of post-harvest losses of agricultural output Volume/value of agricultural output that is sold Total volume/value of agricultural output	Sub-sector (crops, livestock, forestry) Region/province, district		Ministries: Agriculture, Trade; Stats office; NHS
2.6. Electrification					
Electricity production	Per capita electricity production or consumption	Total number of units produced Number of people with access	Region/province, district Rural/Urban	Percent of population with access to electricity Number of days of power outages per year	Ministry of Energy;

		Total population			
Electricity usage cost	Cost of electricity use per household	Cost of electricity use averaged over sample households	Region/province, district Rural/Urban		Ministry of Energy;
2.7. Education					
Education coverage	Number of schools or classrooms or teachers per 1000 people in relevant cohort	Number of schools Number of classrooms Number of teachers Total population in cohort	Public/private Type (primary, secondary, etc.) Region/province, district Rural/Urban	Education policy (education for all, etc.)	
Educational attainment	Population with: professional training/skills in health, teaching, research, engineering, etc.; or highest level of education attainment	Number of trained/skilled professionals Number of people with: no education, BS, MS, PhD, etc Total population	Region/province, district Rural/Urban Gender		Ministry of Education;
Adult literacy rate	Population of adults that can read and write	Number of people aged 15 years and above that can read and write Population of adults	Region/province, district Rural/Urban Gender		Ministry of Education;
Primary school completion rate	Percent of primary school children in relevant cohort that have completed primary education	Number completed primary school Total number of children in cohort	Region/province, district Rural/Urban Gender	Primary school enrollment rate Primary school drop-out rates and factors affecting retention in school	Ministry of Education;
2.8. Health					
Health coverage	Number of hospitals or hospital beds or physicians or health service personnel per 1000 people	Number of hospitals Number of hospital beds Number of physicians Number of health service personnel Total population	Public/private Region/province, district Rural/Urban	Health care policy (primary health care, health for all, etc.)	
Morbidity	Number of productive days lost due to health problems	Number of days averaged over sample population	Region/province, district Rural/Urban Gender	Major health issues, diseases and illnesses and population affected by gender	Ministry of Health; DHS;
2.9. Other targeted transfers					

Access to credit	Population with access to credit; amount of credit received	Number of people with access to credit Total population	Source of credit Rural/Urban Gender		Stats office; NHS;
Food aid received	Population receiving cash transfers, emergency food aid and other transfers	Number of beneficiaries Population considered disadvantaged Total population	Region/province, district Rural/Urban Social group		Disaster prevention organization;

Notes: [1] Disaggregation by district applies to lowest level of fiscal and administrative decentralization; Disaggregation by sector/sub-sector is according to Classification of Functions of Government (COFOG) (IMF 2001). [2] NHS and DHS refer to national household and demographic and health survey, respectively.

Annex 3. Intermediate outcome indicators

Indicator	Definition	Data/Methodology	Disaggregation[1]	Accompanying information	Suggested sources[2]
3.1. Agricultural trade, production and productivity					
Agricultural trade	Value of total agricultural exports		Imports and exports Sub-sector (crop, livestock, forestry, fishery)	Export promotion strategy Tariff and agriculture protection policies	Ministries of Trade and Agriculture; Export promotions office
Agricultural production	Value-added of total agricultural production at factor cost		Sub-sector (crop, livestock, forestry, fishery) Region/province, district		Ministry of Agriculture; Stats office
Factors of agricultural production	Amount (and value) of factors used in agricultural production	Labor force by gender Hectares of total agricultural land (by land use) Value of machinery and equipment (tractors, harvesters, outboard motors, dryers, etc) Value of livestock and fingerlings Value of land investments (SWC, irrigation, trees, etc.)	Sub-sector (crop, livestock, forestry, fishery) Region/province, district	Annual average rainfall Length of growing period Agro-ecological classification	Ministry of Agriculture; Stats office
Adoption of improved technologies	Area under improved technologies	Hectares of land under improved biological (hybrid seeds, agro-forestry, etc.) and chemical technologies (fertilizers, pesticides, etc.)	Sub-sector (crops, livestock, forestry) Region/province, district	List of key technologies adopted	Ministry of Agriculture; NARS office;
3.2. Prices and wages					
Price index	Real price index (consumer, retail, wholesale)	Nominal price index averaged for the year Deflator	Sector/sub-sector Region Rural/Urban		Stats office;
Labor wage	Farm and non-farm wages	Amount of local currency	Sector		Stats office;

		per man-day	Region/province, district Rural/Urban Gender		
3.3. Non-agricultural production and productivity					
Non-agricultural production	Value-added of total non-agricultural production at factor cost		Sector (services, manufacturing/ industry) Sub-sector Region/province, district	Workforce by gender Value of capital	Stats office
3.4. Private sector capital investment					
Private sector investment	Value of total private sector capital investments		Sector/Sub-sector (Agro-processing, roads and transport, marketing, social, etc) Region/province, district	Private sector development strategy	Chamber of commerce; Investment Authority; Private sector Ministry; Stats office; NHS
3.5. Migration					
Migration	Percent of population that has migrated out	Number of economically active people that have migrated out Population of economically active people	Sector/Sub-sector Region/province, district Rural/Urban Gender		Labor org; Stats office; NHS; Census
Migrant remittances	Value of total migrant remittances	Value per household averaged over sample households Total number of households	Sector Region/province, district		Ministry of Finance; Stats office; NHS;
3.6. Transportation and transactions cost					
Access to socio-economic services	Distance from home to various public or socio-economic service centers	Distance in km (to school, health center, market, bank, post office, place of work, etc) averaged over sample population and travel modes	Region/province, district Rural/Urban		Stats office; NHS
User cost of public transportation	Travel time and cost taken from home to various	Number of hours and cost to key	Transport mode (road, rail, water, air)	Public transport safety	Ministry of Roads &

services	service centers	destinations/services (school, health center, market, bank, post office, place of work, etc) averaged over sample population	Region/province, district Rural/Urban		Transport;
Transportation cost (goods)	Cost to transport of one ton of goods over 100 km	Cost averaged over travel modes	Region/province, district Rural/Urban	Volume and value of goods transported Volume and value of domestic trade Volume and value of exports and imports	Stats office;

Notes: [1] Disaggregation by district applies to lowest level of fiscal and administrative decentralization; Disaggregation by sector/sub-sector is according to Classification of Functions of Government (COFOG) (IMF 2001). [2] NHS and DHS refer to national household and demographic and health survey, respectively.

Annex 4. Impact and welfare indicators

Indicator	**Definition**	**Data/Methodology**	**Disaggregation**[1]	**Accompanying information**	**Suggested sources**[2]
4.1. GDP per capita					
Real GDP per capita growth rate	Annual percentage change in constant GDP per capita	Nominal GDP GDP deflator Total population	Sector/Sub-sector Region/province, district		Stats office
4.2. Rural income					
Household income	Household income per capita	Household income averaged over sample population Household size averaged over sample population Total population	Region/province, district Rural/Urban Gender	Sources of household income (by gender) and shares in total household income	Stats office; NHS
4.3. Poverty and food security					
Poverty rate	Population Headcount Ratio	Number of people with income or consumption expenditure below the national poverty line Total population	Region/province, district Rural/Urban	Inequality measures	Stats office; NHS
Household assets	Value of total assets per household	Value of assets averaged over sample households Total number of households	Region/province, district Rural/Urban		Stats office; NHS
Food security	Population that are food insecure, based on household per capita caloric availability	Number of people with insufficient available calories Total population	Region/province, district Rural/Urban		Ministry of Health; Stats office; DHS;
Hunger	Child Malnutrition: population of children under 5 years of age with insufficient energy dietary intake Underweight Children: population of children under 5 years of age suffering from weight loss Child Mortality: population of	Number of malnourished children Number of underweight children Number of child deaths Total number children under 5 years	Region/province, district Rural/Urban Gender		Ministry of Health; DHS;

	children under 5 years of age that have died due to nutrition-related factors and healthy environments				

Notes: [1] Disaggregation by district applies to lowest level of fiscal and administrative decentralization; Disaggregation by sector/sub-sector is according to Classification of Functions of Government (COFOG) (IMF 2001). [2] NHS and DHS refer to national household and demographic and health survey, respectively.

Annex 5. Conditioning factors

Indicator	Definition	Data/Methodology	Disaggregation[1]	Accompanying information	Suggested sources[2]
Total public expenditure	Value of total public spending	Amount of actual spending (not budget) on capital items, salaries, and operations within the year	Central and decentralized Sector shares Sources of financing	National economic development and poverty reduction strategy	Ministry of Finance; NEPAD[3]
Governance	Composition of governing boards		Membership (gender, farmers, CSOs, etc)	Frequency of undertaking strategic planning exercises	Ministries of Finance and Agriculture
Population		Total number of people	Region/province, district Rural/Urban Gender Age		Stats office
Real interest rate		Nominal interest rate (average % per year) Deflator	Sector	Interest rate policy	Stats office
Inflation	Consumer prices	Average % per year			Stats office
Foreign exchange rate	Amount of local currency per 1 USD	Average for the year		Foreign exchange policy	Stats office; Bank
Total exports	Volume and value of total exports	Annual tonnage Annual value (US$)	Sector Sub-sector	Export promotion strategy Key trade partners	Stats office;
Total imports	Volume and value of total exports	Annual tonnage Annual value (US$)	Sector Sub-sector	Tariff and protection policies Key trade partners	Stats office;
Import tax rate		Average % per year	Sub-sector or commodities		
Export tax rate		Average % per year	Sub-sector or Commodities		
Domestic taxes	Sales tax (e.g. VAT) Excise tax	Average % per year	Sub-sector or Commodities		
Rainfall	Amount (mm) of rainfall	Annual average	Region/province, district		

Notes: [1] Disaggregation by district applies to lowest level of fiscal and administrative decentralization; Disaggregation by sector/sub-sector is according to Classification of Functions of Government (COFOG) (IMF 2001). [2] NHS and DHS refer to national household and demographic and health survey, respectively. [3] National level data on agriculture sub-sector spending may be obtained through NEPAD's agriculture expenditure tracking system (AETS) (NEPAD 2005).

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