The impacts of public investment in and for agriculture

Synthesis of the existing evidence

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The Impacts of Public Investment in and for Agriculture:
Synthesis of the Existing Evidence

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Abstract

In light of a reinvigorated policy orientation toward agriculture in developing countries following recent dramatic developments affecting food prices and agricultural land use, public resource allocation decisionmakers ought to have access to the existing evidence from academic research on the impact of public investments related to and in support of agriculture. The objective of this review paper is to synthesize available knowledge on the impact of public investments in and for agriculture in developing countries and to draw conclusions from this body of work to help determine policy and future research directions.

The potential for agricultural investments to have significant and observable effects on health and nutrition is great, through access to own-produced food, by lowering food prices, and by raising incomes with which to buy more and more nutritious food and health services. An emerging literature on the cost-effectiveness of biofortification programs reveals strong impact of these interventions. For example, the internal rate of return (IRR) of biofortification investments range from 66 to 133 percent for golden rice in the Philippines, and the costs of averting loss of disabiliy-adjusted life years (DALYs) through zinc and iron biofortification of wheat and rice in many cases meet standards of high cost effectivess.

Analysis has shown the importance of public investments in agricultural research and development, irrigation, and extension in the growth of production. But the contributions of different types of agricultural investment can strongly differ. Across many studies undertaking such comparisons, based on various methodologies, R&D investments often have the single largest effect on sectoral growth—even more so when considering long-run effects. R&D investment returns in terms of poverty reduction are, across several studies also not only often stronger but also more stable than that of other types of agricultural public spending. Just as the effect of different functional investments in agriculture may vary in magnitude, agricultural public spending might also differ by the commodity being targeted. Ex-ante analyses show stronger economywide effects of investments in staple crops than in export crops, through the formers' stronger cross-sectoral forward and backward linkages and employment effects.

Rather than considering the components of agricultural spending, such as R&D, irrigation, or other functions, or the investments specifically targeted at certain commodities, some studies have explored how effective agricultural expenditure in its aggregate is at increasing welfare and development. In contrast to analyses of investments in particular elements in agriculture, in the case of studies of aggregate agricultural spending the picture is more mixed, suggesting that policy should ultimately target productive components of agricultural expenditures, and that increasing agricultural spending without attention to heterogeneous impacts of different types of agricultural investments may not bring about the strongest outcomes.

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Public investment designed to provide public goods can increase the profitability of private investment, but can also have crowding-out effect on private investment, such as through macroeconomic effects. The net effect on private investment may thus be positive or negative. The existing evidence on this is strongly mixed in thus inconclusive, but is also only limited to a specific developing region, and thus need to be better understood in different settings.

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Contents

I. Introduction

From the 1960s to the early 2000s, various policy streams, priorities, and development paradigms in parts of the developing world challenged the agricultural sector and led to declining, faltering, or inappropriate investments in the sector. In much of Africa and some parts of Asia, for example, a postindependence focus on development through industrialization led governments to neglect investing in agriculture, despite the prevailing ideology at the time of substantial government investments and public-sector presence in the economy. In the 1980s, the belt-tightening directives from the international community to developing economies implied not only a reduction in public expenditures in the social sectors—which is the often-emphasized element of the structural adjustment era in discussions about its implications for public expenditures—but also to a scaling back of investments in agricultural infrastructure and human resources for service provision. In the 1990s and into the early part of the subsequent decade, disappointment with sluggish agricultural growth in some developing regions, combined with perceived (and to some extent real) underperformance of agricultural investments by aid agencies and governments, led to a continuing decline and to low levels of public investment in this sector.

Although this trend existed in some parts of the developing world, in others—most notably in South, East, and Southeast Asia—relatively consistent and significant public investments in technology, infrastructure, and services in or supportive of agriculture, conspired with propitious natural conditions, leading to sustained and impressive agricultural productivity that was coined the Green Revolution. In turn, these developments contributed to significant and steady reductions in poverty and to improvements in nutrition and human health, though with important and vexing exceptions in parts of the region.

Several recent developments suggest serious public attempts to revise resource allocation for those areas in which agricultural investments have been lagging or ineffective. In Africa, for example, recognition of the deleterious impact of the decades-long downward spiral of public investments in agriculture—which contrasted painfully with the sustained successes of Asia's Green Revolution—led to the initiation of a concerted continentwide effort in the early 2000s to increase agricultural investments in the form of the Comprehensive Africa Agriculture Development Program (CAADP). After a slow start, this initiative is beginning to take shape and is generating greater attention to the sector. The global food price spikes of the late 2000s also concentrated the collective minds of national governments and the international community, leading to a realization that putting in place the requisite investments to support agricultural productivity growth must be an important element of addressing the economic and food security crises brought about by the rapid escalation and volatility of food prices.

In light of this policy reorientation toward agriculture, public resource allocation decisionmakers—whether politicians in developing countries or managers of donor agencies—ought to have access to the existing evidence from academic research on the impact of public investments related to and in support of agriculture. Thus, the objective of this review paper is to synthesize all available knowledge on the impact of public investments in and for agriculture in developing countries and to draw conclusions from this body of work to help determine policy directions as well as future research directions.

In Section 2, we lay out the conceptual rationale for public-sector investments within and in support of the agricultural sector. This section describes, in broad strokes, the areas in which public investment may be called for, as well as areas in which other forms of public policies may be preferred. Section 3 offers a review of trends in the size and composition of government spending in general and in agricultural spending in particular for 1980–2007.

Sections 4 and 5 undertake an extensive review of the literature on the impacts of public expenditures and investments in and for agriculture. In so doing, Section 4 first synthesizes the state of evidence on the returns to agricultural research and development and discusses how different forms of agricultural investments (research, extension, irrigation, fertilizer subsidies, and so on) perform comparatively. Going beyond consideration of impacts on the performance of the agricultural sector, Section 4 brings together findings on how agricultural public investments have affected health and nutrition outcomes. In Section 5, the returns to agricultural expenditures are compared with returns in other investments, such as education, health, and infrastructure. In addition, this section considers returns to investments in terms of poverty outcomes. Section 5 also discusses the temporal and spatial dimensions of returns to spending—that is, how returns change over time, how long- and short-term impact varies, and how investments in high-potential areas fare compared with investments in remote or less-favored areas. The section closes with a discussion of the evidence on the effects of agricultural public investment on private investment. Section 6 highlights the key findings and conclusions from this review paper and suggests directions for future policy as well as future research.

In Appendix A, we define key public finance terms that emerge in analyses of the impacts of public investments in and for the agricultural sector. We first step away from the common treatment of the terms used in analytical papers in the fields of agricultural economics, development economics, and so on, to examine how public finance terms are properly defined, categorized, and classified in guiding frameworks that are centrally concerned with government finance. We then return to common usage of the terms in research works and discuss actual and seeming divergences in the treatment of the concepts. We direct the reader interested in the definitions of these terms to visit Appendix A before reading on, as the discussion may provide a useful framework for the sections that follow. Appendix B includes an in-depth summary of existing reviews and meta-analyses of the impacts of research, development, and extension on agricultural outcomes. This summary is provided for the reader who is unfamiliar with this body of literature.

II. The rationale for agricultural public investments

The fundamental rationale for public resource allocation in and for the agricultural sector derives directly from the basic rationale for public investments in general and, even more generally, from the core reasoning underlying public-sector intervention in the economy. Although different economic schools of thought put forward varied justifications for why the government should undertake policies affecting the economy, the most well-established rationales, based on neoclassical economic theory, concern two phenomena: economic inefficiencies brought about by market failures, which can be corrected through public-sector involvement (through public production, subsidization, or regulation); and undesirable levels of inequality or undesirably low material welfare among the poorest segments of society, which too can be remedied through public policy. This section elaborates on these concepts and couches in this framework the rationale for public investments to support the agricultural sector.

Efficiency Rationale for Public Investment in Agriculture Arising from Market Failures

Although one commonly hears complaints that in developing countries, economic inefficiencies—resulting in individual and aggregate depression of production and incomes—exist because of what governments do, there are actually many ways in which inefficiencies prevail because of what governments do not do. Market failures are pervasive in developing countries, particularly in agriculture. *Market failure* refers to the notion that under certain circumstances, unencumbered markets can be inefficient because of the ways in which particular characteristics of goods and services—as well as information about these goods and about the market participants—prevent Pareto optimal outcomes from emerging.

For example, when a producer of the goods or services cannot internalize their full value, fewer of those goods will be produced than is socially efficient. Where relevant information about a good or service—or about the buyer or seller of the good or service—is not equally shared between buyer and seller, mutually beneficial transactions may never take place. In addition, unregulated market space can, in certain cases, limit competition among producers, resulting in reduced aggregate output and welfare. Finally, the inability of different producers to coordinate the production of complementary goods and assets can leave an economy—or a sector, such as agriculture—in a low-level equilibrium. We discuss each of these phenomena in turn, show how they are exhibited in the agricultural sector,[2] and explore what space this creates for public investments that mitigate market failure–driven efficiency problems.

Public Goods

Pure public goods are characterized by nonrivalry and nonexcludability. A good is nonrivalrous when its consumption by one agent does not reduce the amount of the same good that can be consumed by another agent. A good is nonexcludable if agents cannot be effectively barred from consuming the good. Given these features, public goods will be underprovided by private agents, because the goods' nonrivalrous nature means that their social benefits far exceed any private benefit their producer can capture. In addition, their nonexcludability implies that the producer is not able to extract compensation for the use of the good by all who benefit. The privately produced amount of goods that have these characteristics will be lower than the socially optimal amount, which creates a rationale for public provision of (that is, investment in) such goods. Examples of such goods abound; we discuss here a few examples for illustration.

Although agricultural technology and scientific knowledge may have to be adapted to be widely useable, they have a clear nonrivalrous nature. In developing countries, patents and other contracts to establish intellectual property rights for technology pertaining to widely used staple crops are extremely difficult to enforce at reasonable cost, which renders research and development (R&D) on such products effectively nonexcludable. (Even if excludability could be enforced, there are strong equity arguments against it. Poverty and equity rationales for public intervention are briefly discussed later in Section 2.) These features of agricultural R&D generate a powerful reasoning for public-sector involvement in helping to generate improved technologies in the sector. Barnes (2001) developed this rationale further. Although he examined this issue

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[2] Other discussions (not specific to the agriculture sector) of the rationale of public investments include Coady and Fan (2008), as well as texts in public economics (Myles 1995; Hindriks and Myles 2006).

from the developed-country context, it can be argued that the case is even stronger in developing countries.

Most goods do not take the strictest form of a pure public good. For example, although congestion effects on roads may render the latter nonrivalrous, it is not perfectly so, because users can travel on the road with less ease if many users crowd the road as opposed to when there are few users. Yet, roads, like several other forms of infrastructure, not only have a pronounced public goods character, but are also of major importance to agriculture. Thus, they constitute the kind of capital in which public investment is often strongly justified.

Externalities

Goods and services with externalities are outputs in which the producer either does not capture the full value (for goods with positive externalities) or does not incur all the costs (for goods with negative externalities) related to the good. The additional external value or cost falls on agents other than the producer. Externalities are pervasive in economic production, including in agricultural activities. In developing countries, the efficiency argument for providing publicly financed subsidies for agricultural inputs such as fertilizer and seed is often pinned on the positive externalities of modern input and technology use, or on the mitigation (for example, through fertilizer use) of the negative externalities arising from agricultural production. The latter (that is, the negative externalities of production) pertains to the fact that agricultural activity can result in the depletion of soil fertility, and therefore in soil erosion and runoff, which detrimentally affects downstream users of water. Low-productivity agriculture can also result in the expansion of agricultural production to marginal and forested lands, which also increases land degradation. By increasing plant growth, fertilizer can reduce such soil erosion and its concomitant off-site effects[3] (Shiferaw and Holden 1999). It can also reduce deforestation and the need for expansion of agriculture into marginal lands (Gockowski and Sonwa 2011). Because farmers will not factor in the mitigation of negative externalities as a result of their fertilizer use, there will be an underuse of fertilizer relative to what is socially optimal.In addition, direct positive externalities from the use of modern input and technology—especially in areas in which such use is not already widespread—can result from peer imitation and learning effects among farmers. For example, the probability of a farmer adopting high-yielding seed varieties can increase when neighboring farmers have adopted these improved seeds, as the former learns from the experiences of the latter (Foster and Rosenzweig 1995). Such social externalities through farmer-to-farmer information dissemination, as well as externalities related to the environmental impacts of agricultural production, are but two illustrations of this phenomenon. Other externalities include the effects of cultivation of genetically modified (GM) crops on nearby non-GM farms or the benefits of pest control activities in one area on neighboring areas (see Lewis, Barham, and Zimmerer [2008] for a more detailed discussion of spatial externalities). Public financial policy tools, such as subsidies and taxes or fees, are often used to affect changes in production behavior to correct for too much (or too little) production in the presence of negative (or positive) externalities, by changing the cost of production or the revenue or profit from production faced by the agent. Regulatory measures can also be employed to set production limits or establish modes of production.

[3] However, there are also potential negative externalities to excessive fertilizer use through off-site pollution; thus, the net externalities would need to be considered in public support for fertilizer use.

A concept related to that of externalities are the commons, which refers to a jointly used resource (see Meinzen-Dick et al. [2002] for a broad treatment of commons management in agriculture). A key challenge in the use of commons can be illustrated through the example of land that is used for cultivation or for grazing among a community of farmers in which any given farmer or farming household in the community does not have exclusive use rights over a patch of the land. In this example, there is an optimal intensity of land use that is socially efficient in that it maximizes aggregate production among all community members. Although intensity of use above this level would reduce total production, each farmer may consider only his or her private gains, resulting in overexploitation of the land and lower aggregate gains than is feasible. In this context, useful public intervention may take the form of community-level controls and rules on members' use of the land (López [1997], for example, examined the effectiveness of community controls on the efficiency of common property land use in Ghana). In the case of natural resources used jointly among a larger set of actors—as may be the case of water use for irrigation, whereby overuse would lower the water table and make further use too costly—government regulation of resource use or establishment of property rights may play a role in sustaining socially efficient production.

In general, a range of factors help determine policy choice in addressing externalities, including the effectiveness with which the policy alters production behavior, the policy's effects on economic agents that were not targeted, the fiscal cost (especially in the case of subsidies or tax incentives) and the transaction cost of implementing the policy, and the political feasibility of initiating the policy or of phasing it out after it has served its purpose.

Imperfect Information and Information Asymmetries

Problems of economic inefficiencies arising from imperfect information are exhibited through a special case of this phenomenon—asymmetric information. Information asymmetries exist when, in some economic transaction, one party has more information relevant to a particular exchange than does the other party. This asymmetry will result in inefficient production when, for example, market transactions fail to take place for certain goods or services, due to the imbalance in information. Under conditions of symmetric information, these same transactions would have been supplied (as well as demanded) at a given price and would have been profitable transactions for both supplier and demander.

A classic case in which information asymmetries perturb and diminish markets is insurance, including agricultural insurance. Agriculture is the riskiest endeavor among the major economic activities, especially in developing countries, due to high and difficult-to-predict weather fluctuations, great vacillation in prices driven by global market conditions, and the occurrence of often sudden and dramatic natural shocks such as those caused by plant and animal diseases and pests. Given the high prevalence of the poorest populations having agricultural livelihoods, these conditions hit exactly the type of producers who are least able to bear risk. In this sense, agricultural producers should, in principle, have a high demand for agricultural insurance. Information problems are one of the major reasons for the absence or thinness of agricultural insurance markets. It is difficult for an insurer concerned with profitability to set different premium prices for those farmers who are more susceptible to risks than for those who are less exposed to negative shocks. This is because it would be very costly, or simply impossible, to obtain all the relevant information that would allow insurers to ascertain farmers' risk profile. Instead, an insurer sets a homogeneous premium based on an average farmer, which means lower-risk farmers often find such prices unattractive. This leads to the adverse selection of high-risk farmers into a transaction, which, in turn, increases the average premium for the remaining (higher-risk) farmers, leading to another round of adverse selection, and so forth. Thus, the insurance market thins out due to the asymmetric information problem, and lower-risk farmers remain uninsured, even though at a given (lower) premium, it would have been attractive to both the farmer and the insurer to enter into a contract (Ahsan, Ali, and Kurian 1982; Nelson and Loehman 1987).

In addition to the market consequences of information asymmetries about farmers' ex ante risk profiles, the agricultural insurers' lack of information about the sources of farmers' ex post (that is, after receiving the insurance) risk behavior, combined with altered farmer incentives, has similar market-inhibiting effects. The receipt of crop insurance may alter farmers' behavior such that they take greater risks or use less effort in production activities, because they no longer bear the potential cost of such behavior. This altered behavior, in turn, reduces the average returns for the insurer from the contract. In addition, the insurer is usually not able to incorporate a penalty for such farmer behavior due to the difficulties of observing that behavior and of distinguishing which behaviors were elicited by receipt of the insurance (Ramaswami 1993).

In developing countries, most agricultural credits are limited liability contracts. Under such contracts, agricultural credit markets can face the same moral hazard and adverse selection problems that agricultural insurance markets face (Boucher, Carter, and Guirkinger 2008; Besley 1994).

Although governments past and present have used the subsidy instrument in public expenditure policy to increase the use of agricultural credit and insurance by agricultural producers, subsidies alone may not address the underlying problems of information asymmetries that led to underprovision of credit and insurance in the first place. This is in contrast to the case of underuse of inputs due to externalities, as discussed earlier, in which case, subsidies, in principle, can correct the market failure problem. Instead, there may be an important role that the public sector can provide in investing in information provision—for example, in the case of area-yield crop insurance. Area-yield insurance is one alternative mechanism for mitigating the adverse selection and moral hazard problem of providing insurance. In this scheme, the insurer makes a payout to a farmer if the average yield in an area within which the farmer is located declines by a certain amount or percentage due, for example, to weather shocks (Skees, Black, and Barnett 1997; Bourgeon and Chambers 2003). Thus, the farmer's inherent risk characteristics will not have a significant impact on the conditions that trigger payout, and the moral hazard problem will be reduced because the insurance does not insure against the individual farmer's decline in yield. In this context, the government can play an efficiency-enhancing role in investing in regular data collection of area yields, thus enabling the operation of such insurance schemes.

Another and increasingly popular modality of providing agricultural insurance is weather-based index insurance, in which meteorological information, rather than yield changes, is used to trigger payout (Skees 2008). Here again, public investments in data—in this case, in quality weather data collected by meteorological sites in time intervals and spatial precision that is adequate for use in index-based agricultural insurance—is usually strongly efficiency enhancing.

Another, rather different type of information problem can also be salient in the agricultural sector of developing countries. In contrast to the type of information problem in which the producer has inferior information is the case in which the farmer has information that it is inferior to that held by the seller of a service. An example of this is with agricultural extension. In this case, a farmer may not be fully informed about the extent to which the technical advice provided by an extension agent is actually beneficial for improving that farmer's productivity or income. Thus, if the farmer believes that the extension service is less useful than it actually would be because of the lack of information, then the farmer will be willing to pay less than the value of the advice to him or, in the extreme case, will not be willing to pay anything at all. This asymmetric information–based argument for publicly financed extension goes beyond the commonly expressed arguments derived from the justification of public promotion of agricultural technology adoption, some of which was discussed earlier (see also Bennett 1996).

Imperfect Competition in Markets

Imperfect competition in a market may establish itself in various ways. Thus, it may detrimentally affect efficiency in the economy or in a given sector. In the absence of regulations to counteract market behavior, producers with dominant market power may produce products and set prices in such a way that maximizes producer surplus while not producing efficient outcomes in the aggregate. Such a dominant market position may be attained through the merging of two or more producers, through collusion among producers or the prevalence of cartel arrangements, or through the existence of economies of scale in production (in this latter case, however, imperfect competition is not necessarily inefficient).

Economic inefficiencies arising from monopolistic or oligopolistic concentration of market power are not as pervasive a problem in a developing country's agricultural sector as are the other market failure–inducing phenomena. In most low-income countries in Asia and Africa, most agricultural production comes from smallholder farmers. Even in Latin America, where large plantations are more prevalent, market power concentration in primary agricultural production is not a key impediment to efficiency, because given the core features of the sector, such as spatial dispersion, (primary) agriculture does not lend itself as easily to such concentration as manufacturing or service sectors do.

However, problems of imperfect competition do exist in the agricultural sector, as well as in parts of the supply chain other than primary production. For example, agricultural traders may have to face limited or no competition in their transactions with farmers, especially when market information systems and transport infrastructure are poor, which limit the extent to which farmers can learn about market prices or can take their supply to larger markets or alternative traders. Smallholder farmers' bargaining power can also be curtailed in contract farming arrangements, when a big company—whether a supermarket, a food-processing plant, or another large buyer—becomes the sole source of demand for the farmers' output and may therefore exercise monopsonistic power.

Both the relationship between farmer and trader and the governmental arrangement of contract farming can be hugely beneficial for smallholders and a significant improvement to alternative options in their absence. However, in select cases, considerations of inefficiencies arising from constrained competition in the supply chain do suggest the need for public policy intervention. As already implied earlier, public investments in price and other market information systems, as well as in rural transport infrastructure, can induce greater competition among market intermediaries. For example, Minten and Kyle (1999) found that traders' margins are higher on bad roads in the Democratic Republic of Congo. Regulatory policy enabling contract enforcement in cases in which many farmers face one large buyer will ensure that asymmetric bargaining power is not abused (see, for example, a review of contract farming schemes and appropriate public policy in Porter and Phillips-Howard [1997]).

Coordination Failures

In a macroeconomic framework, coordination failures can lead to inefficient outcomes (Rosenstein-Rodan 1943). In economic structures characterized by multiple equilibria, an economy may be operating at the lower (or lowest) of possible equilibrium points. Especially if the extant equilibrium is a stable (as opposed to unstable) equilibrium, without any nonmarket (such as government) intervention, it may be difficult for the economy to evolve toward a higher aggregate equilibrium output level. Reasons for the existence of multiple equilibria are the prevalence of complementarities between many forms of capital and thus between the economic activities that would generate these different types of capital (Kydd and Dorward 2004). For example, in agriculture, simultaneous investments may be needed in telecommunication and other infrastructure to reduce transaction costs for agricultural markets, in R&D and the dissemination of agricultural technology through extension to increase agricultural productivity, and in credit and insurance markets to enable farmers to undertake private investments and bear some production risk.[4] This coordination failure argument, emanating from the existence of multiple equilibria, speaks to the notion of poverty traps, which may prevail at the macro level, as described here, or at the micro level, such as the household level **(**Costas and Stachurski 2005)**.**

Market Failures and Policy Tools

As is apparent from this discussion on the rationale for public intervention in the face of market failures, the appropriate policy tool for addressing these market failures will vary depending on a range of factors. Public investments—which, in the narrow sense of the term, means resource provision from public funds for the formation of capital—are most clearly justified when market failures arise due to goods having a public goods character. *Public goods*—that is, goods that are nonrivalrous and nonexcludable—are, by their nature, forms of capital.[5] However, public investments, in a somewhat broader use of the term, are also warranted to help create information and data where asymmetric information (rather than public goods attributes) is responsible for market failure.

The coordination failure argument has also been marshalled to justify public-sector investments, including investments in capital and infrastructure that are rivalrous or excludable, and to justify noninvestment spending, such as direct ongoing production by the public sector. The coordination failure argument can, in its most liberal form, go well beyond "first principles" for

[4] Note that this notion of complementarities is founded on mechanisms that, in general, are different from those underlying the complementarities of public investments and private investment (see also "The Impact of Public Investment on Private Investment in the Agricultural Sector" in Section 5.). Complementarities between public and private investment refers to the ways in which public goods increase the returns on private investment—for example, road infrastructure makes the transport of fertilizer inputs and crop commodities cheaper for farmers, who are then more likely to invest in modern technology on their farms. In contrast, the coordination failure phenomenon suggests more broadly that investments in one sector (whether public or private) increase the returns on investments (public or private) in another sector. For example, greater investments in agriculture may increase farmers' incomes, leading those farmers to increase their demand for manufactured goods, which in turn makes industrial investment more profitable.

[5] Of course, the reverse does not hold—that is, not all forms of capital are public goods.

the rationale of public investments and thus should be based on careful and robust analysis of what the coordination failure exactly is. It should then be assessed against alternative mechanisms to address such problems.

Market failures emanating from the existence of externalities may lead private actors, such as farmers or businesses in the agricultural supply chain, to produce too much or too little of a good or service relative to the socially efficient level. These goods with externality characteristics may often not be forms of capital—that is, they may be goods that expire upon their consumption and that do not create a stream of future benefits such as crops. In this case, the goal of government intervention is usually to alter the production behavior of these market actors, rather than supplement private production by providing more of the good by the public sector (in the case of positive externalities). Market production behavior can be altered by using fiscal tools, such as subsidies or taxes, or by regulatory policies.

The Equity and Poverty Reduction Rationale for Public Investment in Agriculture

In addition to efficiency considerations for the role of public investments (as well as other public policies) in and for agriculture, two other fundamental considerations are those that relate to the social value placed on improving the welfare of those with low levels of welfare—concerns with poverty—and those that relate to the social value placed on narrowing wide distributions of welfare in society—concerns with inequality. The poverty-reduction rationale for government expenditures is particularly salient in the case of agriculture, given the concentration of the poorest populations in this sector in most developing countries.

Policies to address poverty in rural and agricultural areas take many forms. One prominent policy that is intended to have the most direct and immediate effect is the provision of direct transfers in the form of cash, food, or other in-kind goods to lowest-income households. These transfers either are without additional requirements or are conditional on household investments in human capital or labor contributions for agricultural or other investments. Another common expenditure measure used as a poverty-alleviation tool is the subsidization of poor agricultural producers' costs, such as price subsidies on agricultural inputs. As described earlier , subsidies may be justified on either efficiency or poverty-alleviation grounds, or often on both. In addition, public investments in agricultural research may be geared toward improving the productivity of smallholders by concentrating on the development of new varieties of crops and livestock that smallholders produce (or consume). The aim of such improvements is to reduce the price for these crops through productivity improvements. A range of investments and public services—for example investments in infrastructure such as irrigation and roads, in extension, in other sectors such as education and health—can also be geographically targeted to marginal or remote areas where the share of lowest-income farmers is higher.

However, in general, any of the public interventions intended to improve efficiency by addressing market failures will also address poverty concerns, insofar as the welfare improvements include welfare improvements among the poor. Even if policies may not have been overtly targeted at achieving poverty reduction, they may contribute to this goal and may sometimes be particularly effective at it and even be superior to overtly poverty-focused expenditures. Section 4discusses in detail the empirical evidence of different types of public investments on poverty reduction.

"Government Failure": Going beyond the Notion of Government as a Benevolent Social Planner

Although there seems to be a powerful rationale for public investments on the grounds of efficiency and distributional considerations, conceptual and empirically based arguments suggest that the optimism about the ability of public-sector interventions to effectively counteract market failures and the prevalence of poverty should be tempered. The concept of government failure has been posited as something of a mirror concept to that of market failure, though the government failure concept is much more diffuse and theoretically much less tightly articulated than that of market failure (for attempts at developing the notion of government failure, see Wolf [1979] and Le Grand [1991]).

The rich public choice literature and the newer, but related, political economics literature have both developed carefully and theoretically grounded ideas of the myriad ways in which government may "fail" in bringing about desired welfare results. Even approaches that do not depart far from the social planner approach of modeling the motives and actions of government—that is, the government as a benevolent agent maximizing a social welfare function, with the requisite authority or power to do so and endowed with sufficient information needed for such action—highlight the many possible unintended (and nonbeneficial) welfare consequences of government action. However, the greater part of the political economy literature does fundamentally part with the notion that governments act like benevolent social planners; in so doing, this literature even further expands arguments and theories on how government action can fall short of improving an economy. For example, some political economy theories develop a degree of symmetry between the treatment of market actors in standard neoclassical economics and the modeling of actors in a political world consisting of citizens, voters, government officials, lobby groups, and so on. This analytical symmetry allows one to explicitly model government actors' efforts to maximize their utility on the basis of their own objective functions (which may depart from the standard social welfare function). It also allows one to model the behavior and choice variables not only of individuals who operate as consumers endowed with the labor and time with which they can earn income and accumulate assets, but also of individuals who operate as citizens and members of organized interest groups endowed with political power, which those individuals can use to bring about preferred policy outcomes. Such models describe the ways in which government actions and policies, including public-investment decisionmaking, may depart from those investment policies that would contribute optimally to aggregate efficiency and poverty-reduction goals. Mogues (2012) synthesized the literature on the political economy determinants of public-investment decisionmaking and discussed insights from this literature for public investments in and for agriculture in developing countries.

III. Trends in the Size and Composition of Government Spending

To set the stage for a review of the empirical evidence on the impacts of public investment, we first analyze the trends in government spending from 1980 to 2007. While recent publications cover similar ground—see, for example Fan, Yu, and Saurkar (2008)—the analysis offered here draws on public expenditure data collected and adjusted from the Statistics on Public Expenditure for Economic Development (SPEED) database, developed by the International Food Policy Research Institute (IFPRI 2010). SPEED compiles and manages information on public expenditures from the Government Finance Statistics (GFS) Yearbook of the International

Monetary Fund (various years), complemented by data from the World Bank (2010) and national sources. The government expenditure data include total government expenditure and its composition by function—namely, agriculture, defense, education, health, social security, and transportation and communication.

To convert expenditures, denominated in current local currencies, into international dollar aggregates expressed in the base year of 2005, prices were first deflated from current local currency expenditures to a set of base year prices using each country's implicit gross domestic product (GDP) deflator. To ensure comparability across nations, the expenditure numbers were then converted into international dollars measured in purchasing power parity (PPP) terms. The 2005 PPP exchange rates, reported by the World Development Indicators (World Bank 2010), were used to convert local currency expenditures, measured in terms of 2005 constant local prices, into a value expressed in terms of 2005 international PPP dollars.

The data cover 70 developing and transition economies, partly because of the availability of data and partly because these countries are important in their own right while also representing broader rural development throughout all developing countries. In 2007, these countries accounted for more than 80 percent of GDP of total developing countries and included 15 countries from the Middle East and North Africa (MENA), 17 from Asia and the Pacific (Asia), 14 from Eastern Europe and Central Asia (ECA), 12 from Latin American and the Caribbean (LAC), and 12 from Sub-Saharan Africa (SSA).

Table 3.1—Countries in the dataset

Region	Country
MENA	Algeria, Bahrain, Djibouti, Egypt, Iran, Jordan, Kuwait, Lebanon, Morocco, Oman, Syria, Tunisia, Turkey, United Arab Emirates, Yemen
Asia	Bangladesh, Bhutan, China, Fiji, India, Indonesia, Korea, Maldives, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, Thailand, Vanuatu
ECA	Azerbaijan, Belarus, Czech Republic, Estonia, Hungary, Israel, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation
LAC	Argentina, Bahamas, Bolivia, Brazil, Costa Rica, Dominican Republic, El Salvador, Guatemala, Mexico, Panama, St. Vincent and the Grenadines, Uruguay
SSA	Botswana, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mauritius, Nigeria, Swaziland, Uganda, Zambia, Zimbabwe

Source: SPEED database, IFPRI (2011).

Note: MENA includes countries in the Middle East and North Africa; Asia includes countries in Asia and the Pacific; ECA includes countries in Eastern Europe and Central Asia and Israel; LAC includes countries in Latin America and the Caribbean; SSA includes countries in Sub-Saharan Africa.

Size of Government Spending

Over the past three decades, total government expenditures in developing countries experienced strong growth. Expenditures increased from $821 billion in 1980 to $1,100 billion in 1990, with an annual growth rate of 3.0 percent (Table 3.2). In the 1990s, governments increased their spending power substantially by 9.5 percent per year. By 2000, total government expenditures had increased to $2,725 billion, and the value nearly doubled to $4,932 billion in 2007, growing at 8.8 percent per year. Overall, we have seen accelerated growth in government expenditures in developing countries.

Table 3.2—Total government expenditure

	Asia	ECA	LAC	MENA	SSA	ALL
Total expenditure (constant 2005 billion US$)						
1980	362.3	NA	204.4	207.6	47.2	821.5
1990	649.6	NA	203.0	205.9	41.1	1099.5
2000	1314.6	492.2	312.0	542.5	63.7	2724.9
2007	2464.7	971.6	624.2	779.6	91.8	4931.9
Ratio to gross domestic product (%)						
1980	18.1	NA	10.0	31.2	22.5	16.7
1990	16.5	NA	8.8	23.4	15.7	14.9
2000	16.9	19.2	9.8	25.3	18.0	17.0
2007	18.1	25.0	15.7	25.4	17.5	19.7
Annual growth rate (%)						
1980–1990	6.0	NA	–0.1	–0.1	–1.4	3.0
1990–2000	7.3	NA	4.4	10.2	4.5	9.5
2000–2007	9.4	10.2	10.4	5.3	5.4	8.8
1980–2007	7.4	6.7	4.2	5.0	2.5	6.9
Share in the sample (%)						
1980	44.1	NA	24.9	25.3	5.7	100.0
1990	59.1	NA	18.5	18.7	3.7	100.0
2000	48.2	18.1	11.4	19.9	2.3	100.0
2007	50.0	19.7	12.7	15.8	1.9	100.0

Source: Authors’ calculations.

Notes: MENA includes countries in the Middle East and North Africa; Asia includes countries in Asia and the Pacific; ECA includes countries in Eastern Europe and Central Asia and Israel; LAC includes countries in Latin America and the Caribbean; SSA includes countries in Sub-Saharan Africa. The annual growth rate for ECA covers 1995–2007.

Total government expenditure as a percentage of GDP measures the amount a country spends relative to the size of its economy. This ratio increased from 17 percent in 1980 to 20 percent in 2007. In the 1990s, the growth of total expenditures was slower than the pace of economic expansion, resulting in a declining expenditure-to-GDP ratio. On average, developing countries spend much less than developed countries. For example, total government outlays as a percentage of GDP in Organization for Economic Cooperation and Development (OECD) countries ranged from 27 percent in 1960 to 48 percent in 1996, compared with 13–35 percent in most developing countries for the same period (Gwartney, Holcombe, and Lawson 1998).

However, among developing countries, regional deviations from these averages were quite marked. Across all regions, Asia experienced the most rapid growth in total expenditures (7.4 percent per year), followed by ECA at 6.7 percent per year and MENA at 5.0 percent. Total government spending increased at a much slower pace in SSA (2.5 percent) and LAC (4.2 percent).

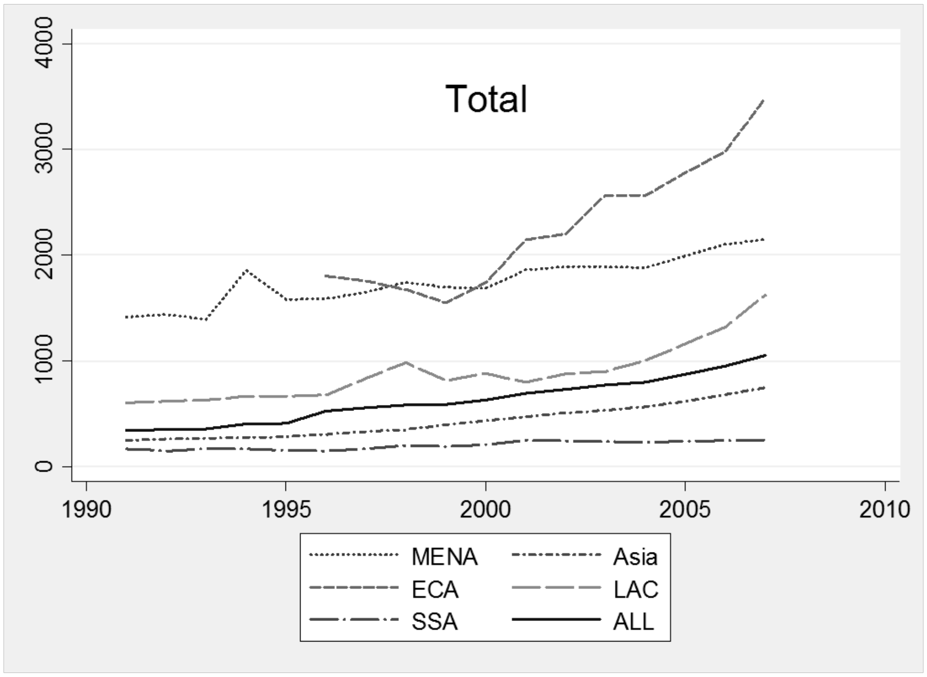
Asia reported steady and consistent increases in total spending at 7.4 percent per year. As a result, Asia accounted for half of the total expenditures in our 2007 sample, because most Asian countries experienced rapid growth and increased their expenditures accordingly. The ratio of total government expenditure to GDP in Asia dropped in the 1980s and 1990s and then recovered to the 1980 level by the 2000s. In ECA, total spending expanded exponentially after a brief period of contraction in the 1990s. By 2007, this region represented about one-fifth of the total expenditure sample.

LAC countries experienced an erratic spending pattern between 1980 and 2007. The share of total expenditure in the sample of 12 countries reduced from 25 percent in 1980 to 13 percent in 2007. Total expenditures did not increase in the 1980s but then grew at 4.4 percent annually in the 1990s. Many countries in the region, including large ones like Argentina and Brazil, were faced with structural adjustment programs, which led to lower spending in the social sectors and lower overall government expenditures before 2000.

Similar to the case in Latin America, total expenditures in MENA countries declined slightly in the 1980s and then surged by 10.2 percent per year in the 1990s. The expansion of total government spending slowed in the 2000s at 5.3 percent per year. Subsequently, countries in the region accounted for about 16 percent of the total sample, which was lower than their 25 percent representation in 1980. The size of government expenditures relative to the economy was the highest in this region, suggesting that government expenditures can have a bigger role in economic performance when compared with other regions.

For SSA countries, total expenditures grew at 2.5 percent from 1980 to 2007. Total expenditures declined in the 1980s at 1.4 percent per year. In fact, there was a brief contraction after 1981, and it was not until 1986 that total government expenditures recovered to 1980 levels, when many SSA countries implemented macroeconomic structural adjustments. During the 1990s, however, SSA countries gained momentum in expanding government expenditures, growing at a modest 4.5 percent per year. The growth of government spending accelerated in the 2000s to 5.4 percent annually. Despite the encouraging growth, however, this region only made up less than 2 percent of total expenditures in the sample, highlighting the low availability of resources for governments. Figure 3.1 shows the trends in per capita total public expenditure by economic activities.

Figure 3.1—Trends in per capita government spending, constant 2005 US$



Source: Authors' calculations.
Notes: MENA includes countries in the Middle East and North Africa; Asia includes countries in Asia and the Pacific; ECA includes countries in Eastern Europe and Central Asia and Israel; LAC includes countries in Latin America and the Caribbean; SSA includes countries in Sub-Saharan Africa.

ECA countries reported both the highest resource allocation and the fastest expansion of public spending since the mid-1990s. Per capita expenditure was also high in the MENA region, with total expenditures reaching $2,148 by 2007, which is more than double the sample average of $1,050. Per capita public expenditures was about $250 in Sub-Saharan Africa, which is the lowest as compared with other regions and only about one-quarter of the sample average.

Composition of Government Spending

The composition of government expenditure reflects government spending priorities; thus, considerably different patterns are observed (Table 3.3, Figures 3.2 and 3.3). The disaggregation of expenditures allows researchers to analyze the relationship between investment and growth in order to capture the tremendous differences across various sectors. For most countries in the total sample, the top three expenditures are education, social protection, and defense, with fast growth also observed in health and social protection expenditures to protect disadvantaged groups.

Table 3.3—Trends in government spending

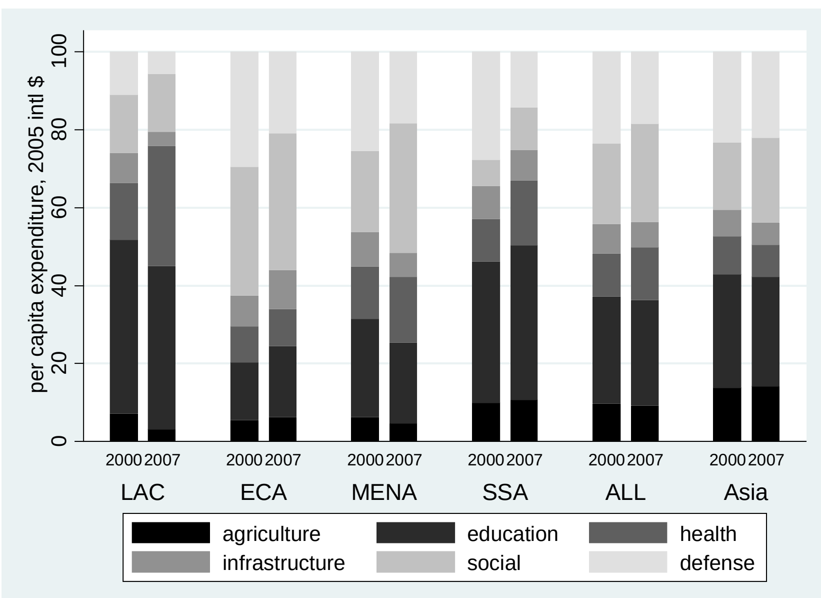
	Agriculture	Education	Health	Infrastructure	Social protection	Defense	Total	GDP	Ag. GDP
Per capita expenditure in 2007 (constant 2005 US$)									
Asia	44	87	26	18	68	69	746	4,131	509
ECA	98	288	149	158	557	330	3,482	13,907	653
LAC	28	376	276	34	131	52	1,620	10,318	588
MENA	53	237	194	70	381	209	2,148	8,450	765
SSA	11	41	17	8	11	15	253	1,443	420

	Agriculture	Education	Health	Infrastruc-ture	Social protection	Defense	Total	GDP	Ag. GDP
ALL	44	131	66	31	122	90	1,051	5,346	537
Share in total expenditure in 2007 (%)									
Asia	5.9	11.7	3.4	2.4	9.1	9.2	100.0		
ECA	2.8	8.3	4.3	4.5	16.0	9.5	100.0		
LAC	1.7	23.2	17.0	2.1	8.1	3.2	100.0		
MENA	2.5	11.0	9.0	3.3	17.7	9.7	100.0		
SSA	4.4	16.0	6.7	3.2	4.4	5.8	100.0		
ALL	4.2	12.5	6.3	2.9	11.6	8.5	100.0		
Expenditure intensity, 2007 (expenditure/GDP)									Ag. exp/ Ag. GDP
Asia	1.1	2.1	0.6	0.4	1.6	1.7			8.7
ECA	0.7	2.1	1.1	1.1	4.0	2.4			15.0
LAC	0.3	3.6	2.7	0.3	1.3	0.5			4.7
MENA	0.6	2.8	2.3	0.8	4.5	2.5			7.0
SSA	0.8	2.8	1.2	0.6	0.8	1.0			8.4
ALL	0.8	2.4	1.2	0.6	2.3	1.7			8.2
Annual growth rate, 2000–07 (%)									
Asia	7.7	6.6	4.9	4.1	11.1	6.3	8.2	7.1	3.1
ECA	10.4	11.6	8.7	12.1	9.3	3.2	10.4	6.3	1.5
LAC	–2.0	9.6	23.0	0.0	10.1	0.9	9.1	1.9	2.6
MENA	–0.6	0.6	7.0	–1.8	10.8	–1.3	3.5	3.5	–0.1
SSA	4.0	4.1	9.1	1.7	10.2	–6.4	2.8	3.3	0.2
ALL	6.1	6.6	10.2	4.0	10.1	3.2	7.6	5.3	2.4

Source: Authors' calculations.

Note: MENA includes countries in the Middle East and North Africa; Asia includes countries in Asia and the Pacific; ECA includes countries in Eastern Europe and Central Asia and Israel; LAC includes countries in Latin America and the Caribbean; SSA includes countries in Sub-Saharan Africa.

Figure 3.2—Composition of government spending, 2002 and 2007



Source: Authors' calculations.

Note: MENA includes countries in the Middle East and North Africa; Asia includes countries in Asia and the Pacific; ECA includes countries in Eastern Europe and Central Asia and Israel; LAC includes countries in Latin America and the Caribbean; SSA includes countries in Sub-Saharan Africa.

Figure 3.3—Composition of government spending, in constant 2005 US$

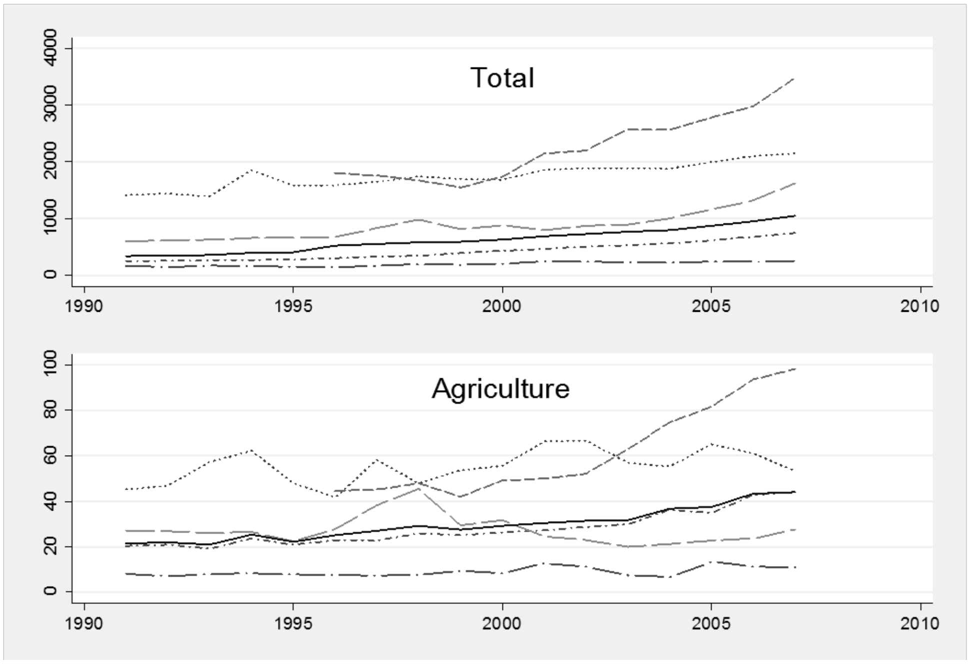
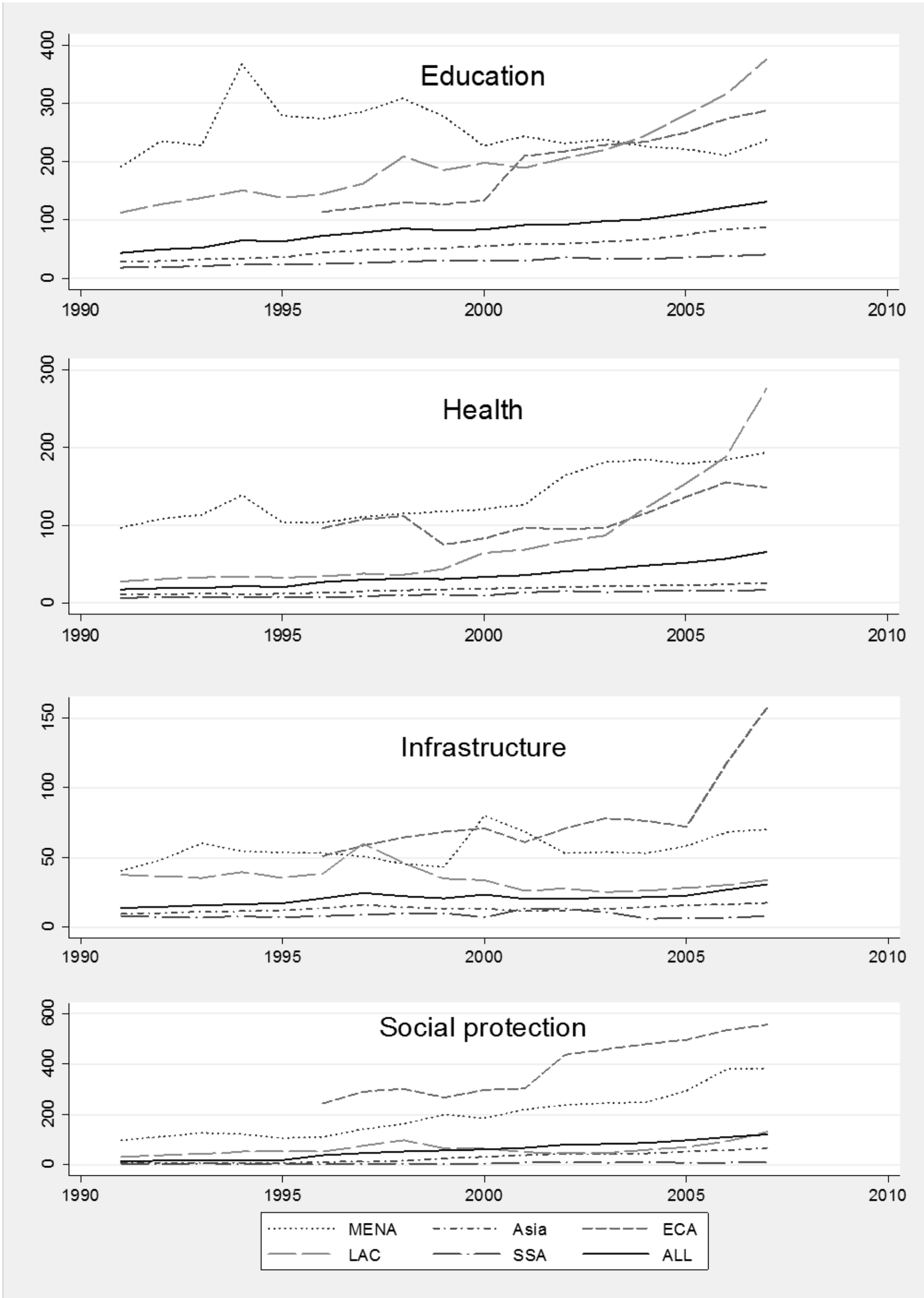


Figure 3.4—Continued.



Source: Authors' calculations.
Note: MENA includes countries in the Middle East and North Africa; Asia includes countries in Asia and the Pacific; ECA includes countries in Eastern Europe and Central Asia and Israel; LAC includes countries in Latin America and the Caribbean; SSA includes countries in Sub-Saharan Africa.

Given Asia's high population density, the per capita expenditure level is modest when compared with other regions. Education spending is the largest among all sectoral government expenditures in Asia: at $87 per person, it accounted for 12 percent of expenditures in 2007. Defense and social protection spending ranked second and third, each accounting for 9 percent of total government expenditures. Between 2000 and 2007, expenditures on social protection in Asia increased the most rapidly, at 11 percent per year, followed by agriculture (7.7 percent) and education (6.6 percent). Although the share of defense expenditures in total government spending declined from 18.7 percent in 1980 to 9.2 percent in 2002, the percentage was still as high compared with the same spending in LAC and SSA, which spent 3.2 and 5.8 percent, respectively, on defense. Defense spending also outpaced Asia's spending on infrastructure and health.

Eastern Europe and Central Asia topped the levels of public investment in agriculture, infrastructure, social protection, and defense. For example, per capita spending in transportation and communication was $158 in 2007, which was more than five times the sample average. On average, $557 was spent on each resident for social protection purpose, dwarfing that of Asia ($68) and Africa ($11). Given the high level of agricultural spending (almost $100 per person), the intensity of agricultural spending in terms of agricultural GDP also doubled the sample average, at 15 percent. After some unstableness immediately after the dissolution of the Soviet Union, government expenditures increased after 2000. The growth rate of sectoral spending ranged from 8.7 percent for health to 12.1 percent for infrastructure. ECA countries had remarkable increases in their expenditures on infrastructure, including transportation and telecommunication, and doubled the per capita infrastructure expenditure within seven years.

Public expenditure on education and health was the highest in Latin America. Per capita education expenditure was $376 in 2007, which was more than triple the sample average of $131. Similarly, government budget allocations also favor the health sector, with a per capita health expenditure of $276, which was more than four times that of the sample average. Education alone accounted for more than 20 percent of total expenditures in 2007. Combined with the health sector, more than 40 percent of total public spending was used for activities related to human capital. The intense investment in human capital, however, was offset by a neglect of productive sectors: agricultural spending declined at 2 percent per year from 2000 to 2007, and infrastructure expenditures stagnated in Latin America.

The rank of social protection spending rose quickly in the Middle East and North Africa, indicating that higher income inequality among population groups in the region may call for government intervention. In 1995, about 7 percent of the total budget was used for welfare; this ratio increased to 11 percent by 2000 and further surged to 18 percent of total government spending in 2007. Per capita health expenditures also increased considerably at 7 percent per year, outpacing other productive sectors like infrastructure and agriculture. Although the level of education spending was still higher than that of the health sector, education activities received less attention in the budget process and grew at 0.6 percent per year. As a result, the growth of agriculture and infrastructure spending in this region lagged behind population growth and produced a negative growth rate in per capita expenditure.

Compared with other regions, SSA countries spent a modest share of their budget on productive sectors. Given the extremely low public expenditure level, spending averaged a meager $11 per capita for agriculture and $8 for infrastructure in 2007. The education sector received priority in resource allocation, with 16 percent of the total government budget being dedicated to education-related activities. Although less than 7 percent of the budget was allocated to health, expenditures on health-related activities expanded at 9 percent per year. SSA governments have also paid more attention to social welfare in recent years. In 2007, per capita public spending in social protection was on a par with that of agriculture, though growing at a much faster speed of 10.2 percent per year between 2000 and 2007.

Even though the share of social protection in total expenditure varied substantially across regions, spending on social safety nets and welfare grew at 9–11 percent per year, which outpaced other sectors in every region except for ECA. Although education and health received more funds, a discouraging trend was seen in MENA and LAC countries, which spent little on transportation and telecommunication. In 2007, about 2–3 percent of total government expenditures across all regions was used for infrastructure. However, the level of infrastructure spending was stagnant in Latin America and even declined sharply at 1.8 percent per year in the Middle East from 2000 to 2007.

Other expenditures, including government spending on fuel and energy, mining, manufacturing and construction, and general administration, accounted for roughly 54 percent of total government spending across all regions in 2007. The share of other expenditures grew marginally in Asia from 2000 to 2007. For ECA, this ratio increased from 48 percent in 2000 to 55 percent in 2007. Allocation for other expenditures actually declined in Latin America, from 50 to 45 percent in seven years. The share of aggregate spending in six sectors—agriculture, health, education, infrastructure, social protection, and defense—remained unchanged in MENA and SSA, at 53.3 and 40.6 percent, respectively. Most of these expenditures were either government subsidies or expenses relating to general administration. The large and increasing share of these expenditures may have competed with more productive spending items, such as agriculture, education, and infrastructure.

Agricultural Spending

Agriculture is the largest sector in many developing countries, as reflected in the share of GDP and employment. More important, the majority of the world's poor lives in rural areas and depends on agriculture for their livelihood. Sustainable agricultural development is therefore imperative in the quest for development. Consequently, agricultural expenditure is one of the most important government instruments for promoting economic growth and alleviating poverty in the rural areas of developing countries. However, until recently, the agricultural sector suffered from underinvestment (Fan and Breisinger 2011). On average, the level of per capita agricultural expenditure increased from $20 in 1980 to $29 in 2000 to $44 in 2007. Agriculture expenditures increased at an annual growth rate of 6.1 percent between 2000 and 2007 (Table 3.3). During the same period, population grew by approximately 0.8 percent per year, and agricultural GDP by 2.4 percent per year. Therefore, there was an increase in agricultural expenditures per capita and agricultural expenditures per unit of agricultural output.

Governments in the Asia and Pacific region appeared to focus more budgetary attention on agriculture, with per capita agricultural spending growing at 7.7 percent per year from 2000 to 2007. Similarly, agricultural spending also picked up steam in the transitional economies in Eastern Europe and Central Asia, where per capita agricultural expenditure doubled between 2000 and 2007. On the other hand, the total budget allocated for agriculture decreased in the Middle East and North Africa, where agricultural expenditure accounted for a small fraction of total government expenditures (2.5 percent), mainly due to the small share of agriculture in national GDP (less than 10 percent). The declining trend was even more obvious in Latin America and the Caribbean, where total expenditure dropped by 2 percent per year. Agriculture played a vital role in SSA's economic growth, contributing to nearly 30 percent of total GDP. However, less than 5 percent of total government expenditure was allocated to the agricultural sector in this region.

Agriculture expenditure intensity, a percentage of agricultural expenditure in agricultural GDP, measures government spending on agriculture relative to the size of the sector. Compared with developed countries, agricultural expenditure intensity is extremely low in developing countries. Whereas developed countries usually have an intensity of more than 20 percent, the latter averages at less than 10 percent in all regions, with the exception of Eastern Europe and Central Asia. In Asia, agricultural expenditure intensity was low in 2007 (8.7 percent). Eastern Europe and Central Asia reported higher agricultural spending relative to agricultural production. For Latin America, agricultural spending as a percentage of agricultural GDP was the lowest among all regions, followed by the Middle East. Sub-Saharan Africa's performance was parallel to that of Asia, at 8.2 percent.

IV. The Existing Empirical Evidence on the Impact of Public Investments in Agriculture

This section brings together and draws policy lessons from all available empirical evidence on the impact of public expenditures for agriculture in developing countries. Other reviews of this topic include Fan and Brzeska (2010), which focuses on East Asia, and Fan and Rao (2008), which synthesizes the evidence from IFPRI research. This section aims to be comprehensive, presenting lessons and findings from all of the academic literature from IFPRI research, as well as from other sources of research, as well as findings across all developing regions on the returns to and impacts of public spending in agriculture. This spending includes that termed *investment spending* as well as other forms of spending. Much of this review presents impacts in a comparative fashion, contrasting impacts across countries and in different subsectors within agriculture.[6]

The section begins with a brief review of one of the most important public goods in the sector, agricultural research and development (R&D). It then highlights evidence of the implications of such investments for improving health and nutrition outcomes, especially through biofortification. The following subsection then compares returns to different agricultural investments.

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[6] Given the ambition of this paper to include a comprehensive review of the literature on this set of topics, we have had to be rigorous about both setting and remaining within the scope of our review. In this vein, it may be worthwhile to further explain the scope generally outlined here. In light of our focus on international peer-reviewed literature, only studies that are published in academic journals or academic books are included. The review also restricts itself to those studies that account in some way for the costs public investments and expenditures—as opposed to, say, studies that measure the impact of irrigation, where "irrigation access" is measured by a dummy variable (farmer has access = 1), with no information on public costs or expenditures. Studies that examine neither agricultural investments nor agricultural outcomes are also excluded—for example, a study of the impact of health, road, and education spending on enrollment would be excluded. Analyses of exclusively developed countries or regions are also not included. Finally, for topics for which there already exist extensive meta-analyses—as for the impact of agricultural R&D—this review focuses on bringing together the key findings from the meta-analyses rather than on discussing individual studies separately.

The Impact of Public Agricultural Investments on Agricultural Outcomes, Health, and Nutrition

A vast literature on the returns to public investments in agricultural research, development, and extension (RDE) finds that annual internal rates of return are substantial. This finding is consistent across a number of comprehensive reviews. In particular, Evenson (2001), Alston et al. (2000a, 2000b), and Alston (2010) presented extensive reviews of the available reported estimates of returns to agricultural R&D and extension investment. Using a variety of models to estimate investment outcomes, these reviews report results in terms of internal rates of return. For a detailed discussion of these comprehensive reviews and their findings, we refer the interested reader to Appendix B.

Recent country-level studies support the findings of the comprehensive reviews discussed in Appendix B. For example, agricultural research in Thailand is estimated to have a significant positive impact on total factor productivity (TFP) and a marginal internal rate of return (IRR) of 30 percent (Suphannachart and Warr 2011), whereas an analysis of an extension service in Uganda reveals IRRs of between 8 and 36 percent (Benin et al. 2011). Suphannachart and Warr (2011) estimated the effect of public spending in agricultural research on Thai crop production via a TFP growth-determinants model. Explanatory variables in the model include public agricultural research, which is measured by real government budget expenditure on R&D activities; extension, which is measured by the real public extension budget; international research spillover, which is measured by the total research expenditure of the three Consultative Group on International Agricultural Research (CGIAR)—the International Rice Research Institute (IRRI), the International Center for Maize and Wheat Improvement (CIMMYT), and the International Center for Tropical Agriculture (CIAT); and infrastructure, which is measured by the share of irrigated land in total agricultural land, as well as by the length of rural roads. Other explanatory variables include resource allocation, trade openness, and weather factors.

The determinants model indicates that public research was a positive and significant determinant of TFP growth from 1970 to 2006, with an elasticity of 0.16 in the short run and 0.07 in the long run. In fact, the long-run elasticity of 0.07 persists into perpetuity as the steady-state equilibrium. Other significant determinants of TFP include international research spillovers (short-run elasticity of 0.09, long-run elasticity of 0.11), extension (short-run elasticity of 0.14, no impact in the long run), rural roads (short-run elasticity of 0.03, long-run elasticity of 0.04), and the commodity price boom of 1972–1974 (short-run elasticity of 0.13, long-run elasticity of 0.15). The highest elasticity figures are seen in the short-run effect of agricultural research on TFP and the long-run effect of the commodity price boom. The social returns of agricultural research (or the marginal IRR) are estimated to be 30 percent.

Benin et al. (2011) determined the returns to public spending on a large-scale extension service program in Uganda. In calculating the cost of the program, the authors accounted not only for the direct spending, but also for the estimated cost of capital (the program was financed through loans received by the government), as well as for the costs to participating farmers. The study found that the program's benefit–cost ratio ranged from 1.3 to 2.7,[7] reflecting different methods of estimating the benefits. This range translates to an IRR of 8 to 36 percent for the program.

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[7] This is under a more conservative estimate of the cost to farmers of participating; a less conservative estimate generates higher returns.

Overall, the substantial literature on public investments in RDE strongly suggests that returns to research and extension are significant. Trends emerging from the comprehensive reviews and recent analyses indicate that higher returns are found in R&D for agricultural endeavors that have shorter production cycles, such as field crops; higher returns have been found in R&D in Asia and developed countries; and R&D is associated with higher returns than are extension and combined RDE. These findings are robust across countries, through time, and across studies, reviews, and methodology. The policy implication of these high returns is that governments have significantly underinvested in agricultural RDE.

As with agricultural outcomes, the potential for agricultural investments to have significant and observable effects on health and nutrition is great. Increased agricultural productivity can offer people greater access to food through at least three pathways: (1) by increasing production for self-consumption, in the case of subsistence farmers; (2) by reducing prices for net buyers of food (IFPRI 2011); and (3) by increasing marketable output for agricultural producers who sell all or part of their output, thus increasing their incomes. The income gains of the third pathway can translate into better nutrition through greater calorie consumption and gains in dietary diversity, as well as improved health through a better ability to purchase medicine and access health services. However, not all agricultural investments will be equally successful in bringing about such gains in productivity, consumption, income, and health. Moreover, impacts of agricultural investment and growth are not inevitably positive—for example, a risk of exposure to food-borne illness and diet-related diseases are also in the realm of possible outcomes.

Although the body of research on the health and nutrition impacts of agricultural growth and productivity is slowly growing, cost–benefit analyses and estimates of returns to the investments that underlie such growth and productivity gains remain underprovided. The exception is an emerging literature on the cost-effectiveness of biofortification programs. Biofortification, or the development and dissemination of micronutrient-enhanced staple crop varieties, is an innovative nutrition intervention designed to reach the rural poor (Meenakshi et al. 2010). Although biofortification involves high start-up costs (such as costs for development and dissemination), once biofortified staples are integrated into the food chain, they continue to provide micronutrient intervention with little additional input (Stein et al. 2008). In addition, biofortification is especially designed to reach the rural poor, as the staple crops targeted for micronutrient biofortification are those that are grown and consumed by the rural poor, often making up a significant part of their daily diets (IFPRI 2011).

The biofortification literature quantifies benefits in terms of disability-adjusted life years (DALYs), a methodology established in Murray and Lopez (1996) that was first applied to a cost–benefit assessment of biofortification in Zimmerman and Qaim (2004) and further developed for evaluation of biofortification programs by Stein et al. (2005). The sum of years of life lost due to premature mortality and years lost due to disability, a DALY captures the loss of one year of healthy life (WHO 2011). For the purpose of cost–benefit analysis, benefits can be calculated in either DALYs lost or DALYs averted. DALYs lost are defined as "the sum of years of life lost because of a preventable death . . . and the years lived without disability because of a preventable disease or condition" (Meenakshi et al. 2010, p. 66); DALYs averted[8] are defined as the sum of "years of life saved because a death has been prevented . . . and years of life spent in

[8] "A public health intervention is expected to reduce the number of DALYs lost, and the extent of such a reduction is a measure of the benefit of the intervention. . . . The DALYs averted are therefore a direct metric for analysing the benefits of the intervention" (Meenakshi et al. 2010, p. 66).

good health because a non-fatal outcome or disability has been cured or prevented" (Meenakshi et al. 2010, p. 66). The use of DALYs to quantify intervention impact offers several advantages: DALYs are comparable across interventions; they capture both morbidity and mortality outcomes; and they do not require the monetization of health outcomes. Each of the studies discussed below present ex ante assessments and assume nutrient deficiency or low bioavailability of the selected nutrients in the selected regions.

Zimmerman and Qaim (2004) pioneered the biofortification cost–benefit analysis literature with their 2004 paper on the health benefits of golden rice (GR) in the Philippines. Calculating the IRR of the GR project, the authors found an IRR of from 133 percent under optimistic scenarios to 66 percent under pessimistic scenarios. Estimated costs of the intervention include the costs of R&D undertaken at the IRRI—including the adaptive research and testing phases of development—as well as the in-country costs of information dissemination in the Philippines and the maintenance and monitoring of the biofortified rice after it was disseminated. Benefits are estimated by quantifying 1 DALY as US$1,030 (the annual per capita income in 2000). Although the estimated IRRs are sensitive to parameter assumptions (for example, an assumed coverage rate of 100 percent versus 25 percent changes the IRR from 155 to 97 percent under optimistic scenarios and from 100 to 50 percent under pessimistic scenarios), they consistently reflect large returns to the GR biofortification project.

Stein et al. (2007, 2008) evaluated the cost-effectiveness of zinc and iron biofortification of rice and wheat crops in India. Throughout their analyses, costs include R&D, crossbreeding, dissemination, and maintenance breeding costs. For the source of these costs, the authors drew on the budget estimates of relevant HarvestPlus biofortification programs. In their evaluation of the cost-effectiveness of zinc biofortification, Stein et al. (2007) found that costs per DALY averted of zinc biofortification of rice are from $0.40 under optimistic scenarios to $3.90 under pessimistic scenarios. Costs per DALY averted of zinc biofortification of wheat are from $1.98 (optimistic) to $39.45 (pessimistic). The authors also assessed the cost-effectiveness of a combined rice and wheat biofortification program . Under both optimistic and pessimistic scenarios, the biofortification of rice is more cost-effective, and that of wheat is less cost-effective, than a combined program. The authors also estimated IRRs to zinc biofortification of these two crops over a 30-year period (assuming 1 DALY is valued at US$1,000). The result is high IRRs for rice —173 percent (optimistic) and 66 percent (pessimistic)—and for combined rice and wheat biofortification (150 percent and 56 percent under optimistic and pessimistic scenarios, respectively).

Similarly, Stein et al. (2008) offered a cost–benefit analysis of iron biofortification in India. Costs per DALY averted of iron biofortification of rice are comparable to those of zinc biofortification—from $0.30 under optimistic scenarios to $3.96 under pessimistic scenarios. However, costs per DALY averted of iron biofortification of wheat are lower than for that of zinc: from $0.60 (optimistic) to $8.71 (pessimistic). In addition, as in Stein et al. (2007), under both optimistic and pessimistic scenarios, the biofortification of rice is more cost-effective, and that of wheat is less cost-effective, than a combined crop biofortification program.

Both studies found that zinc and iron biofortification of rice is most cost-effective, according to the World Bank's 1993 World Development Report standards.[9] Comparing biofortification with

[9] The World Bank's 1993 World Development Report describes the cost-effectiveness of health interventions; these descriptions are referred to in the biofortification literature as reference standards (Stein et al. 2008). The World

other micronutrient interventions, the authors found that the cost-efficiency ratios of biofortification are better than those seen in the form of zinc and iron fortification—that is, the inclusion of these micronutrients in food during the food-processing stage, as opposed to during the agricultural production stage—and of supplementation (that is, the administration of micronutrients in the form of tablets, injections, and so on). In fact, biofortification is significantly less expensive than the alternatives under optimistic scenarios. However, Stein et al. (2008) cautioned that different types of interventions have their merits and that biofortification should not be considered a substitute for other efforts in micronutrient intervention.

In a cross-country, cross-crop, cross-micronutrient cost–benefit analysis, Meenakshi et al. (2010) added comparative analyses to the biofortification literature. They examined the ex ante impact of vitamin A, iron, and zinc biofortification of staple crops in African, Latin American, and South Asian countries or study areas[10] under optimistic and pessimistic scenarios. Costs include those for R&D, adaptive breeding, dissemination, and maintenance breeding and are estimated according to the HarvestPlus budget. Defining highly cost-effective public health interventions as approximately $196 per DALY averted (in 2004 US$), following the World Bank (1993) standards, Meenakshi et al. (2010) found that under optimistic scenarios, vitamin A biofortification can reduce DALY burden at less than $20 per DALY averted across cassava, maize, and sweet potato crops in each of the selected countries/areas, except for northeastern Brazil (which has $127 per DALY averted). Although slightly more costly, iron biofortification of beans still falls well below the highly cost-effective threshold, whereas biofortification of rice and wheat crops is $5 per DALY averted or below in each of the selected countries except the Philippines ($55 per DALY averted). Significantly more costly than the aforementioned interventions, zinc biofortification of beans is still considered highly cost-effective in Honduras ($160 per DALY averted) and northeastern Brazil ($153 per DALY averted); however, it is less cost-effective in Nicaragua ($576 per DALY averted). Finally, the zinc biofortification of rice and wheat is estimated at $1–$2 per DALY averted in the selected south Asian countries and at $12 per DALY averted in the Philippines.

Under pessimistic scenarios, the cost of many of the selected interventions are still well below the highly cost-effective threshold. This interventions include vitamin A biofortification of cassava, maize, and sweet potato in all but northeastern Brazil (cassava) and Ethiopia (maize); iron biofortification of beans, rice, and wheat in all but Honduras (beans), Nicaragua (beans), and the Philippines (rice); and zinc biofortification of rice and wheat in all the selected South Asian countries. Zinc biofortification of beans in the selected Latin American countries, however, rises significantly under the pessimistic scenario to $1,494–$5,940 per DALY averted.

Finally, the analysis includes a comparison of crop biofortification to the alternative micronutrient interventions of fortification and supplementation. Although noting that direct comparison of biofortification with these alternatives is methodologically tenuous due to

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Bank report considers $1–$3 per DALY averted as "most cost-effective" and $50–$150 per DALY averted as "highly cost-effective." Stein et al. (2007, 2008) and Meenakshi et al. (2010) reported costs and corresponding World Bank 1993 standards in 2004 US$.

[10] The interventions include (1) vitamin A biofortification of cassava in the Democratic Republic of the Congo, Nigeria, and northeastern Brazil; maize in Ethiopia and Kenya; and sweet potato in Uganda; (2) iron biofortification of beans in Honduras, Nicaragua, and northeastern Brazil; rice in Bangladesh, India, and the Philippines; and wheat in India and Pakistan; and (3) zinc biofortification of beans in Honduras, Nicaragua, and northeastern Brazil; rice in Bangladesh, India, and the Philippines; and wheat in India and Pakistan.

differences in the calculation of costs, one can nevertheless draw the conclusion that biofortification is relatively more cost-effective than the alternatives in optimistic scenarios. The exceptions include vitamin A fortification in northeastern Brazil and zinc fortification in the Latin American countries—in these two cases, fortification is more cost-effective than biofortification.

Meenakshi et al. (2010) noted that some of these differences in cost-effectiveness across country and crop are due to assumptions in the analyses on the coverage rate (defined as the proportion of total staples that are biofortified staples in production and consumption) and on consumer uptake. For example, due to Africa's less-developed seed systems, the analyses include lower maximum coverage rates for African countries. In addition, vitamin A biofortification of maize, sweet potato, and cassava changes the color of these staples to orange, which may discourage producers and consumers from more fully integrating them into the food system. However, overall, the empirical analyses present consensus: biofortification is highly cost-effective—not only in terms of costs per DALY averted and IRRs, but also in comparison to other micronutrient interventions where nutrient deficiency is a problem and where the biofortified crops enjoy high coverage and consumption rates.

All Public Agricultural Expenditures Are Not Equal: Comparing the Returns to Different Types of Agricultural Spending

Agricultural investments might include investment in general R&D, in rural infrastructure, and in particular crop types or specific technologies. This subsection compares the different returns to these agricultural investments, beginning with a comparison of the impact of technological investments including, but not limited to, R&D.

An analysis of regional[11] cross-section time series (1969–90) data in Indonesia, focusing on four crops—rice, maize, cassava, and soybean—shows the importance of investment in research, irrigation, and extension in the long-run growth of food crop production (Rosegrant, Kasryno, and Perez 1998). The study demonstrates the extent to which growth in rice, maize, cassava, and soybean crops has responded to technology investments over the same period. It finds that 85 percent of the growth in rice, 85 percent of the growth in maize, 93 percent of the growth in cassava, and 71 percent of the growth in soybean crops can be attributed to research, extension, and irrigation investments, with the remaining growth determined by output, input, and factor price changes.

The study, however, also presents evidence that the contributions of different types of agricultural investment to crop-specific output can strongly differ. In the case of maize, cassava, and soybean crops, agricultural R&D investments have the single largest effect on crop growth (62, 51, and 61 percent, respectively), whereas in the case of rice, extension investments have the largest effect. Estimating the determinants of a change in total crop area for the four crops, Rosegrant, Kasryno, and Perez (1998) found that the impact of investments in irrigation are positive, whereas the coefficients on research and extension are not statistically significant. Elasticity estimates of these relationships (see Table 4.1) show that the existing stock[12] of

[11] Eight regions in Indonesia were used: East, Central, and West Java; North Sumatera and other Sumatera; South Sulawesi and other Sulawesi; and other Indonesia.

[12] Rosegrant, citing Huffman and Evenson (1989), used investment stocks, rather than flows, because, "For public investment in technology and knowledge, it is the stock of capital or knowledge, not the annual investment flow, that affects output" (Rosegrant, Kasryno, and Perez 1998, p. 339).

investment in agricultural research has large impacts on the amount of land brought under cultivation over the short and long run, whereas elasticity estimates for new investments and extension are negative in the short run.

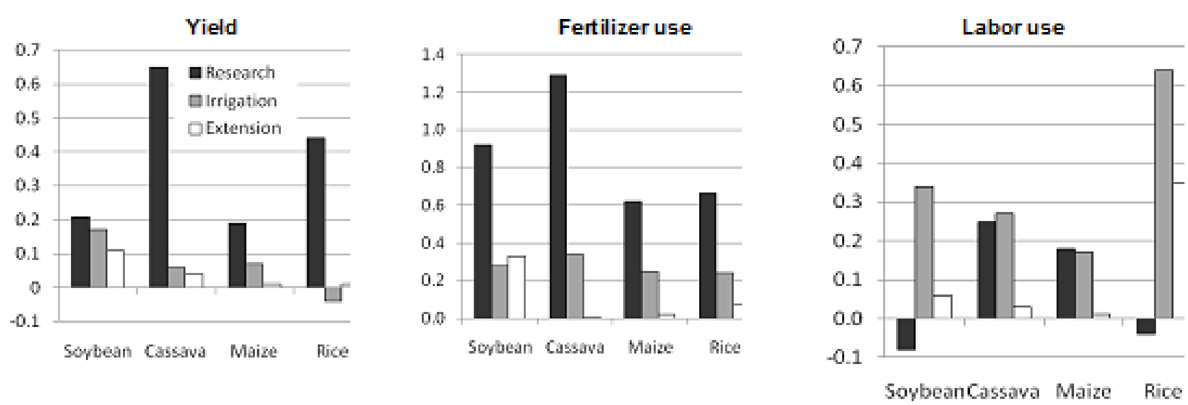
Table 4.1—Food crop area response elasticities with respect to agricultural public investments

	(a) Existing stock of investment	(b) New investment	Net effect (the sum of (a) and (b))
Short run			
Research	0.0599	–0.0330	0.0269
Irrigation	0.0213	–0.0140	0.0073
Extension	0.0005	–0.0006	–0.0001
Long run			
Research	0.0910	0.0501	0.1411
Irrigation	0.0324	0.0213	0.0537
Extension	0.0008	0.0009	0.0017

Source: Adapted from Rosegrant, Kasryno, and Perez (1998).

An estimation of the effect of the stocks of research, irrigation, and extension—as well as of expected crop prices, input prices of fertilizer and labor (as a share of other input prices) on yield, fertilizer use, and labor use by crop—shows that the coefficients on research, irrigation, and extension stock are positive in nearly every case. However, as with the effects on crop growth, the different investments are differentially effective in improving yield and spurring modern input use. Figure 4.1 presents the elasticity estimates. Productivity and research stock elasticities are consistently and substantially higher than those of irrigation or extension expenditures, whereas those of irrigation are consistently higher than those of extension. R&D investments are also better able to affect the use of modern inputs (fertilizer) than are other agricultural investments. The high elasticities on research indicate that agricultural research (generating improved seed varieties) can increase the profitability of fertilizer, given the complementarity between these two inputs. In turn, irrigation investments have a greater impact on fertilizer use than do extension expenditures. Figure 4.1 also shows that at least for some crops, agricultural technology can be labor-saving.

Figure 5.1—Yield and input demand elasticities of agricultural public investments



Source: Adapted from Rosegrant, Kasryno, and Perez (1998).

Just as the effect of different functional investments in agriculture (irrigation, extension, research) may vary in magnitude, agricultural public spending might also differ by the commodity being targeted by the spending. An ex ante analysis of commodity-specific investments in agriculture in Rwanda (Diao et al. 2010) estimates and compares the returns to public expenditures during the period 2006–2015 on specific groups of agricultural products. Although the returns to all types of agricultural investment are high, the returns cover a wide span, from a more than $12 increase in agricultural gross domestic product (GDP) for each additional dollar invested in the fishery sector to equivalent returns of $1.02 for export commodities.[13]

Table 4.2—Dollar returns, in terms of GDP or agricultural GDP, due to a dollar increase in public investment in agricultural commodities, 2006-2015

1. Subsector	2. GDP	3. Ag. GDP	Subsector	GDP	Ag. GDP
Cereal grains	2.75	2.73	Pulses	9.09	8.21
Maize	7.02	6.59	Fishery	12.50	12.35
Paddy rice	1.41	1.22	Cash and export crops	1.02	1.24
Wheat	5.34	5.15	Coffee	1.01	1.74
Roots and tubers	5.03	4.65	Tea	1.95	2.52
Cassava	5.46	4.61	Bananas	5.35	4.94
Irish potatoes	5.88	5.66	Oilseeds	5.89	4.73
Sweet potatoes	2.53	2.22	Other	1.08	1.07
Livestock	2.02	1.90			
Poultry	10.54	10.09	Staple crops and livestock	3.84	3.63
Other	1.81	1.74	Agriculture, total	3.19	3.11

Source: Adapted from Diao et al. (2010).

The analysis also distinguishes between impacts on agricultural GDP and those on overall GDP. In the case of nearly all commodities and commodity groups, the economywide returns are larger than the effects on just agricultural GDP. This finding is not surprising, because agricultural investments not only benefit the sector but also have indirect effects on nonagricultural sectors. These effects are realised through forward linkages, such as when agricultural outputs serve as inputs for food processing, and through backward linkages, such as when greater agricultural incomes expand the demand for outputs for nonagricultural goods and services.

One of the exceptions to the above is coffee, for which the economywide returns are significantly lower than are those for the agricultural GDP returns. This finding indicates the weak backward and forward linkages with the rest of the economy associated with this product, in part driven by the fact that coffee is predominantly an export commodity. These poor linkages are also responsible for coffee's inferior agricultural and overall GDP returns relative to those of staple products. For example, both the agricultural GDP and economywide returns to roots and tubers investments are nearly four times as large as those for cash and export crops, and the returns to public spending on cereal grains are more than double the export crop investment returns.

The above discussion compares different commodity-targeted investments, whereas a study on India (Dastagiri 2010) compares commodity-directed expenditures with public agricultural

[13] This estimates the effect of a monetary-unit increase on the cumulative public investment undertaken during the 2006–2015 period, from the actual and projected (as per government development plans) levels of investment during this period. The returns considered are the full returns during, as well as beyond, the 2006–2015 period. The analysis applies a 10 percent social discount rate, so that the returns for a given amount of public investment eventually go toward 0. In most modeling scenarios across the different crops and commodity groups, the period required for the ex ante analysis to capture all returns is about 20 to 30 years following 2015.

investments that are not specifically geared to any one commodity. According to this study, commodity-directed investments have greater returns to livestock-specific outcomes, which is not surprising; however, it also found, perhaps less obviously, that such investments are more effective in mitigating poverty than are general public investments in agriculture. Using country-level time series (1970–2004) data, Dastagiri (2010) examined the impact of government expenditure on animal husbandry and dairying. The author also looked at the effect of public gross capital formation[14] in agriculture not only on various output measures in the livestock and livestock products sector (for example, including total value of the output of livestock, of milk and of meat), but also on rural and national poverty. Estimating with and without a one-year lag, Dastagiri (2010) found that government expenditures have a significant positive effect both on the livestock sector and on rural and overall poverty reduction. In contrast, gross capital formation in agriculture is effective in improving output in only some of the livestock-related commodities, and the positive effect on poverty reduction is much weaker than that of livestock-specific expenditures. Dastagiri (2010) concluded that government annual expenditure on animal husbandry and dairy has significantly contributed to an increased output value of dairy, livestock and other sectors, while also reducing rural and national poverty. The policy implications of these findings are that, to better meet the dual objective of growth and poverty reduction in India, the government should further invest in the agricultural sector.

Using data on 35 developing countries in four regions[15] between 1974 and 1984, Diakosavvas (1990) disaggregated government agricultural expenditures into current and capital expenditures. In comparing their impact, the author found varying results by region. Agricultural output elasticities of current expenditure are larger than those of capital in Africa and Latin America, whereas in Asia and the Near East, the output elasticities of capital expenditure exceed those of current expenditure. In Ghana, an analysis of returns to public spending reached conclusions consistent with the above mentioned findings in Asia and the Near East with regard to the relative performance of capital and recurrent agricultural spending. Benin et al. (2012) concluded that the higher contribution of capital spending in the agricultural sector to agricultural production reflects the low capital to recurrent ratio in spending composition in the sector in Ghana.

Diakosavvas (1990) also compared the contribution to agricultural output of agricultural private assets and inputs with that of agricultural public spending. Compared with land and labor inputs, current and capital expenditures have smaller elasticities in all cases, though there are regional variations to this general observation. In the case of Africa, Latin America, and the Near East, the output elasticities of labor inputs have the greatest magnitude, whereas in Asia, land inputs are greater than labor inputs. This finding is broadly consistent with the relative scarcity of different factors across regions and with the fact that scarcer factors will have greater returns. Finally, as one of the very few studies that examines the impact of volatility in agricultural investments,[16] this paper indicates that a 10 percent increase in the instability of total

[14] Dastagiri (2010) provided no definition of the term *public gross capital formation*.

[15] The selected countries, by region, are (1) Africa: Cote d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Morocco, Niger, Nigeria, Senegal, Sierra Leone, Tanzania, and Tunisia; (2) Near East: Egypt, Sudan, Syria, and Turkey; (3) Asia: Bangladesh, India, Indonesia, Korea Republic, Malaysia, Pakistan, Philippines, Sri Lanka, and Thailand; and (4) Latin America: Argentina, Bolivia, Colombia, Costa Rica, Dominican Republic, Ecuador, Jamaica, Mexico, and Peru.

[16] There is, in contrast, a rich literature on the impact of aid volatility on economic growth.

government spending on the agricultural sector causes, on average, a 0.36 percent decline in agricultural growth.

Rather than considering the components of agricultural spending, such as R&D, irrigation, or other functions, or of investments specifically targeted at certain commodities, some studies have explored how effective agricultural expenditure in its aggregate is at increasing welfare and development, with the latter data captured using various metrics, such as economic growth, rural incomes, agricultural growth, and poverty reduction. Unlike in the case of analyses of specific types of agricultural investment, here the picture is more mixed. This suggests that policy should ultimately target productive components of agricultural expenditures, with a blanket recommendation that increasing agricultural spending without giving attention to heterogeneous impacts of different types of agricultural investments may or may not bring about desired impacts. One example is a sectoral examination of the impact of public spending in 100 countries at various stages of development, using decade average public investment ratios (share of total spending) for 1970–88. Easterly and Rebelo (1993) found that agricultural spending does not have any statistically significant effect on aggregate growth (captured as growth in per capita GDP). Spending on education, housing and urban infrastructure, and transportation and communication, in contrast, have positive and statistically significant impacts on economic growth. Transportation and communication infrastructure expenditures, in particular, have the most robust effect across a number of model specifications.

Drawing on Easterly and Rebelo (1993), among others, research conducted a decade later on 74 developed and developing countries using an extension of the Solow-Swan growth model (Milbourne, Otto, and Voss 2003) finds very similar results: agricultural spending has a statistically insignificant effect on economic growth, whereas spending in the education and the transportation and communication sectors contributes positively and significantly to income growth.

Mogues (2011) performed a country-level analysis on Ethiopia. The author found that public expenditures on agriculture as a whole do not have comparatively high rural income returns and are surpassed by public investments in road infrastructure and education. Mogues (2011) traced the effects of agricultural performance on rural welfare, as well as the effects of public agricultural spending on agricultural performance. This multistage analysis makes clear that the weak link is the latter effect, whereas the role of agricultural productivity for increasing rural incomes is strong and robust. This finding suggests that the technical efficiency of agriculture outlays, as well as its allocative efficiency, needs to be examined.

The link between aggregate spending and poverty is examined in Mosley, Hudson, and Verschoor (2004) in cross-country research. In the process of constructing a pro-poor expenditures index, the authors estimated the impact of various government expenditures on the dollar-a-day poverty head count ratio. Agricultural expenditure as a share of GDP has a statistically significant positive impact on poverty reduction. A 1 percent change in agricultural expenditure as a share of GDP produces a 0.43 percent reduction in poverty. However, compared with education expenditure, as well as with spending in housing and social services, agricultural spending has the lowest positive impact on poverty reduction. Meanwhile, health expenditure has a statistically significant effect of increasing poverty, with an elasticity of 1.84.[17]

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[17] Although perhaps counterintuitive, this result is either consistent with or points in a similar direction as other studies that compare health and other public expenditures on welfare, incomes, and poverty. According to Mogues

The modest or disappointing results regarding the effects of *aggregate* agricultural expenditures is worth further exploration. Some of the aforementioned studies that found a statistically insignificant effect of aggregate agricultural spending considered economic growth as the outcome of interest. The path from spending through sectoral outcomes to economic growth is not traced, however; thus it is not clear where the weak link exists in these studies—that is, is it in the link from spending to agricultural performance or from agricultural growth to economic growth? One of the studies (Mogues, 2011) did examine different links and traced the weak link to poor linkages between spending and agricultural performance, whereas the link between agricultural performance and rural welfare was found to be strong. Furthermore, although most papers identifying a modest (in absolute or relative terms) showing of aggregate agricultural expenditure returns did not further probe the potential reasons for this result, the literature deriving the impacts of specific types of agricultural investments and spending may provide relevant pointers. As shown in this section and the next, there is great heterogeneity in impacts across the different types of agricultural expenditures, such as input subsidies, research, extension, irrigation, and other areas. An examination of aggregate spending in the sector is likely to wash out these effects, especially if the expenditure composition in the country or countries studied is such that a relatively large share of resources is being allocated to the lower-impact activities. Section 6 reflects on policy implications of the findings emerging from the extant literature on aggregate agricultural spending, as well as subsectoral and functional expenditures within agriculture.

Besides the issue of allocative efficiency, more may be learned from an examination of the technical efficiency of agricultural expenditures (aggregate or specific types of spending) and of the determinants of technical inefficiency. We are not aware of any work undertaking such analysis, and it thus constitutes an important area for future research. Similarly, analysis based on public expenditure tracking surveys (PETS), which trace public funds in agriculture from their initial allocation by the ministry of finance all the way to the lowest units that make use of such public funds (such as farmer training centers or irrigation management units), would be useful in identifying loci of strong and weak links in the path from spending to outcomes. Several PETS have been undertaken in other sectors, most commonly in health and education, but nearly none have been conducted in agriculture.

5. The Existing Empirical Evidence on the Impact of Public Investment for Agriculture

As compared with Section 4, this section goes beyond investments *in* agriculture to look at investments *for* agriculture, as well as at the poverty impacts of agricultural spending. In this section, we consider and draw policy lessons from the available empirical evidence on the impact that nonagricultural public expenditures have on agricultural outcomes in developing countries, while also considering the impact of agricultural spending on poverty outcomes. This section begins with a review of literature on the comparative performance of research and development (R&D) spending with other forms of public spending in terms of achieving agricultural productivity and growth outcomes, as well as in reducing poverty. The subsections that follow examine how the impact of public investments for agriculture evolve over time and then contrast these impacts across space—in particular, in high-potential versus low-potential

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(2011), health spending has the lowest returns to rural welfare in Ethiopia. Likewise, it has the lowest returns to both agricultural productivity and poverty reduction in Uganda (Fan and Zhang 2008).

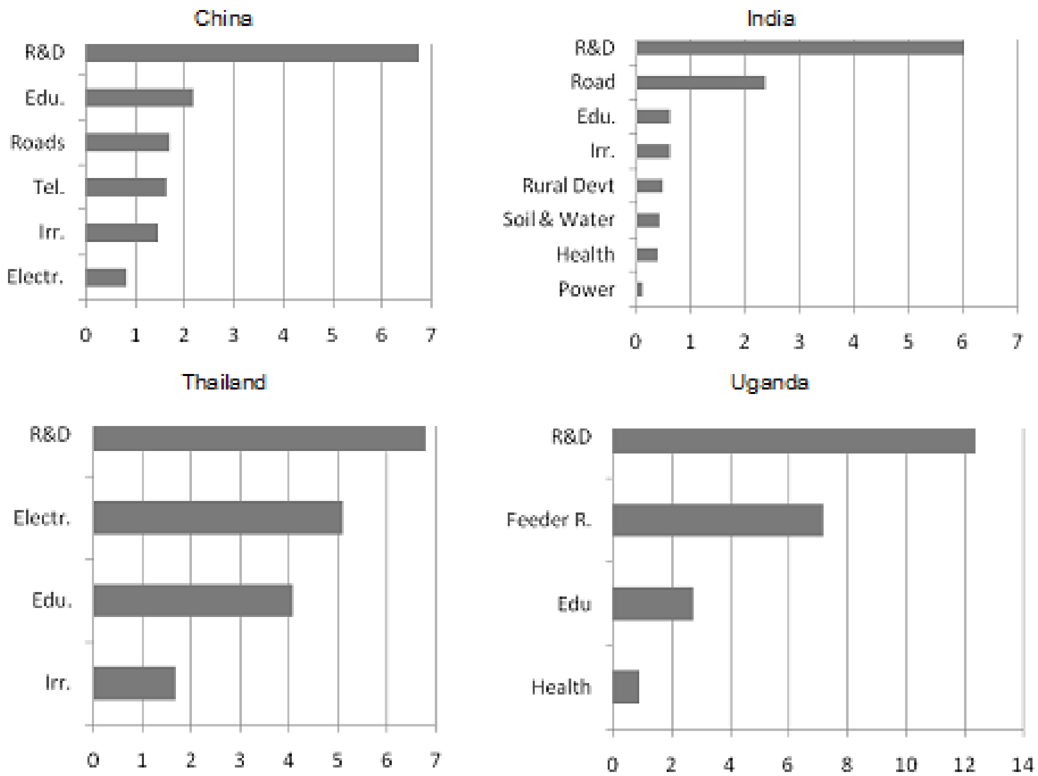
areas. Finally, the section concludes with a discussion of the effect of public investments on private investments in agriculture.

How Does the Impact of Agricultural R&D Compare with That of Other Public Investments?

One feature that nearly all of the studies on agricultural R&D and extension that were discussed in Section 4 have in common is that they all examine the returns to agricultural research in isolation. That is, these studies do not explain whether, even if the returns to R&D investments are high, one may not get even better results for agricultural productivity through prioritizing other types of public investments. The studies reviewed in this section, however, address exactly this question by comparing the returns to public spending in agricultural R&D with the returns to other forms of public spending. Figure 5.1 summarizes results for such analyses undertaken in four developing countries: China (Fan, Zhang, and Zhang 2004), India (Fan, Hazell, and Thorat 2000), Thailand (Fan, Yu, and Jitsuchon 2008), and Uganda (Fan and Zhang 2008).

One of the first striking features of the core findings across several, quite distinct countries is that if policymakers were to focus on agricultural productivity growth in undertaking their public spending decisions, they would prioritize much different kinds of investments within these countries, though with one exception. Across all countries, the dollar-for-dollar impact of public investments on the value of agricultural production is consistently highest, and substantially so, in agricultural research. Investments in this activity rank highest across a range of alternative areas of spending. After agricultural R&D, however, the impact of various investment areas differs by country. In Uganda and India, spending on road infrastructure generates the second highest agricultural productivity returns after spending on agricultural research. In Thailand, the second greatest gains come from investments in rural electrification, whereas this type of investment ranks last in China.

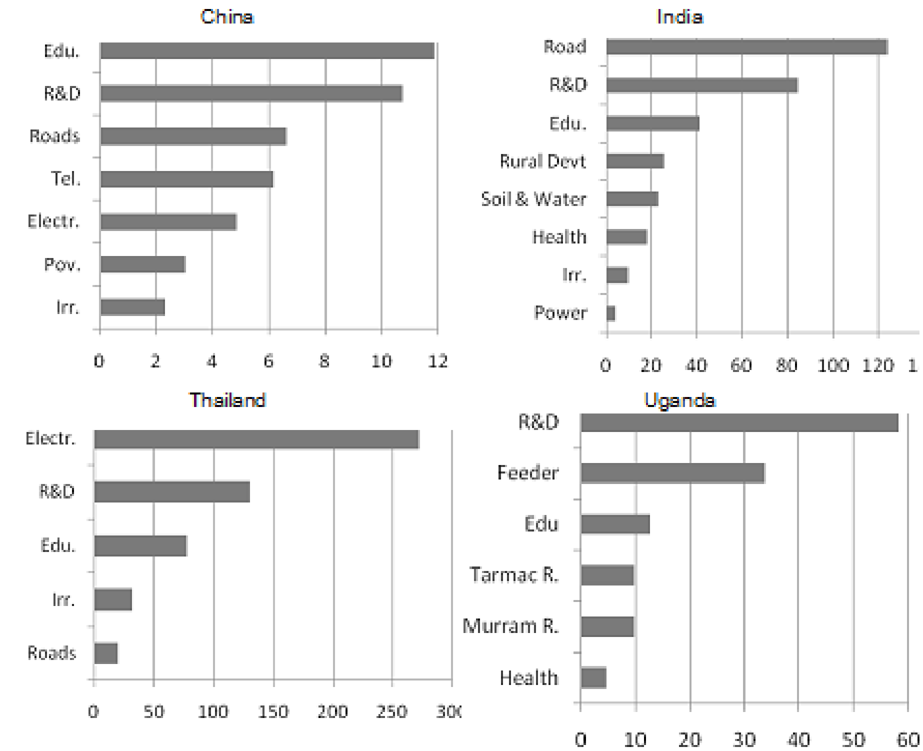
Figure 5.1—Returns to public spending in terms of agricultural performance



Source: Adapted from Fan, Zhang, and Zhang (2004); Fan, Hazell, and Thorat (2000); Fan, Yu, and Jitsuchon (2008); and Fan and Zhang (2008).
Notes: Edu. = Education; Tel. = Telecommunication; Irr. = Irrigation; Rural Devt = Rural Development; Soil & Water = Soil and Water Conservation; Electr. = Electricity; Feeder R. = Feeder Roads. The magnitudes are returns to one monetary unit of different types of public spending in terms of (the same) monetary unit of the value of agricultural production or productivity. The agricultural performance variable is measured slightly differently in each country: agricultural GDP in China, agricultural total factor productivity in India, and agricultural labor productivity in Thailand and Uganda.

The analyses across these countries consider public investments that are agriculture-related as well as those that are agriculture-supportive. In addition to agricultural R&D, the only other activity in the analyses directly related to agriculture is irrigation (with the exception of Uganda, where irrigation is not analyzed). It is notable that irrigation—the only other investment in agriculture included in the analysis—does not rank high when compared with R&D and investments in agriculture; it has the lowest return of four sectors in Thailand, the second lowest of six sectors in China, and ranks fourth in India, with returns of road and R&D spending far outpacing gains from irrigation investments. Although this may not necessarily be strongly indicative of how different investments compare in other developing countries, it does indicate that the impact of agriculture-supportive investments may, at times, greatly surpass the impacts of direct agriculture-related spending.

Figure 5.2—Returns to public spending in terms of poverty reduction



Source: Adapted from Fan, Zhang, and Zhang (2004); Fan, Hazell, and Thorat (2000); Fan, Yu, and Jitsuchon (2008); and Fan and Zhang (2008).
Note: The magnitudes are the reductions in the population size of the poor per monetary unit spent in each area of spending. The respective monetary units are as follows: 1 million baht in Thailand (that is, number of poor population reduced per 1 million bahts spent in different sectors); 1 million rupees in India; 10,000 yuan in China; and 1 million Ugandan shillings in Uganda.

A comparison of the effects of public investments on agricultural performance (Figure 5.1) and on poverty reduction (Figure 5.2) immediately shows that the optimal shift in spending prioritization is not the same when increasing agricultural growth is the paramount policy goal as when reducing poverty levels is the main goal. For example, although in India the agricultural growth gains from a monetary unit spent on irrigation is only exceeded by those from a monetary unit invested in R&D, road infrastructure, and education, the country’s poverty-reduction gains from several other types of expenditures are greater than the equivalent gains from irrigation spending. In other words, the relative merits of irrigation investments are greater for agricultural productivity than they are for alleviating poverty. However, although some differences in the ranking of returns exist between these two development outcomes, in general, there would only be a few (if any) drastic trade-offs in expenditure policy and prioritization if one or the other outcome were considered more important. Notably, agricultural R&D appears highly important for the pursuit of both productivity and equity goals, even if it ranks slightly lower (second in the Asian countries, but still first in Uganda) in terms of its relative contribution to cutting poverty.

Cross-country and regional studies confirm the dual impact of R&D investment on agricultural growth and on poverty reduction. National and international maize research in western and central Africa has found that from 1971 to 2005, maize had a benefit–cost ratio of 21, indicating a rate of return of 43 percent. The country-level benefit–cost ratios range from 10 in Togo to 84 in Nigeria, and country-level rates of return range from 28 percent in Senegal to 74 percent in Nigeria (Alene et al. 2009). In addition, the study found that on average, from 1981 to 2004, every US$1 million invested in international maize research at the International Institute of

Tropical Agriculture (IITA) reduces the poverty head count by 35,000–50,000 people. At the national level, the impact of poverty reduction ranges from an annual reduction rate of 0.22 percent in Cameroon to 0.9 percent in Nigeria.

Likewise, agricultural research in Africa, Asia, and Latin America has played a substantial role in both agricultural growth and reduction of national and regional poverty. Comparison of the impact of agricultural R&D (in R&D expenditures per hectare, constant 1995 US$) across 48 developing countries with (1) the impact of other inputs such as fertilizer (in 100 grams per hectare of arable land), (2) labor (in agricultural value-added per agricultural labor, constant 1995 US$), (3) machinery (in tractors per hectare of arable land), and (4) land quality (in land quality index from Wiebe [2000]) reveals that R&D is one of the larger contributors to yield (Thirtle, Lin, and Piesse 2003). With an elasticity of 0.44, R&D inputs are second only to land quality (0.65) in terms of impact on yield across the entire sample. Differences by region reveal that labor (0.63) has the highest yield elasticity in Africa, followed by R&D (0.36); and land quality has the highest yield elasticity in Asia and Latin America, at 1.04 and 0.53, respectively. In Asia the yield elasticity of R&D, at 0.34, is second to that of land quality; meanwhile, the yield elasticity of R&D in Latin America is 0.2 and is superseded by fertilizer, labor, and land quality.

Rates of return to R&D spending are also estimated for each country and region. The mean and weighted mean[18] returns for the Asian region are 26 and 31 percent, respectively, whereas they are 18 and 22 percent for Africa and 10 and –6 percent for Latin America. The low and negative returns in Latin America are largely due to Brazil's R&D budget—although Brazil spends a substantial amount more than other countries on R&D, due to its already high development level relative to the other countries in the sample, the returns are much lower (Thirtle, Lin, and Piesse 2003). Country-level returns range from –12 percent in Lesotho to 57 percent in Morocco for the Africa region; from –1 percent in Sri Lanka to 50 percent in the Philippines for the Asia region; and from –22 percent in Venezuela to 40 percent in Honduras for the Latin American region. Estimating the poverty outcomes of agricultural R&D, Thirtle, Lin, and Piesse (2003) found the highest poverty elasticity of investment in Africa (–0.26), with Asia (–0.165) and Latin America (–0.03) also exhibiting poverty reduction response to R&D investment. An elasticity of –0.199 was estimated for the full sample.

Overall, although the extent differs by country and region, there is substantial evidence that R&D has significant and positive impacts, even when compared with other investments in and for agriculture. These significant and positive impacts are seen not only in agricultural growth, but also in poverty reduction.

The Evolution of Returns to Public Spending over Time

It is intuitive that certain public investments may exhibit declining returns over time. For example, in the context of the Green Revolution, initial investments in research generated the first fast expansion of the use of improved seed varieties and complementary modern inputs. These activities are said to have constituted the *low hanging fruit*, meaning that subsequent investments would not be able to replicate the earlier returns (Evenson, Pray, and Rosegrant 1998). Although such diminishing returns may be in play, the effect of complementarities in public investments could stall this decline. If the effect of agricultural research on farmers'

[18] The regional weighted means allow for country size, whereas the simple means do not.

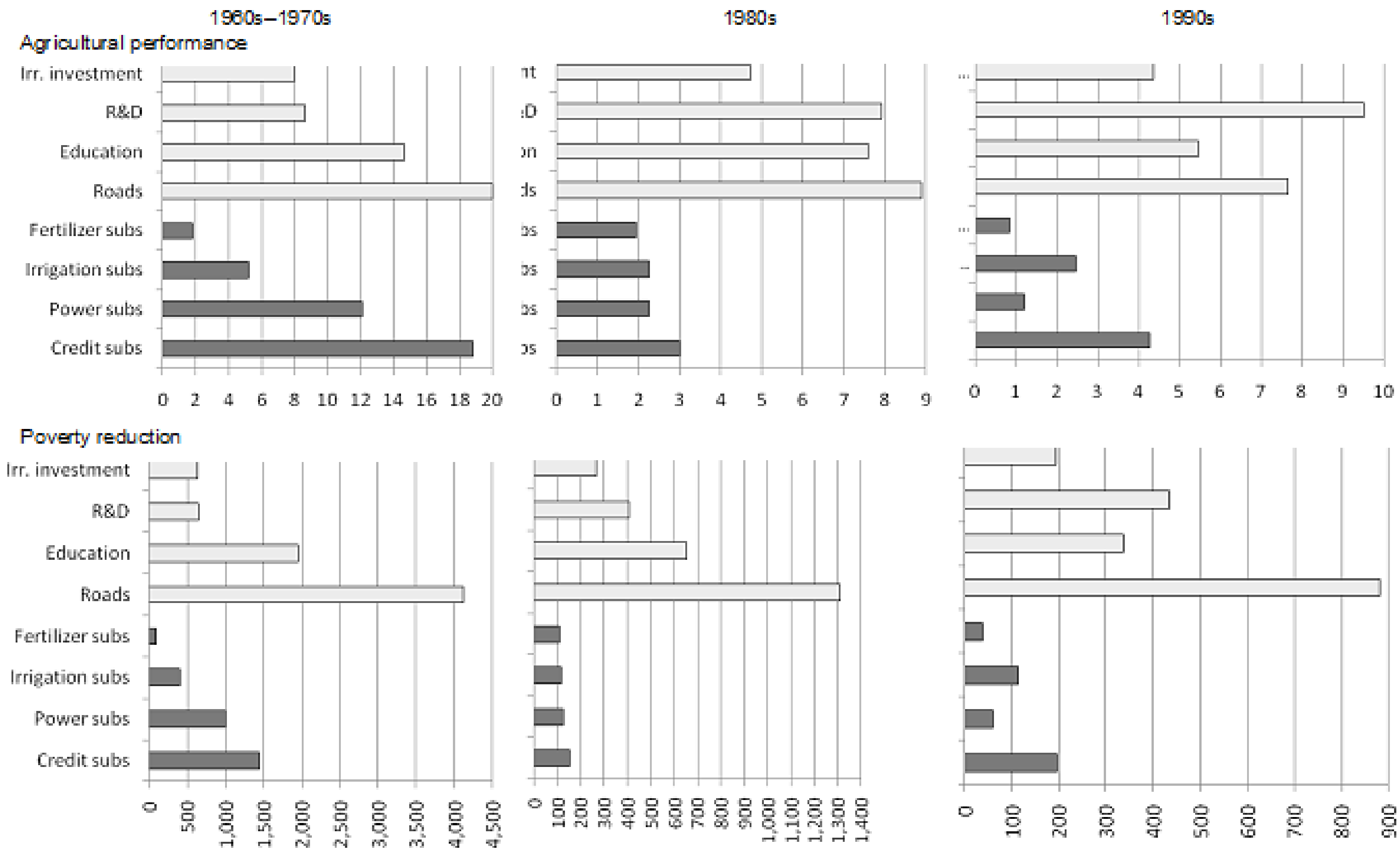
incomes is enhanced by better road infrastructure, thus lowering the transaction costs of accessing inputs and marketing outputs, then continued and simultaneous investments in both R&D and infrastructure may mean that the returns to expenditures in the former would not see diminishing returns over time in one sector; this, in turn, would hold investments in the other sector constant.[19] Even where complementarities are not as prevalent, however, technology investments can exhibit nondiminishing returns, a point elaborated on by a large theoretical and empirical body of work, including in the endogenous growth literature.

One of the challenges to extending the type of analysis discussed so far (that is, returns to public investments in and for agriculture in developing countries) in order to capture the changing returns over time is that there is not much data with sufficiently long time series. Such data is usually needed in order to have a sufficiently long panel for analysis, even for estimations that do not consider the evolving nature of returns over time. Thus, information on investments and outcomes over an extended period would be needed for this additional temporal dimension in analysis.

Several studies explore the issue of diminishing returns to investment over time, all with similar findings. One major academic study of India (Fan, Gulati, and Thorat 2008) illustrates how the returns to agricultural public investments compare with the returns to public subsidies and how the relative performance of investments and subsidies can change over time. The core results of this study are summarized in Figure 5.3. In the early years of India's Green Revolution (the 1960s and 1970s), there was strong variation among the returns to different types of subsidies. For example, whereas the benefit–cost ratio for fertilizer subsidies amounted to 1.79 (that is, fewer than 2 rupees of agricultural production were gained for each rupee of public spending on fertilizer subsidies), the same benefit–cost ratio for credit subsidies reached as much as 18.77, or nearly 10 times the returns to fertilizer subsidization. Similarly, the returns to public investments varied from a benefit–cost ratio of 8.00 for irrigation investments to 19.99 for public investments in road infrastructure. However, in general, although subsidy spending had somewhat lower returns than public investments, the returns to these two categories of spending were, on average, not too dissimilar at that time.

[19] This argument echoes—in a temporal dimension—the school of thought on sectoral complementarities and poverty traps discussed in Section 3.

Figure 5.3—Evolution of returns to public spending over time in India, and comparison between returns to investments and subsidies



Source: Adapted from Fan, Gulati, and Thorat (2008).

Note: The magnitudes in the top panel are returns to one monetary unit of different types of public spending in terms of (the same) monetary unit of agricultural gross domestic product. The bottom panel shows the reduction in the population size of the poor for a one million rupee increase in different types of public spending.

Over the decades, however, a clear divergence between the returns to subsidies and the returns to investments emerges. By the 1980s, although overall gains from public spending in the agricultural sector and rural areas declined compared with gains made during the earlier stages of the Green Revolution, the gains in agricultural production due to subsidy spending began to fall far behind investment returns. The benefit–cost ratios for this period spanned the narrower and generally much lower range, from 1.94 for fertilizer subsidies to 3.00 for credit subsidies. In contrast, public investments in irrigation (with a benefit–cost ratio of 4.71), rural education (7.58), agricultural research (7.93), and rural road infrastructure (8.89) far exceeded returns to subsidies. The gap between benefits from subsidies and those from investments remained in the 1990s.

In addition, there is an overall tendency for the effects of public expenditures on poverty reduction to decline over time. As can be seen in Figure 5.3, these returns fell from a high (for road investments) of 4,134 (the reduction in the number of poor per one million rupee spent; see also the note for Figure 5.3) in the 1960s and 1970s, to 1,312 in the 1980s, and further to 881 in the 1990s. As was the case before, despite the overall gradual decline in the effects of R&D investments on poverty, these effects declined by far less than that of other investments and, from the 1960s to the 1990s, R&D spending emerged as the type of public expenditure with the second-largest impact on poverty reduction, second only to public investments in road infrastructure.

Even though subsidy spending is often justified on the basis of equity and poverty considerations, it is particularly striking that in terms of poverty reduction, the returns to public subsidies are generally significantly lower—and have always been so throughout the decades examined—than returns to public investments. This finding is in contrast to the earlier discussed returns in terms of agricultural growth, where, in the earlier decades, there was at least some parity between the contributions of public investments and those of subsidy expenditures.

It is notable that even though returns to public investments have tended to decline over time (for example, the benefit–cost ratio for irrigation investments fell by nearly half from the first decade of the Green Revolution to the second, and education and road investment returns declined by more than half), the returns to agricultural R&D have remained constant over the decades, without seeing a similar decline. Similar findings are seen in Evenson's (2001) comprehensive review of R&D and research, development, and extension (RDE) investments and Suphannachart and Warr's (2011) estimate of the effect of public spending in agricultural research on Thai crop production. In an analysis of hundreds of studies from the 1960s through the 1990s, Evenson (2001) observed no time trends, indicating that internal rates of return (IRRs) were as high in the 1990s as they were in the 1960s. Likewise, Suphannachart and Warr's (2011) total factor productivity (TFP) determinants model indicates that public spending in research was a positive and significant determinant of TFP growth from 1970 to 2006, with an elasticity of 0.16 in the short run and 0.07 in the long run. Although the long-run elasticity is a decrease from the short run, the long-run elasticity of 0.07 has persisted into perpetuity as the steady-state equilibrium.

As with the decline in social returns to public investments seen in India (Figure 5.3), some evidence indicates that the private investment response to public investment in agriculture has decreased over time in the country. In an analysis of national data from the 1960s through the 1980s, Misra and Hazell (1996) identified a positive, though statistically insignificant, relationship between public and private investment in agriculture in India for the 1960–1990 period. Disaggregating this relationship by decade intervals, however, they found a highly significant relationship with decreasing magnitude for the 1960–1969 and 1970–1979 periods (with coefficients of 1.6 and 0.69, respectively). However, the effect of public on private investment in the third period, 1980–1989, is negative and significant (–0.31). Updating this finding with data from the 1980s and 1990s, Chand (2001) showed, through separate regressions at the state level of two time periods (1980–81 and 1990–91), a significant positive impact of public investment on private investment in agriculture for the 1980–81 period only. The impact for the 1990–91 period is insignificant. Chand (2001) interpreted this difference as an indication that the complementarity of public and private investments has declined over time.[20]

Another important temporal dimension of investment impacts are long- versus short-run effects.[21] Evidence suggests that returns to agricultural investments seem to materialize more strongly in the long run. For example, Rosegrant, Kasryno, and Perez (1998) found increasing returns to investment in agricultural technology in Indonesia. Elasticity estimates of the short- and long-run food crop area outcomes due to research investments (see Table 4.1) show that the existing stock[22] of accumulated past investments in agricultural research has larger impacts over the long run than over the short run, whereas elasticity estimates for new investments and for extension are negative in the short run.

In a similar vein, time series data from Taiwan for 1952–2001 reveal a lag in returns to agricultural spending. Lee and Hsu (2009) demonstrated that over the long run, the land productivity elasticity of government investment in agriculture is positive and significant at 0.56. However, due to the lag time of the land productivity outcome, the government is unable to demonstrate any effect of its public investment over the short run.

Should High-Potential Areas or Marginal Lands Get More Public Spending Attention?

There is a long-standing academic debate—and controversy—on the merits of investing public resources in agriculturally high-potential areas, where it may be easier to help expedite agricultural growth, as opposed to marginal areas, where poor populations tend to be concentrated. One normative position in the literature is that even if poverty reduction were the overriding goal in a given country, it would still be important to continue to selectively invest in high-potential areas. This line of argument partly relies on evidence that poverty reduction in rural areas is most effectively brought about through agricultural growth, and such growth, in turn, can be most effectively spurred through policy in those areas with initial natural conditions that are favorable to agricultural productivity (for example, Palmer-Jones and Sen 2003). Under this argument, it would still require careful selectivity to determine which high-potential areas still offer strong opportunities for poverty reduction—for example, favorable agroecological zones that, possibly due to the modesty of past investments, still suffer from relatively high rates of poverty.

Although this position speaks to the challenges of efficiently investing in marginal areas, it leaves more or less untouched the concern that the incidence of poverty is dramatically higher in

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[20] A more thorough discussion on crowding in and crowding out is available in Section V.4.
[21] See Mogues (2012) for a discussion of the implications of long gestation periods for research and development spending on the incentives of policymakers to undertake these investments.
[22] Rosegrant, Kasryno, and Perez (1998), citing Huffman and Evenson (1989), uses investment stocks, rather than flows because, "For public investment in technology and knowledge, it is the stock of capital or knowledge, not the annual investment flow, that affects output" (p. 339).

less-favored areas of a given country. This higher incidence often (though not always) translates into greater numbers of poor people being located in marginal areas rather than in high-potential areas, either because marginal areas contain a sizable share of the overall population or because the effect of the high poverty incidence in these areas offsets their small size. However, even if the population size of the poor were not larger in remote areas, substantially larger poverty incidence in remote regions would challenge arguments for maintaining an emphasis on high-potential areas to tackle poverty in the country. If in addition to overall poverty and overall inequality in a country, regional inequality were an additional (possibly political) concern, then the argument that it is more efficient to invest in those high-potential areas where poverty still prevails may not be fully satisfactory.

There is an additional argument, however, that seeks to respond to these concerns, but that still heralds the idea of continuing the prioritization of high-potential areas. This argument proposes that factor and output market linkages will lead to reduced poverty in marginal areas because of supportive policies in agroecologically favorable regions. The increase in wages and the reduction in food prices from these policies are not limited to those areas in which investments were undertaken; instead, through integrated markets, it will expand to the less-favored areas, thus positively affecting incomes and food security of the poor. Furthermore, through labor outmigration from low- to high-potential regions arising from employment opportunities due to public investments, the marginal lands will see an alleviation of land degradation as population pressure eases.

However, the general assertion on the benefits of tilting agricultural and other investments to a country's agroecologically better-off regions is countered by the suggestion that, over time, returns to public investments in high-potential areas may decline—in other words, further improvements in agricultural productivity in these areas can only be achieved at a large cost after there is a relative saturation of high-potential areas with the outputs of public investments (Ruben and Pender 2004). Furthermore, limited commodity and factor market integration would dampen the hoped-for indirect effects through wage increases and food price decreases affected by high-potential area investments. Given the clearly greater concentration of poverty in marginal lands, direct effects on poverty from investments in these areas may be greater than the indirect effects outlined earlier, even if productivity effects from investments in favored areas were still superior.

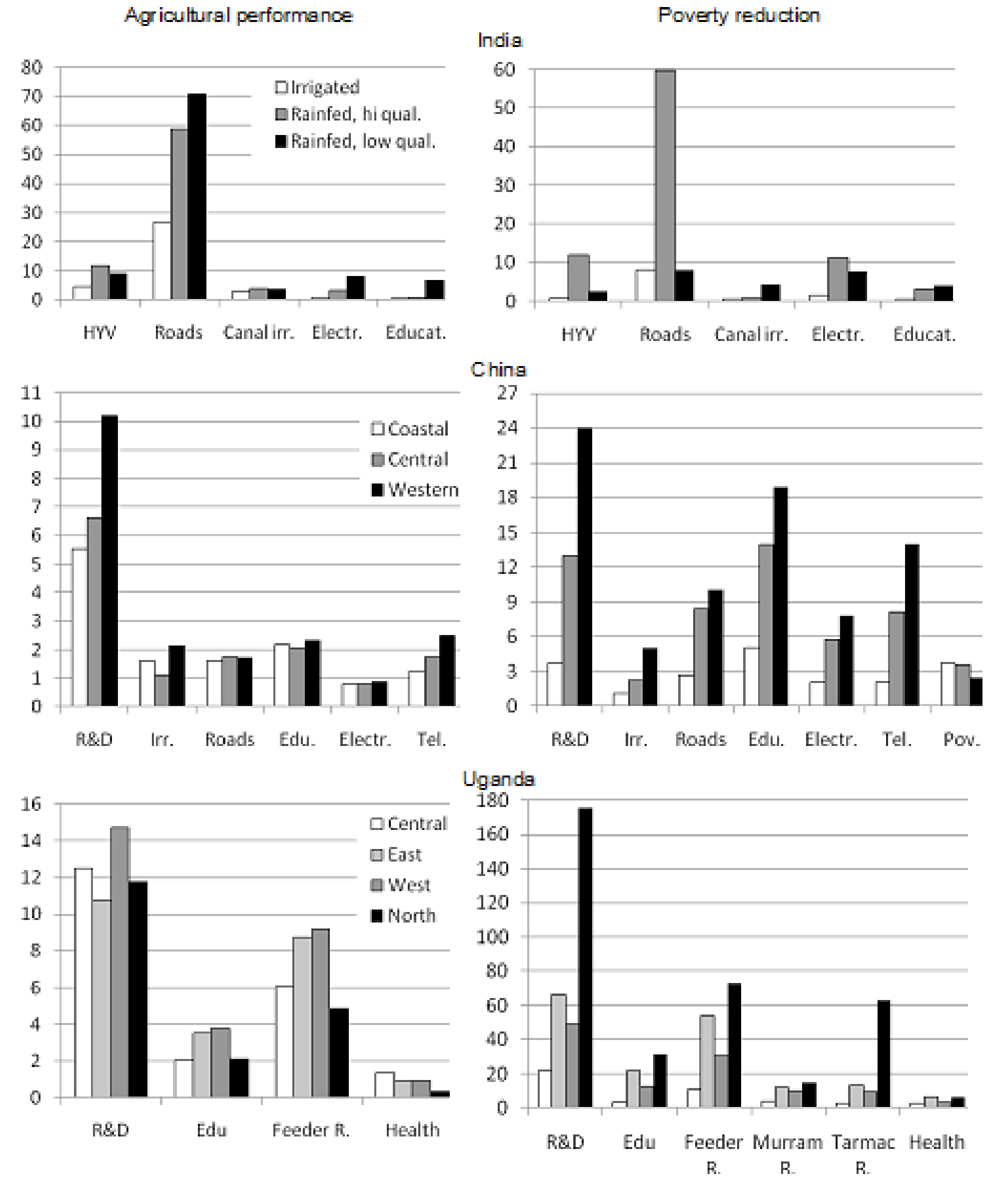
These arguments and counterarguments suggest that a conceptual discussion alone, even one that is based on empirical evidence of growth–poverty linkages in low- versus high-potential areas, cannot provide conclusive answers to policy questions about how agricultural and other public investments should be prioritized geographically. Empirical evidence on the agricultural productivity, as well as poverty-reduction impacts, of public expenditures in a range of sectors is needed to begin to address these policy questions. Few studies have undertaken such empirical analysis; we present here the evidence available on the issue, applied in countrywide studies to India, China, and Uganda, and in microeconomic analysis in northern China.

To undertake the analysis differentiated by agricultural potential, a study on India (Fan, Hazell, and Haque 2000) categorizes rainfed Indian districts by agroecological zones, as defined by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and separately estimates the returns to investments in each agroecological zone,[23] as well as in irrigated areas. This study results in distinct estimates for 14 irrigated areas and 13 rainfed agroecological zones, with the agroecological zones ordered from lowest to highest potential. For an overview, we present the returns to investments averaged for the six lowest-potential rainfed areas, for the remaining seven higher-potential rainfed zones, and for the irrigated areas. The analysis estimates the returns to different public investments in terms of agricultural productivity—specifically, the TFP in the agricultural sector—and in terms of poverty reduction.

As seen in Figure 5.4, across all sectors, public investments consistently generate higher agricultural productivity returns in rainfed regions of India than in the historically favored areas. Even among the former, the payoff to investing in more marginal lands is higher than in areas with higher agricultural potential. The superiority of public investments in rainfed areas of India in terms of their effects on poverty is also apparent (Figure 5.4). However, from the perspective of poverty reduction, for several investment types, the poverty-reduction gains are greater in those areas with higher-quality rainfed land as opposed to those with lower-quality rainfed land, especially when it comes to expenditures on agricultural technology and road infrastructure.

[23] In the study, some of the ICRISAT-defined agroecological zones are grouped together to gain a sufficiently large number of observations for analysis.

Figure 5.4—Returns to investments in high-potential versus less-favored areas



Source: Adapted from Fan, Zhang, and Zhang (2004); Fan, Hazell, and Haque (2000); and Fan and Zhang (2008).

Note: HYV = High-Yielding Varieties; Irr. = Irrigation; Electr. = Electricity; Edu(cat.) = Education; qual. = quality; Tel. = Telecommunication; Pov. = Poverty Reduction Transfers; R. = Roads; The magnitudes in the left panel are returns to one monetary unit of different types of public spending in terms of (the same) monetary units of the value of agricultural production or productivity. The agricultural performance variable is measured slightly differently in each country: agricultural GDP in China, agricultural TFP in India, and agricultural labor productivity in Uganda. The magnitudes in the right panel are the reductions in the population size of the poor per monetary unit spent in each area of spending. The respective monetary units are as follows: 1 million rupees in India; 10,000 yuan in China; and 1 million Ugandan shillings in Uganda.

The analysis on China (Fan, Zhang, and Zhang 2004) classifies the country's provinces into coastal, central, and western regions. The coastal region is characterized by high per capita income and a low poverty rate; the western region is generally considered to be the lagging area in the country, with the highest incidence of rural poverty and the lowest agricultural productivity; and the central region lies broadly between these two regions in terms of economic (including agricultural) performance and extent of poverty. The effect of a range of public investments shows some, albeit modest, spatial variation. Across the board, the agricultural income effects of investments are highest in the most marginal area—

that is, the western region. This finding is most pronounced for investment in agricultural R&D. In the western region, which has been historically neglected by public investments, the returns to spending on agricultural technology have an impact that is nearly double that seen in the rich coastal region.

The inverse relationship between net benefits from investments and regional potential is even more strikingly evident when we consider how investments translate to poverty reduction across regions. As seen in Figure 5.4, the poverty effects of investments are by far highest in the western region, and clearly lowest in the high-potential coastal areas. It is remarkable, and upon initial consideration surprising, that the only type of public spending for which this pattern does not hold is for expenditures on measures directly geared toward achieving poverty reduction. These expenditures, which are usually in the form of subsidized loans intended for poor households, appear to be weak in achieving their goal.

Spatially differentiated analysis in Uganda shows results for four regions of the country (Fan and Zhang 2008). The central region is the economically most developed region with the lowest concentration of poverty. The northern region stands in stark contrast: both rural and urban poverty rates are highest here, and the region has suffered, and continues to suffer, from prolonged violent conflict. The eastern region is the second most developed in socioeconomic terms, and the western mostly temperate region can be placed approximately third in its level of development.

Figure 5.4 shows that the spatial pattern of public-investment effects on poverty is quite consistent with those for the other two countries, especially with China. The results show that the most marginal area of China—the northern region—would experience the greatest poverty-reduction effect from each type of public investment. The eastern region would experience the second greatest benefits in this respect, and the least—though in absolute magnitude, still large—would accrue to the most advanced central region. The relationship between a region's economic development and the returns to spending in terms of agricultural outcomes is less clear, as different types of spending seem to have their greatest effects in different regions.

Although these studies compared the effects of investments in high- and low-potential areas at a countrywide level, one can interestingly draw similar conclusions from results of a more micro-scale analysis across villages. In a study including 10 villages with different resource endowments and at varying levels of development, Dong (2000) found that public investment and social services expenditures have a greater impact in less-developed villages. The study divides investments into two different types: public investments include (but are not limited to) maintenance of village irrigation networks and roads, whereas social services include (but are not limited to) provision of mechanized plowing, crop protection, threshing, technical guidance, subsidization of farm inputs, marketing assistance, and other nonagricultural services, such as the installation of drinking water, enhancement of access to electricity, and the provision of educational services (schools, libraries, and daycare).[24]

To capture outcome differences among the diverse village types, the villages are categorized into three types: Type I villages are characterized by high resource endowment (mineral and soil fertility), access to markets, and highly developed agricultural sectors and infrastructure; Type II villages, by relatively developed agricultural sectors and basic infrastructure; and Type III

[24] This is yet another example of the issue, discussed in Appendix A, of the diverse (and often imperfect) ways that the empirical studies treat the notion of 'public investment' and other categories. However, in the synthesis of the findings here we adhere to the language used by the paper itself.

villages, by poor resource endowment, poor soil quality, and vulnerability to natural disasters due to their remote mountain location. Because the village-level investments are drawn from collective capital assets and enterprises, as well as the tax base,[25] public investments and social service expenditures are higher in Type I villages than in Type II or III. Household returns are measured by gross revenue of household operation—both agricultural and nonagricultural activities, but excluding wage employment and other income-generating activities outside of household production.

Across various estimation methods, household returns to public expenditures are significant across village types. However, Type III villages display a significantly larger effect than the other two village types, implying a greater impact of such investments in poorer areas. Whereas the response to a 100-yuan increase in public investment in Type I and Type II villages is a farm household output increase of 5.3 percent, in Type III villages, the same investment increases farm household output by 41.7 percent. A similar difference is seen with a 100-yuan increase in social service expenditure: the Type I and Type II villages realize a 7.1 percent increase in output, whereas in Type III villages, the output increases by 46.5 percent.

Despite the higher unit increase returns to Type III villages, Type I villages display greater output elasticity than either Type II or Type III (see Table 5.1). The difference in response to unit increase versus output elasticity is due to the higher mean public investment and social service expenditure values in Type I villages relative to those in Types II and III. Due to these higher mean investment and expenditure values, a 1 percent increase in spending over the current spending represents a greater quantity and will therefore have a greater impact than it would in Type II and III villages.

Table 5.1—Impact of public spending across villages with different agroecological endowments

Village type	Public investment	Social service expenditure
Estimated output elasticity		
Type I	0.099	0.096
Type II	0.033	0.029
Type III	0.027	0.065
Estimated marginal rates of return		
Type I	1.10	1.49
Type II	1.99	2.70
Type III	7.36	8.24
All households	3.85	4.57

Source: Dong (2000).

The marginal rates of return[26] of public investments and social services—measured as the increase in gross household revenue for a 1-yuan increase in each of the two types of public spending per capita—are much higher in Type III villages than in Type I or II villages. These high rates indicate underinvestment in the more marginal Type III villages.

[25] This relationship between village assets, household income, and public investment raises endogeneity concerns for the regression models. Dong (2000) addresses these concerns as follows: (1) he notes that the availability of public services in the villages is determined more by the degree of control the collective exercises over capital assets and non-agricultural enterprises than by household income, (2) he performs a Hausman test of the null hypothesis that the public investment (PI) and social service expenditure (SSE) variables are independent of the error term using instruments for PI and SSE; the test fails to reject the null.

[26] Estimated by multiplying gross revenue by the regression coefficients and dividing the product by 100.

The Impact of Public Investment on Private Investment in the Agricultural Sector

Public investment designed to provide public goods—such as infrastructure, knowledge creation through technological development, and so on—is necessary to support growth. However, capital with a public-goods character will be underprovided by private actors (see also the discussion on the rationale for public investments in the face of market failures, in Section 2). These public investments can also increase the profitability of private investment—for example, when road infrastructure reduces the cost of transportation and thus the cost of agricultural inputs and output marketing, or when investments in R&D result in crop varieties with higher yields, bringing greater revenues and profits for agricultural enterprises. In this sense, public investment can expand the opportunity set for market actors and induce more (that is, crowd in) private investment.

However, public investment can also have a crowding-out effect on private investment. One way this may happen is through one of the key macroeconomic consequences of public investment—namely, the increase in the interest rate. As the cost of borrowing increases, the profitability of private investment decreases, and thus less private investment will be undertaken than would occur without this increase in the cost of capital. Furthermore, if the nature of the public investment is to produce goods and services that are also produced by market actors, the infusion of this source of output competition would contribute to a decline of private investment in the economy.

Both of these partial effects may exist at the same time. That is, public investments may have the effect of increasing the profitability of private investment through provision of complementary public goods while also reducing profitability by making borrowing more expensive when public-sector borrowing to finance the public goods raises interest rates. The net effect on private investment may be positive or negative, and this net outcome, though it can be modeled theoretically, ultimately needs to be investigated empirically.

The bulk of the literature examining this question considers public and private investments only in the aggregate, rather than examining particular types of investments, such as just those in agriculture. In such aggregate analyses, the evidence across developing countries—or across a combination of developing and developed countries—appears mixed (Erden and Holcombe 2005), with some studies identifying a stimulating effect of public on private investment, and others showing a crowding-out effect.

The body of work in which this question has been raised specifically with regard to the agricultural sector has focused overwhelmingly on India, and to a lesser extent on Pakistan, in papers mostly by scholars from these countries. In this country context, the existence and extent of complementarities between public and private agricultural investment have been debated by a number of scholars, and the findings mirror the mixed nature of the academic evidence of how aggregate public investments affect aggregate private investment. Chand (2001) found that although agricultural terms of trade have a significant impact on the formation of private capital in the sector, public investment in agriculture does not. Examining national data from India from 1980–81 to 1996–97 under different analytical methods, agricultural public investments are either insignificant or negative in their effect on agricultural private fixed-capital formation in agriculture. Other studies find similarly little or no boosting effect of public on private investment (Mishra and Chand 1995; Misra and Hazell 1996; Mitra 1997).

A study that takes a cross-country view over a nearly two-decade period (1970–1988), also presents less-than-encouraging findings (Easterly and Rebelo 1993). Public agricultural investment is found to have a statistically significant and negative impact on private investment; meanwhile, the impact of public investment in other sectors—such as education, health, housing and urban infrastructure, transportation and communication, and industry and mining—on private investment is not significantly different from 0. However, it should be noted that the crowding-out effect of public investment in agriculture is not robust to alternative estimation approaches; specifically, when instrumenting the public investment variables to mitigate endogeneity-causing coefficient inconsistency, the effect of agricultural public investment on private investment becomes insignificant as well. Another important distinction of Easterly and Rebelo (1993), when compared with the Indian studies above, is that their cross-country study considers aggregate private investment. Thus, the a priori expectation of a significant effect of agricultural public capital spending on across-the-spectrum private-sector investment should be lower than if agricultural private investment were considered.

The mixed nature of the evidence, however, suggests that studies draw quite different conclusions. For example, in work focused on agricultural growth and rural development in a northern Indian state (Himachal Pradesh), Baba et al. (2010) found a positive and highly significant effect of public-sector investment in agriculture on private-sector investments in agriculture for 1969–2002. The marginal effect estimate of this relationship indicates that an increase in public investment of 10 rupees brings about a 1.6 rupee increase in private investment, and the public–private investment elasticity is 0.3. Although Baba et al. (2010) is a study of just one state in India, other India-wide analyses are consistent with these general findings (Dhawan and Yadav 1995; Dhawan 1996). It should be noted, however, that these other analyses focus on a particular type of agricultural investment—namely, canal irrigation. A set of country-level studies on Pakistan draw similarly hopeful conclusions, revealing that the public-on-private investment effect in agriculture support the crowding-in theory (Saeed, Hyder, and Ali 2006), as aggregate public capital expenditures (for example, in construction, transportation, electricity, and so on) contribute positively to agricultural private investment (Ahmad and Qayyum 2008).

Although in this subsection, we are centrally interested in the effect of investment by the public on investment by the private sector, it is worth noting, as is apparent from the review of the vast amount of evidence discussed in this paper, that public investments can affect development outcomes through means other than boosting private investment. In addition, when comparing private and public investment impacts, the latter can sometimes be larger. For example, in Dong's (2000) analysis of three types of villages in northern China, the marginal rates of return to public spending (both public investments and social service expenditures) across the entire sample are greater than those for private investments on inputs. Meanwhile, the magnitude of returns differs by village type and by type of public investment. In the well-developed, wealthier Type I villages, private investment realizes a greater return than public investment; in the moderately developed Type II villages, public investment realizes slightly greater returns than private; and in the poorly developed, marginal Type III villages, public investment realizes substantially greater returns than private investment. Across each village type, social service expenditures have greater returns than private expenditures; however, as with returns to public investment, they are greatest in Type III villages.

Concluding Remarks and Directions for Future Research and Policy

This paper has sought to provide a comprehensive review of the academic literature on the impact of public expenditures and investments in and for agriculture. A review of the existing evidence is preceded by a detailed discussion of the role of and rationale for public-sector agricultural investments, as well as a summary of trends in government and agricultural spending from the 1980s through 2007. In this section, we provide a brief summary of the main insights and findings from this paper.

Clarifying Definitions of Key Terms Used

As Appendix A shows, concepts such as public investments, public expenditure, capital spending, and so on, are used in quite disparate ways—not only across the standard economic literature interested in analyzing the impacts of public spending, but also between the economics literature on the one hand and formal classification schemes of government expenditures, such as that by the International Monetary Fund's Government Finance Statistics and other public finance categorizations, on the other. Several reasons exist for these discrepancies, including data constraints, definitions that emerge from particular theoretical approaches, analytical convenience, and so on. Having a proper understanding of the formal taxonomy of public expenditures is helpful in understanding and interpreting the diverse uses of concepts in the analytical literature.

The Role and Rationale for Public Investments in and for Agriculture: Market Failures, Poverty, and Inequality

The basic rationale for public investments in and for agriculture derives directly from the core reasoning for public-sector interventions in general. This core reasoning rests on two main elements: public investments can contribute to increasing the overall efficiency of the economy or the sector by addressing market failures; and public investments mitigate levels of inequality and poverty that society deems undesirable.

Public goods and externalities: Public investment to counter private underprovision. Market failures are pervasive in developing countries, in general, and in the agricultural activities of those countries, in particular. Public goods, such as agricultural technology created through investments in knowledge accumulation, are scarcely provided by the private sector, because agricultural technology is both a nonrivalrous and (in developing countries, especially) a mostly nonexcludable good. Several goods and services in agriculture have strong external effects beyond the agent who produces or consumes the good. Modern inputs are one such example—for example, the use of improved seeds by one farmer can have imitation and peer-learning effects on other farmers, thus increasing the other farmers' improved seed use and their concomitant productivity. The use of fertilizer can also mitigate negative off-site externalities arising from on-site agricultural production, by limiting soil erosion through plant growth, for example. Public investment in agricultural research and development (R&D) and effective and well-targeted public subsidies for modern input use can correct the underprovision of public goods and goods with externalities.

Information asymmetries: Public investments should target the root cause, not the symptoms. Market failures emerging from information asymmetries in market exchange are also a ubiquitous challenge in the agricultural sector. In particular, agricultural insurance and agricultural credit markets are hampered when unequal information between the farmer and the insurer or lender result in transactions failing to take place that would have been beneficial to both transacting parties. Several schemes have been introduced to obviate the market-stunting effects of adverse selection and moral hazard problems that arise from asymmetric information. Examples in insurance are area-yield crop insurance and weather-based index insurance. An important public role in these examples is a prudent investment in information and data (such as area-yield surveys or estimates and weather data) that is usable by both farmers and insurers/lenders, thus intervening at the source of the problem. Public subsidization of the cost of credit or insurance may be less effective in addressing the central information problem that was responsible for the market failure in the first place.

Imperfect competition and coordination failures: A second(ary) rationale for agricultural public investments. Although imperfect competition in markets—another major type of market failure—is not as prevalent in primary agriculture in developing countries, features of it do exist elsewhere in the supply chain, such as among traders and in contract farming arrangements. In the former case, public investments in market information systems and in appropriate market infrastructure are in order; in the latter, rather than public investment, the main role of government is of a regulatory nature, helping to ensure that contracts are honored. In a context beyond the microeconomic level, coordination failures are said to exist when complementarities across different economic activities and sectors stand in contrast to the inability of the market actors specializing in these different activities to coordinate their efforts in order to exploit and gain from the cross-sectoral complementarities. This phenomenon underlies the argument for the broad engagement of and investment by the government in various sectors, because only the government would have this coordinating capacity. Care should be taken with this argument, especially in its more general form, as it implies a broad and not well-delineated role of the public sector, and inefficiencies arising from government failure may dampen the benefits from efforts to correct market failure.

Existing Evidence of the Impact of Public Investments in and for Agriculture

Compelling evidence across hundreds of studies shows that returns to agricultural R&D investments are substantial—and that there is thus significant underinvestment. A strongly consistent finding across the literature are the high social returns to public investment in agricultural R&D. Comprehensive meta-analyses spanning the second half of the 20th century show that the majority of estimates of internal rates of return (IRRs) to investments in agricultural research are greater than 20 percent, and a substantial 40 percent of estimates find an IRR greater than 60 percent. Any positive IRR implies that greater public investments should be channeled into agricultural research, and the IRRs in the literature are not only positive in the overwhelming majority of cases, but are also immense in magnitude. Although the contribution of agricultural research investments remains substantial across developing regions, the size of the returns varies. The highest IRRs are recorded for Asia, followed by Latin America, and then by Africa. Yet, even for the latter region, 72 percent of the estimates in the literature identify IRRs for agricultural research that are greater than 20 percent.

Public spending on agricultural research is a top performer for agricultural performance outcomes. When comparing the returns to investments in agricultural research with those on public investments in other activities, the superiority of the former emerges across most studies undertaking such comparisons. The dollar-for-dollar impact of R&D public spending on agricultural production or productivity is greater than the equivalent returns for public spending in other activities directly related to the sector, such as irrigation, extension, and fertilizer subsidies. It is also greater than the agricultural production and productivity returns from investments in other sectors, such as rural road infrastructure, education, electrification, health, and telecommunication.

R&D public investment is a high performer for poverty reduction. Agricultural investments in agriculture do not merely serve to increase agricultural-sector performance. Analyses considering the contribution of agricultural R&D investments to the reduction of poverty consistently show strong effects, whether taken on their own or when compared with alternative ways to invest resources. However, although R&D investments ranked first in terms of their dollar-for-dollar effect on agricultural production, they usually rank (a still high) second in reducing poverty levels. This high comparative contribution of R&D spending to poverty reduction suggests that the commonly referenced trade-off between optimal policies to achieve income gains for the lower end of the economic distribution and policies to achieve aggregate growth in the sector is mostly absent when it comes to agricultural R&D. Thus, it makes sense to expand investments in research, regardless which of the two goals is prioritized by policymakers.

Agricultural investments pay off for health and nutrition outcomes. In addition to raising the incomes of the poor, agricultural investments can make an important difference for human health and nutrition. Capturing these outcomes by the established metric of disability-adjusted life years (DALYs), a body of work has identified a high cost-effectiveness of public investments in biofortification—the development and dissemination of micronutrient-enhanced staple crop varieties—in averting loss in DALYs (commonly described as “DALYs averted”). For example, the estimated cost of iron or zinc biofortification of rice is estimated at between US$0.30 and $3.96 (under different analytical scenarios) per DALYs averted, which is well below the international standard of $196 per DALY averted (in 2000 US$) that has been established to identify which public health interventions are deemed to be highly cost-effective. Returns to expenditures on biofortification also compare very favorably with expenditures to provide micronutrients through fortification and supplementation—that is, the inclusion of micronutrients in the food-processing stage or as tablets or injections, respectively.

In agriculture, there are best, good, and poor buys. As for other agricultural investments, the picture is more mixed. Results on some of these investments clearly point to their absolute and comparative performance, whereas for others, it is less clear whether they are having adequate effects on agricultural growth or poverty reduction to be prioritized, especially when compared with alternative (including nonagricultural) investments. For example, findings from meta-analyses on public investments in extension have shown that these investments have a high mean (across studies) rate of return of about 80 percent and a high median of about 60 percent (in one meta-analysis) or 40 percent (in another). These findings suggest that extension investments are a good buy. On the other hand, returns to irrigation investments rank a low fifth out of six types of investments in China, fifth out of eight in India, and last out of four in Thailand. Irrigation investments lie between agricultural research (high) and extension (low) in terms of their elasticity effects on yield in Indonesia. In India, fertilizer subsidies appear to be a poor buy, as they rank last out of eight different types of agricultural and nonagricultural spending in terms of their contribution to agricultural productivity.

All agricultural investments are not equal, resulting in modest returns to aggregate (as opposed to specific types of) public spending. The idea that "all agricultural investments are not equal" is also reflected in the moderate, and in some cases modest, results across studies that consider the marginal effect, rate of return, or elasticity of aggregate public expenditures (as opposed to separately considering R&D spending, irrigation spending, and so on) in terms of rural welfare, agricultural growth, economic growth, or poverty reduction. These analyses show mostly nonsignificant impacts of additional increases in aggregate public expenditures or positive effects that are lower than returns to alternative expenditures.

Returns to public investments in and for agriculture have been declining over time; the exception is agricultural research. There is remarkable consistency across various works on the temporal dimension of returns to public investments in agriculture. First, across several studies on Asian countries, the impact of different types of public investments has declined over time. A notable exception has been agricultural research and development investment. Across studies in Asian countries, but also in evidence from global meta-analyses, R&D investments sustained their high returns from one decade to the next in the course of the second half of the 20th century. Another temporal dimension of returns concerns long- versus short-run effects. In studies where these concepts have been compared, long-run effects have been consistently larger—whether they be the effects of R&D, extension, or aggregate agricultural spending. This finding points to the importance of considering lag times not only of research but also of other agricultural activities.

Evidence from existing studies indicates a greater "bang for the buck" from investments in less-favored areas than those in high-potential areas. Few studies have explicitly compared the productivity and poverty impacts of public expenditures in high-potential versus marginal areas. However, this greater bang for the buck has been a consistent finding across case study areas and contexts in which the spatial dimension of public investment returns have been examined. This finding pertains to studies on China, Uganda, and India, as well as meso- and micro-level analyses. Therefore, a tentative conclusion to the important debate on whether greater policy attention should be given to high-potential areas within countries or to marginal regions is that greater investments than have been committed in the past in neglected areas are warranted. Results from the existing studies paint a picture suggesting that the marginal returns in low-potential lands are higher, in terms of both poverty-reduction potential and—perhaps surprisingly—agricultural performance. However, one ought to be cautious to extrapolate too strongly from the limited number of studies on this topic; further empirical examination in a wider set of contexts is called for.

There is no strong evidence suggesting that agricultural public investments have a crowding-in effect on private capital formation. A final major conclusion from the existing evidence in the literature raises important questions about the source of high returns to agricultural investments (where indeed they are high). The body of knowledge on how agricultural public investments affect private capital formation in agriculture is astoundingly slim. However, from the little that is known, the conclusion that must be drawn is at best mixed. ***Thus***, the contribution of public-sector investments in agriculture for the agricultural sector, and for broader development, does not appear to come predominantly from any significant crowding in of private capital formation. Several analyses on India and a cross-country panel study all draw this same conclusion. On the other hand, other studies, all on South Asia (India and Pakistan), have identified crowding-in effects. One of these studies focuses on one state within India, another is limited to irrigation, and yet another is concerned with the agricultural private-investment effects of all public investments (in and outside agriculture).

General Implications for Policy, Advocacy, and Research

At the outset, it is important to emphasize that the policy implications from the findings in the body of work discussed in this paper can never be to stop funding one activity altogether, nor to channel all resources to another. These options would be consistent neither with the analytical interpretation of the studies nor, of course, with political feasibility. Despite the diversity in empirical inquiry, methodology, and country context underlying the literature, nearly all of the studies examine effects at the margin—that is, they establish the effect of an increase in additional resources to a sector, subsector, or function. Given this analytical approach, policy implications should also be considered at the margin. In other words, if returns in one area of investment are much higher than in another, then more resources should be dedicated to the high-return activity than has been allocated so far. Drastic resource shifts would likely also drastically alter the productivity of these resources, and thus conclusions regarding the optimality of such wholesale changes in public-investment portfolios cannot be drawn from results in this literature. Furthermore, despite the comprehensive nature of this literature review, the usual caution is warranted in drawing conclusions on regions, time periods, or specific features of findings that reach beyond the temporal, geographic, or thematic scope of the extant body of work. Having made this general remark and broad clarification, we consider the key (rather than an exhaustive list of) policy and research implications emanating from this review.

The compelling and substantial evidence on the high social returns to public investments in agricultural research and technology in developing countries suggests, quite unambiguously, that there is clear underinvestment in this area. Therefore, more needs to be done to shift public resources to the accumulation of knowledge and technology. The problem of underinvestment in R&D has also been recognized in the past; thus, a related question needs to be raised as to why public underinvestment seems to persist. A better understanding of this question will suggest how to overcome potential political economic challenges that may stand in the way of expanding investments in this area. (See a synthesis review on the political economy determinants of public spending decisionmaking in developing countries in Mogues [2012].) In addition, policy can help circumvent common trade-off problems when agricultural investments are seen as coming at the expense of investments in other areas, such as health and nutrition. By supporting investments such as biofortification, the benefits of agriculture for health and nutrition can be realized—and need to be highlighted and advertised as such.

The evidence in the literature discussed in this review also suggests that policymakers should choose judiciously from among different agricultural investments, because not all agricultural investments are equal. In the same vein, when advocating the channeling of more funds to agriculture as a whole, it is critical that policymakers make distinctions between high- and low-payoff activities. The relevant stakeholders, such as technical agencies, divisions in aid organizations, or nongovernmental organizations concerned with agricultural development, should especially advocate on behalf of those investments that have clear payoffs in terms of productivity, poverty reduction, or other outcomes. This is because central decisionmakers, such as ministries of finance or presidential offices, often look to what agriculture ministries achieve in the aggregate, and if these achievements seem unimpressive to them (whether rightly or wrongly), overall budgets to agriculture will be reduced or will fail to be increased.

This judicious policy choice between alternative public investments in and for agricultural development should take several broad factors into consideration:

- Public investments have opportunity costs, there are costs associated with raising public funds, and levying taxes or borrowing to finance investments may distort economic behavior in undesired ways. Therefore, investments in and for agriculture should be founded on principles that justify the use of public funds for these investments, such as the presence of market failures or core distributional concerns.
- Policymakers and other stakeholders in the sector should be aware that benefits from such public investments may materialize after a long lag. Thus, short-term analysis may hide the economic gains to be had from public investments with long gestation periods.
- Many cases warrant a careful geographic strategy in investments. The returns to government resources on agricultural development are likely to be highly heterogeneous across space. This spatial differentiation in the effectiveness of investments also indicates the importance of central governments coordinating with subnational levels of government, not only to understand what investments are needed where, but also to ensure that the amount and composition of the combined central and local government resources that flow to a given region or province are adequate and appropriate.
- This review highlights not only the ways in which agricultural investments can contribute to outcomes that are usually seen as the concern of other sectors and agencies (for example, health), but also the ways in which investments undertaken by agencies not centrally concerned with agriculture (such as road infrastructure, electrification, education, and so on) may be among the most important inputs in increasing agricultural growth.[27] This finding points to the need to address any administrative and institutional obstacles that hinder coordination across agencies—not only across ministries in developing-country governments, but also across units in donor agencies. A first (and easier) step may be to improve the sharing of information about these types of cross-sectoral effects of public investment and about the amount and features of investments being undertaken by different agencies. As second and more challenging step would be to attempt to improve allocation across and within agencies for mutual benefit and for the achievement of multiple development goals.

Important implications for future research emerge from this comprehensive review of the topical literature. Even if not by its all-out absence, the work that is conspicuous by its scarcity is microeconomic evidence of the impact of public expenditures and investments in and for agriculture. Much of the existing evidence is meso-level sectoral analysis on the topic or cross-country analysis. In turn, the micro-level impact evaluations of agricultural interventions practically all fail to accommodate the cost side of interventions; that is, although they may show the extent to which an investment had impact, there is no information on how many resources it took to get a certain level of impact. The absence of this type of information limits the study's usefulness in considering agricultural against alternative investments. Despite the strengths and limitations of each meso-level and micro-level analysis, the balance of

[27] Badiane and Ulimwengu (2009) discussed ways to generate win-win allocations across ministries on this basis.

empirical work on the impact of public investment on agriculture has been on the former, and more needs to be done on the latter, despite obvious methodological challenges in doing so.

Thematically, there are several areas for which knowledge is currently very thin, only a few of which will be highlighted here. First of all, as evidenced in this paper, analysis on the impact of agricultural public investment on private capital formation appears to be limited to only two countries. This is possibly due to data limitations; however, given the importance of this research question, the knowledge gap needs to be addressed. Second, the sources of public investment are not monolithic, and where resources originate—and by whom they are managed—may make a difference in their effectiveness. Both theoretical/conceptual and empirical work on how the sources of agricultural investments (for example, central government, local governments, donors, and so on) may matter is warranted. Third, a much better understanding of the governmental and institutional settings that condition the effectiveness of a given investment for the sector is needed. (Mogues [2012] is dedicated to reviewing the literature on a related but fully different question: how governance and political economy dynamics affect the types of public investments that are undertaken.) For example, future research should begin to address questions such as whether decentralization of certain investments and interventions in agriculture improve or constrain their impact, or whether expenditures on R&D result in greater productivity under different systems of national agricultural research management.

Appendix A: Public Investment and Public Spending: A Conceptual Distinction and the Empirical Treatment of Key Terms

To provide a framework for the synthesis of the existing evidence on the impacts of public investments and expenditures in and for agriculture provided in this paper, this discussion takes two steps back to first ask fundamental questions regarding the definition of terms commonly used in such analyses. These questions include the following:

- What is public investment? What exactly is the difference between public investment and public expenditures?
- How do the production or provision of public and private goods and services by the government relate to the notion of public investment and to public spending that is not investment?
- Is *development expenditure* the same as *capital expenditure*, and is that in turn the same as *public investment*?
- Are *government consumption expenditure* and *recurrent expenditure* synonymous terms?
- In our concern with agricultural investments, is there a case to be made for examining agricultural public spending that goes beyond the notion of investment by some definition?

Before beginning to answer some of these questions, it is useful to first realize the many different and conflicting ways these concepts are used in the economics literature undertaking analysis of public expenditures. We start with the concept of *public investment*, which has been defined, described, or proxied variously as public expenditures "providing various public goods, such as research and development (R&D), infrastructure, and education" (Zhang and Fan 2004, p. 89) or as "all kinds of public expenditures that generate future fiscal benefits" (Easterly, Irwin, and Servén 2008, p. 42). The literature also includes discussions of "investment in research, extension, rural infrastructure, and irrigation" (Fan and Pardey 1998, in Fan and Brzeska 2010, p. 3419). A study on public investment and corruption uses the notion of "public investment spending free from corruption" and measures it as "health and education spending," whereas the same study sees "investment spending subject to corruption" being measured as "expenditure on housing, fuel and energy, agriculture, mining and manufacture, transport (and other economic activities)" (de la Croix and Delavallade 2009, p. 204). Although many other examples of how public investment is conceived of in the economics literature that is centrally concerned with this concept, these examples suffice to show the disparateness of conceptualizations of public investment.

The same exercise could be undertaken to examine how the other concepts mentioned herein are treated and how public investment is distinguished from noninvestment expenditures. One would come to the same conclusion that these concepts and the distinctions among them vary widely across the empirical literature. This variation may exist for a variety of reasons. One reason may be that a clear and unambiguous definition may not have asserted itself in the economics literature. Another is that although authoritative definitions exist within related but different fields, such as public finance, economics researchers may not be aware of these. Yet another possible reason may be research convenience in the face of data constraints. Finally, a choice of definition may be dictated (or at least suggested) by the theoretical or conceptual framework of a particular research topic (be it corruption, agricultural productivity, or other themes), which may diverge from definitions prevailing in public finance.

As stated above, we step back in this discussion to review definitions and classifications of public expenditure. The first subsection details how public spending is organized according to economic classification. The next subsection discusses the functional classification of public spending. Throughout the discussion, we provide examples relating to public expenditures and public investment in agriculture. This discussion mainly draws on key documents by leading international organizations that have developed definition and classification systems for fiscal operations. Primarily, the sources of information are the *Government Finance Statistics Manual* by the International Monetary Fund (IMF 2001), and the *Classifications of Expenditure According to Purpose* by the Organization of Economic Cooperation and Development (OECD) and the United Nations (UN 2000). However, we also draw on the sixth and seventh editions of the System of National Accounts, published jointly by the European Commission, the IMF, the OECD, the UN, and the World Bank (IWGNA 1993, 2009), and on the *Government Finance Statistics Guide* of the European Central Bank (ECB 2010).

Economic Classification of Public Expenditures

Government expenditures are categorized into two main groups: expenditures that are termed "expenses" in the IMF *Government Finance Statistics* terminology, and expenditures that contribute to public capital formation.

Expenses, or Current Expenditures

All transactions that result in a decline of the government's net worth are defined as *expenses*. The government's net worth, or net wealth position, is its total stock of assets minus its liabilities. Expenses are outlays that do not contribute toward public capital formation or the purchase of public assets. The *expense* concept is very close to (though not identical to) the term more commonly referred to in the economics literature as *current expenditure* or *recurrent expenditure*.[28] We will, however, carry on with the term *expense* to remain in line with the formal language of government finance classification.

There are eight main types of expenses, briefly described as follows:

1. *Compensation of employees.* This includes payments to public employees in the form of wages and salaries, such as for officials at the ministry of agriculture, agricultural scientists, and extension agents. This category also includes social insurance benefits, pensions, and other employment-related social benefits. Note that the latter is to be distinguished from social benefits to the total or to target populations (see definition 3).
2. *Subsidies.* This refers to unrequited payments from government to producers, such as farmers or agribusinesses. The amount of subsidies may be based on the volume of output produced, such as tonnage of crops or head of livestock, or the value of output sold or traded internationally. The purpose of subsidies may be varied—for example, to influence amounts of output produced, to control equilibrium prices of outputs, or to supplement incomes or profits of the producers. This category does not include what is commonly referred to as *subsidies to consumers* in the economics literature, such as food subsidies. Such payments would fall under definition 3.

[28] The term *recurrent expenditure* or recurrent *spending* is never used in the formal manuals and guides on government finance statistics, such as IMF (2001) or ECB (2010), though the term is quite popular in the economics literature analyzing public expenditures.

3. *Social benefits*. Unlike the social benefits associated with public-sector employment in category 1, these social benefits are social assistance (financial or in-kind) transfers that target individuals or households. Examples of such benefits include safety net transfers for food-insecure rural dwellers, food subsidies for the urban poor, subsidies for healthcare for low-income individuals and families, unemployment compensation, and social security schemes. These types of social transfers need not be only to target populations; some may also be for all individuals or households. The distinction between this and category 2 should be emphasized. Whereas category 2 (subsidies) pertains to subsidies to producers, such as farmers, firms, and so on, this category relates only to private individuals or households. Of course, a farmer may qualify for receipts of government expenditures from categories 2, 3, or both. However, category 3 transfers would not relate to his or her activities as a producer, but rather to criteria such as his poverty status, income, or demographic characteristics.
4. *Use of goods and services*. This category describes government expenditures on goods and services that would be further used as intermediate goods in a production process. It may be easier to first characterize this category by highlighting what it does not refer to. It does not include any goods or services transferred as-is to individuals or households as social transfers—these transactions would qualify as social benefits (category 3); any goods and services transferred to producers to affect their production or profits—these would be expenditures as subsidies (category 2); or any goods and services provided to public employees as a form of compensation for their labor—this would be category 1. Expenditures on goods and services that go toward producing fixed assets also do not fall into this category, as will be discussed later. Examples that do fall into this category include expenditures on chemicals for use in agricultural research labs, utensils such as writing material for extension agents' work in training farmers, protective clothing for staff involved in pest-control activities, and rental payments for the use of rented-in buildings or machinery.
5. *Interest*. This concerns expenditures by a government unit in the form of interest payments on principal outstanding for borrowed funds, whether this pertains to funds the government borrowed from the domestic private sector, foreign governments, international organizations, or different government units within the country.
6. *Grants*. Examples of grants include a government unit making transfers to foreign governments, such as in the form of development aid; transfers to international organizations in the form of annual fees; or intergovernmental grants to lower-tier government units, such as to provincial or district governments.
7. *Consumption of fixed capital*. When public assets decline in value due to depreciation or normal accidental damage, this is recorded as an expense, although it is not an explicit transaction. (The definition of *assets* is discussed in greater detail in the next subsection.)
8. *Other expenses.* Expenditures in this residual category include rents a government unit pays for the use of a financial asset (other than interest payments, which fall into category 5). Another example of *other expenses* is the payment of dividends that public corporations may make to their shareholders. Other expenses also capture rents for the use of nonproduced assets, such as land.

Table A.1 summarizes these eight expense categories. Based on this categorization, the concept of "government final consumption expenditure," which is frequently used in analytical work, is appropriately approximated by adding up category 1, the in-kind component of category 3, and categories 4 and 7 (compensation of employees, purchase of goods and services transferred as social benefits, use of goods and services, consumption of fixed capital) and subtracting the sale of goods and services.

Table A.1—Economic classification of expenses

Categories	Description and remarks
1. Compensation of employees	Payments to public employees in the form of wages, salaries, social insurance benefits, pensions, and other social benefits
2. Subsidies	Subsidy payments to public or private producers
3. Social benefits	Social security transfers, social assistance, or safety net transfers
4. Use of goods and services	Spending on goods and services for use in a production process, including rents for the use of fixed assets owned by others
5. Interest	Interest payments to domestic private sector, domestic residents, higher- or lower-tier governments within the country, and foreign creditors
6. Grants	Transfers to foreign governments, international organizations, and higher- or lower-tier governments within the country
7. Consumption of fixed capital	Decline in value of assets due to depreciation
8. Other	Dividends paid by public corporations; rents for the use of nonproduced assets, such as land

Source: Adapted from IMF (2001).

Expenditures Contributing to Public Capital Formation, or Capital Expenditures

The second major type of government outlay is expenditures on (nonfinancial) assets and public capital formation. The concept of *capital expenditures* commonly used in economic analysis is similar to this category. In turn, sometimes the term *development expenditure* is used in place of *capital expenditure*, especially in the development economics literature.[29] Before discussing expenditures on nonfinancial assets, it is important to carefully define *assets* in the context of government finances. Assets are classified in the Government Finance Statistics system into nonfinancial and financial assets. Financial assets held by the government include financial claims (such as cash, loans and bonds, deposits, and financial derivatives), monetary gold, and IMF-allocated Special Drawing Rights (SDRs). The continued discussion in this section will focus on nonfinancial assets, which are classified into four main types:

1. *Fixed assets.* Fixed assets have the following three key characteristics: they are (1) produced (as opposed to naturally occurring) assets; (2) used in a production process, as opposed to primarily serving another purpose, such as a store of value; and (3) used continuously or repeatedly for an extended period in production processes, as opposed to assets that expire after being used once in a production process. Examples of fixed assets include buildings and structures, such as roads, schools, hospitals, farmer training centers, power lines; machinery and equipment, such as tractors, transport vehicles, and office equipment; plants and animals used for a continuous production process; and intangible fixed assets, such as computer software. Some examples can be used to illustrate the characteristics of fixed assets mentioned above: Land is not a fixed asset, because it is naturally occurring instead of being produced. High-value works of art are fixed assets if they are displayed in public museums, as they provide a continuous economic service in this function; however, they are not fixed assets if they are not used in this fashion and instead are used as a store of value. Draft animals are fixed assets, whereas cattle raised solely for slaughter are not, as use of the latter is not continuous but is a one-time event. Similarly, military weapons, such as bombs or missiles, are not considered fixed assets, as they expire upon first use; instead, expenditures on such weaponry are classified as a use of goods and services under expenses.

[29] IMF (2001) never uses the terminology of *capital expenditure* or *capital spending*, whereas ECB (2010) does. However, none of the formal government finance documents ever use *development expenditure/spending*.

2. *Inventories.* Inventories are defined as goods that are held but not immediately used. They may be held for future use in a production process, for future direct use, or for later sale. These can be a variety of materials or supplies. An important type of inventory is strategic stocks, which are usually goods of strategic importance to the country, such as reserves of grains or of energy resources. Other items classified as inventories include goods that are in the process of being produced or created, such as irrigation dams, buildings, or roads in the midst of construction.
3. *Nonproduced assets.* A typical nonproduced asset—and one of particular import to agriculture—is land. The definition of *land* as a nonproduced asset includes both the soil and surface water on the land, as well as any produced structures on the land the main function of which is to improve or make available the land, such as ditches or dykes. However, not included as part of the value of the land are structures built or grown on it, such as buildings and economic trees (which will be classified as fixed assets). In addition to land, other nonproduced assets include subsoil assets, such as underground reserves of oil, gas, and minerals; other naturally occurring assets, such as natural forests and groundwater resources; and intangible nonproduced assets, such as patents and contracts.
4. *Valuables.* This fourth and final category refers to produced assets that are mainly used neither for direct consumption (such as housing not used in the production process) nor for production (such as machinery). Rather they function as a store of value. Examples include government-held reserves of gold. Referring to an earlier example, works of art not used to provide services (for example, by being displayed in museums) qualify as valuables.

Transactions in assets include both acquisitions and disposals. Although an expenditure described as an expense in Government Finance Statistics terminology results in a decrease of the government's net worth, the acquisition of nonfinancial assets does not have an effect on the government's net worth (and, in that sense, is distinct from *expense*). Instead, such a transaction simply exchanges one asset (for example, an irrigation dam) for another (such as the financial payment to acquire or build the irrigation dam).

Acquisitions of assets may take place through the purchase of, payment in-kind for, or receipt as a grant or transfer-in of already existing assets. Transactions in assets also take place when new assets come into being by being produced by the government unit. In addition to the acquisition or production of assets, other transactions include the reconstruction, renovation, or enlargement of existing assets that expand their productive capacity, even though this process may not create separate and distinct assets. Examples of this process include major rehabilitation of road infrastructures or major improvements to public lands. Expenditures associated with (nonmajor) repair or regular maintenance of assets are not considered transactions in assets, but are instead classified as an expense.

Table A.2—Categories of nonfinancial assets

Categories and subcategories	Description and examples
1. Fixed assets	
a) Buildings and structures	
(i) Dwellings	Residential housing, such as housing for military personnel
(ii) Nonresidential buildings	Schools, hospitals, office buildings, industrial buildings, warehouses, hotels, restaurants
(iii) Other structures	Roads, bridges, power lines, tunnels, railways, pipelines, dams, sewers, mining shafts
b) Machinery and equipment	
(i) Transport equipment	Motor vehicles, ships, aircraft, bicycles, trailers
(ii) Other machinery and equipment	Electrical machinery, communication equipment, office equipment, medical appliances
c) Other fixed assets	
(i) Cultivated assets	Breeding stocks; dairy cattle; draft animals; sheep (for wool production), trees, vines, and shrubs cultivated for fruits, sap, bark, and other products
(ii) Intangible fixed assets	Computer software, literary and artistic originals, mineral exploration
2. Inventories	
a) Strategic stocks	Grain reserves, petroleum stocks
b) Other inventories	Materials and supplies held as inventory, "works in progress": goods and services partially produced but not yet finished
3. Nonproduced assets	
a) Land	Land including the ground, soil, any surface water, and major improvements of the land attached to it; excluding buildings and trees built or grown on the land, subsoil assets, and water resources below the ground.
b) Subsoil assets	Subsoil reserves of oil, natural gas, coal, metals, other mineral reserves
c) Other naturally occurring assets	Virgin forests and fisheries, aquifers and other groundwater resources, electromagnetic spectrum
d) Intangible nonproduced assets	Patents, leases, and other contracts
4. Valuables	High-value goods held as store of value, such as precious stones and metals, jewelry, works of arts

Source: Adapted from IMF (2001).

Two critical elements in the classification of public expenditures as *expense* versus as *capital formation* should be noted, especially as these may frequently be treated differently in the economics literature analyzing public expenditures. First, any expenditures on public employee salaries, on the purchase of goods and services, and so on, which are incurred directly toward the purpose of capital formation, are not classified as *expense*. Instead, they are expenditures associated with capital formation for the asset in question.[30] Second, expenditures on research and development (R&D) are *not* treated as acquisition of assets or as capital formation; instead they are classified as the use of goods and services under *expense*. This is despite the fact that R&D expenditures may produce benefits over an extended period, as do assets.

[30] This treatment is consistent with IMF (2001). However, it is treated differently in the *Government Finance Statistics Guide* (ECB 2010). In the latter's framework of public financial accounts, such expenditures are recorded twice, both in the ECB's (2010) equivalent of *expense*, as well as under *expenditures for capital formation*.

Gross public investment is appropriately captured as the acquisition and production of nonfinancial assets with valuables excluded, minus the disposal of such assets. Although this is acquisitions less disposals, it still represents gross public investment, because the “gross” reflects the fact that depreciation has not been netted out of this variable. Net public investment, then, is gross public investment less consumption of fixed capital.

Functional Classification of Public Expenditures

The Classification of Functions of Government (COFOG) was initially developed as part of the 1993 System of National Accounts (IWGNA 1993); several years later, it was revised by the OECD (UN 2000). In a nutshell, the distinction between economic and functional classifications can be summarized as the difference between what expenditures are spent on versus what expenditures are for. Although the economic classification of government expenditures described in the previous section details the particular items on which resources are expended (expenditures on salaries, goods and services, capital formation, and so on), the functional classification organizes public expenditures in such a way as to provide information about the purposes toward which these expenditures are undertaken (expenditures to provide agricultural services, healthcare, road infrastructure, and so forth). Each purpose or function usually requires several expenditure items, per the economic classification. For example, the public agricultural R&D expenditures require resource allocation to pay salaries of research and other staff, expenditures on capital formation for buildings and other structures used for scientific work, and expenditures on equipment and supplies used in research laboratories.

Box A.1 outlines the functional classification of public expenditures according to the COFOG. The COFOG, in its full version, is very detailed; the table in Box A.1 includes subcategories below the first level only for functions of interest. There are 10 broad categories. Several familiar functions, such as health or education, are listed as one of the categories. Agriculture is treated as a subcategory under the Economic Affairs category, and this subcategory groups together crop and livestock agriculture, forestry, and fishing and hunting. A second subcategory under Economic Affairs is R&D, and under that, as a sub-subcategory, is agricultural R&D.

Although the functional classification of government expenditures is usually of great interest for economics analysts, especially those with particular interests in select sectors, data available from government accounts are usually not structured along functional lines (see, for example, the discussion of the classification of agricultural spending in Nigeria’s government accounts, in Mogues et al. [2012]). Therefore, the use of such accounts in data analysis of, for example, the impact of the functional composition of spending or the share of expenditures within one function, such as agriculture, can only be undertaken imperfectly if government public accounts are relied upon. Instead, government public accounts commonly organized along administrative lines, with expenditures grouped by the ministries and agencies undertaking the expenditures. However, expenditures on a particular function are often undertaken by more than one ministry (agriculture is a good example of this scenario). Although many agricultural services will commonly be undertaken by the ministry of agriculture, the ministry of water is often responsible for investing in irrigation for crop production; and the ministry of education, for agricultural vocation and training and agricultural R&D at universities. In addition, significant public expenditures in agriculture sometimes take place through special presidential initiatives or through public agencies that may not report directly to the ministry of finance. Analysis of the returns to public spending in agriculture in Ghana by Benin et al. (2012) offers an example of how disparate the sources of funding for agricultural spending can be and, thus, how difficult it may be to collect such data at the country level.

Box A.1—Functional classification of expenditures

1. Education
2. Health
3. Economic Affairs
    a) General economic affairs
    b) Agriculture, forestry, fishing and hunting*
        (i) Agriculture
        - Administration of agricultural affairs and services; conservation, reclamation, or expansion of arable land; agrarian reform and land settlement; supervision and regulation of the agricultural industry
        - Construction or operation of flood control, irrigation, and drainage systems, including grants, loans, or subsidies for such works
        - Operation or support of programs or schemes to stabilize or improve farm prices and farm incomes; operation or support of extension services or veterinary services to farmers, pest control services, crop inspection services, and crop grading services
        - Production and dissemination of general information, technical documentation, and statistics on agricultural affairs and services
        - Compensation, grants, loans, or subsidies to farmers in connection with agricultural activities, including payments for restricting or encouraging output of a particular crop or for allowing land to remain uncultivated

        (ii) Forestry
        - Administration of forestry affairs and services; conservation, extension, and rationalized exploitation of forest reserves; supervision and regulation of forest operations and issuance of tree-felling licenses
        - Operation or support of reforestation work, pest and disease control, forest fire-fighting and fire-prevention services, and extension services to forest operators
        - Production and dissemination of general information, technical documentation, and statistics on forestry affairs and services
        - Grants, loans, or subsidies to support commercial forest activities

        (iii) Fishing and hunting
        - Administration of fishing and hunting affairs and services; protection, propagation, and rationalized exploitation of fish and wildlife stocks; supervision and regulation of freshwater fishing, coastal fishing, ocean fishing, fish farming, wildlife hunting, and issuance of fishing and hunting licenses
        - Operation or support of fish hatcheries, extension services, stocking, or culling activities
        - Production and dissemination of general information, technical documentation, and statistics on fishing and hunting affairs and services
        - Grants, loans, or subsidies to support commercial fishing and hunting activities, including the construction or operation of fish hatcheries

    c) Transport
    d) Fuel and energy
    e) Mining, manufacturing, and construction

Box A.2—Continued.

f) Communication

g) R&D economic affairs**

- *(i) R&D in agriculture, forestry, fishing, and hunting**
  - Administration and operation of government agencies engaged in applied research and experimental development related to agriculture, forestry, fishing, and hunting
  - Grants, loans, or subsidies to support applied research and experimental development related to agriculture, forestry, fishing, and hunting undertaken by nongovernment bodies, such as research institutes and universities
  - Excludes basic research, which is classified under "General Public Services"
- *(ii) R&D in transport*
- *(iii) R&D in fuel and energy*
- *(iv) R&D in mining, manufacturing, construction*
- *(v) R&D in communication*
- *(vi) R&D in other industries*

h) Other industries

i) Other economic affairs

4. Environmental protection
5. Social protection
6. Housing and community amenities
7. Recreation, culture, and religion
8. Defense
9. Public order and safety
10. General public services

Source: Adapted from IMF (2001)

Notes: Second- (bulleted in the table as *a), b), c)*, . . .), third- (bulleted as *(i), (ii)*, . . .), and fourth-level (as dashed bullets) subcategories from the detailed COFOG list are selectively included, where it is of interest for the topic of this paper. *Shaded categories in this table are those of interest as they are related to agriculture. **As in the case of the category of "Economic Affairs," each of the other nine categories have an R&D subcategory (such as R&D in health).

In conclusion to this detailed discussion of the definition and classification of public expenditures, it is now possible to revisit the remarks made at the beginning of this section about the various common, but incongruent, uses of terminology across academic studies in economics—in particular, studies concerned with public spending and public investment, including those studies focused on the agricultural sector. First, it is apparent that some conflation (often knowingly and not always unjustifiably) takes place between economic and functional classification. That is, some studies proxy public investment with data on public expenditures on transport infrastructure, energy, telecommunications, and so on, and proxy consumption expenditure with health and education spending. This is because expenditures on transport infrastructure are capital-intensive, and much of the output from these expenditures are assets, whereas the lion's share of expenditures on health and education go toward paying service provider staff, and a relatively small share goes toward capital formation, such as schools and clinic buildings and major appliances.

Second, as we have seen in the discussion, terminology in formal government finance is not necessarily the same as terminology preferred in the economics literature. These semantic discrepancies may also contribute to divergence between conceptual treatments and meanings in the public finance world on the one hand, and those used in (nonfinance) economic studies on the other. For example, as we have seen, R&D investments are not considered as expenditures toward public capital formation in the Government Finance Statistics classification, but they are routinely treated as public capital expenditures in the economics literature. Similarly, although in some studies, health and education spending are subsumed into "consumption expenditure," in other studies, they are treated as public investments, motivated by the basic idea that expenditures on health and education (whether these be expenditures on teacher and clinician salaries or on schools and hospitals) contribute to the accumulation of human capital.

Of necessity, in our review of the empirical evidence about public investments in and for agriculture in Sections 4 and 5, we mostly leave the definition and classification of expenditures in various studies as they are, because it is an impossible task to redefine them in such a way that makes all studies consistent in terminology. However, where needed and possible, we include footnotes of particular approaches used in studies to clarify their usage of terms such as *agricultural public investments, capital spending,* and so on. Although it is not the objective of the above discussion to graft this formal classification onto the studies reviewed in this paper, we believe the elaboration provided here is useful in shedding light on, and removing some confusion about, the meaning of core concepts used in the analysis of public expenditures in, for, and beyond agriculture.

Appendix B: The Impacts of Investments in the Generation and Dissemination of Agricultural Technology

A vast literature on the returns to public investment in agricultural research, development, and extension (RDE) finds that annual internal rates of return (IRRs) are substantial. This finding is consistent across a number of comprehensive reviews. Evenson (2001) and Alston et al. (2000a, 2000b, 2010) present extensive reviews of the available reported estimates of returns to agricultural research and development (R&D) and extension investment. Using a variety of models[31] to estimate investment outcomes, these reviews report results in terms of internal rates of return.[32] The IRR represents the return to an investment by the value of the future payoff of that investment. In technical terms, the IRR is defined as the discount rate that offers a net present value (NPV) of 0. A discount rate captures the decrease in value of holding money in the future versus the value of holding money today, whereas NPV is the present value of a positive cash flow. In this respect, the discount rate that offers an NPV of 0 is the rate of return to the initial investment, and higher rates of return indicate better investments.

In a review of 375 applied research programs and 81extension programs spanning wheat, rice, maize, cereal, fruit and vegetable, forest, and livestock commodities across Asia, Latin America, Africa, and the OECD, reported research and extension IRRs vary by region and commodity, with the Asian region and crops such as rice, maize, and fruits and vegetables generally reflecting higher returns (Evenson 2001). Four-fifths of the reported IRRs of applied research programs are greater than 20 percent, and two-fifths are between 20 and 60 percent (see Table A.3). Similarly, three-quarters of the extension programs reviewed have IRRs greater than 20 percent, and two-fifths are between 20 and 60 percent. However, Evenson (2001) noted a greater number of applied research programs than extension programs with IRRs exceeding 40 percent.

> Returns vary by region as well. Compared with Africa and Latin America, Asia has higher returns to applied research: nine-tenths of the 120 reported IRRs are greater than 20 percent, and somewhat more than half are greater than 60 percent. While also very high,

[31] Such models include supply-and-demand models of commodity markets (Alston 2000a) and partial productivity frameworks (Evenson 2001), among others. Discussion of these models is beyond the scope of this paper; we refer the interested reader to the discussions in Alston et al. (2000a, 2000b, 2010) and Evenson (2001) for more information.

[32] Although other estimates of returns, such as cost–benefit estimates, are reported in the papers reviewed by Alston et al. (2000a, 2000b, 2010) and Evenson (2001), these comprehensive reviews report returns only in terms of IRR.

IRRs in African and Latin American countries lag behind: of the 44 reported IRRs for Africa, somewhat less than three-quarters are greater than 20 percent, whereas somewhat more than one-quarter are greater than 60 percent. Of the 80 reported IRRs for Latin America, less than nine-tenths are greater than 20 percent while about one quarter are greater than 60 per cent. Although returns to extension are lower in Africa than in Latin America and Asia, these estimates come from a smaller sample: only 10 of the reported IRRs are from Africa, whereas 23 and 21 are from Latin America and Asia, respectively. Returns to applied research in different commodity programs vary by crop, with rice, maize, and fruits and vegetables offering the highest returns.

Table A.3—Internal rates of return (IRRs) of agricultural research, development, and extension

	No. of IRRs reported	Percent distribution						Approx median IRR
		0–20	21–40	41–60	61–80	81–100	100+	
Extension								
Farm observations	16	0.56	0	0.06	0.06	0.25	0.06	18
Aggregate observations	29	0.24	0.14	0.07	0	0.27	0.27	80
Combined research and extension	36	0.14	0.42	0.28	0.03	0.08	0.16	37
By region								
OECD	19	0.11	0.31	0.16	0	0.11	0.16	50
Asia	21	0.24	0.19	0.19	0.14	0.09	0.14	47
Latin America	23	0.13	0.26	0.34	0.08	0.08	0.09	46
Africa	10	0.4	0.3	0.2	0.1	0	0	27
All extension	81	0.26	0.23	0.16	0.03	0.19	0.13	41
Applied research								
Project evaluation	121	0.25	0.31	0.14	0.18	0.06	0.07	40
Statistical	254	0.14	0.20	0.23	0.12	0.10	0.20	50
Aggregate programs	126	0.16	0.27	0.29	0.10	0.09	0.09	45
Commodity programs								
Wheat	30	0.3	0.13	0.17	0.1	0.13	0.17	51
Rice	48	0.08	0.23	0.19	0.27	0.08	0.14	60
Maize	25	0.12	0.28	0.12	0.16	0.08	0.24	56
Other cereals	27	0.26	0.15	0.3	0.11	0.07	0.11	47
Fruits and vegetables	34	0.18	0.18	0.09	0.15	0.09	0.32	67
All crops	207	0.19	0.19	0.14	0.16	0.1	0.21	58
Forest products	13	0.23	0.31	0.68	0.16	0	0.23	37
Livestock	32	0.21	0.31	0.25	0.09	0.03	0.09	36
By region								
OECD	146	0.15	0.35	0.21	0.1	0.07	0.11	40
Asia	120	0.08	0.18	0.21	0.15	0.11	0.26	67
Latin America	80	0.15	0.29	0.29	0.15	0.07	0.06	47
Africa	44	0.27	0.27	0.18	0.11	0.11	0.05	37
All applied research	375	0.18	0.23	0.2	0.14	0.08	0.16	49
Pre-invention science	12	0	0.17	0.33	0.17	0.17	0.17	60
Private-sector R&D	11	0.18	0.09	0.45	0.09	0.18	0	50
Ex ante research	87	0.32	0.34	0.21	0.06	0.01	0.06	42

Note: Reproduced from Evenson (2001).[33]

The categories of pre-invention[34] science and private-sector R&D in Table A.3 capture the spillover effects of product improvement and industrial R&D, respectively, to the public sector. Spillovers include both spill-outs and spill-ins. Spill-outs occur when research conducted in one state or nation or on one crop has outcomes that benefit another state, nation, industry, or crop; this same benefit, from the perspective of the state, nation, industry, or crop receiving the spill-out, is considered a spill-in. With all pre-invention science IRRs above 20 percent and four-fifths of private-sector R&D IRRs above 20 percent, the returns to these investments are quite high, suggesting that the social rate of return (the private rate of return plus the spillover) is much higher than the private rate of return (Evenson 2001). After commodity program research in rice and fruits and vegetables, the categories of pre-invention science and private-sector R&D have the greatest proportion of IRRs above 40 percent. Ex ante studies, though also exhibiting high IRRs, span a narrower range of IRRs than ex post studies.

[33] This table is reproduced from Evenson (2001, 81). The column titled "No. of IRRs reported" does not sum correctly in the original table; we have been unable to resolve that issue here. However, the "No. of IRRs reported" is useful in that it helps the reader understand the relative values in the distribution columns. Therefore, it has been retained here.

[34] Evenson (2001) used the term *pre*-invention *science* to capture the spill-in effect that occurs in the development of new technology.

However, the range of IRRs across both extension and applied research programs is broad; therefore, it is difficult to draw conclusions based on differences in means among various categories (Evenson 2001).

Compiling a comprehensive meta-dataset of all quantitative studies of rates of return of agricultural research that have been conducted in the course of the second half of the 20th century, Alston et al. (2000b) assembled a dataset comprising 292 research and extension studies and 1,852 estimates of rates of return, with an average of 6.5 estimates per study. These studies, which encompass the diversity of RDE research, include studies from government, university, private, and international research centers; studies on a variety of agricultural endeavors, including tree and field crops,[35] livestock,[36] and natural resources; both ex post and ex ante studies; and studies on research investments in developed and developing countries. Analysis of this meta-dataset reveals that research is associated with higher returns to investment than either extension or RDE programs, that research in developed countries shows higher returns than that in developing countries, that RDE investment does not suffer from diminishing returns, and that investment in RDE in products with shorter production cycles offers higher returns. These and other findings are detailed below.

Simple aggregation of the research and extension IRRs indicates high payoff to RDE investment (Table A.4). The Alston (2000b) meta-dataset has a mean IRR of 81 percent, a sample mode of 40 percent, and a median of 44 percent. After dropping outliers and observations with incomplete information, the mean IRR falls to 65 percent, the mode to 28 percent, and the median to 42 percent in the remaining 1,128 estimates. Within this restricted dataset, the mean return to combined RDE expenditures is 47 percent, whereas the returns for research only and for extension only are each about 80 percent.

In a regression of IRR outcomes on various types of research investment, among a number of other explanatory variables, returns to extension alone or to combined RDE are lower than those to research alone—lower by 58 percent in the case of extension and by 34 percent in the case of RDE.[37] In addition, returns to research conducted in developed countries are 13 percent higher than are returns to research conducted in developing countries. The authors find no evidence that rate of return to RDE has declined overtime, indicating that there are no diminishing returns to investment.

Table A.4—Ranges of rates of return in agricultural research, development, and extension

		Rate of return (%)				
	No. of obs.	Mean	Mode	Median	Min.	Max.
Full sample						
Research only	1,144	99.6	46	48	–7.4	5,645
Extension only	80	84.6	47	62.9	0	636
Research and extension (RDE)	628	47.6	28	37	–100	430
All observations	1,852	81.3	40	44.3	–100	5,645
Regression sample						
Research only	598	79.6	26	49	–7.4	910
Extension only	18	80.1	91	58.4	1.3	350
RDE	512	46.6	28	36	–100	430

[35] Field crops include “all crops,” barley, beans, cassava, groundnuts, maize, millet, “other crops,” pigeon pea/chickpea, potato, rice, sesame, sorghum, and wheat. Maize, wheat, and rice comprise the largest categories.
[36] Livestock includes beef, swine, poultry, sheep/goat, “all livestock,” dairy, “other livestock,” pasture, and “dairy and beef.”
[37] Alston et al. (2000b) referred to these values as *percentage point* differences; however, the regression and output suggest that they are percent differences.

		Rate of return (%)				
	No. of obs.	Mean	Mode	Median	Min.	Max.
All observations	1,128	64.6	28	42	–100	910

Note: Adapted from Alston et al. (2000b).

As compared with investment in general agricultural RDE, investment in field crop RDE, including maize, wheat, and rice, offers returns that are 25 percent greater, while investment in natural resource RDE, including forestry and fisheries, offers returns that are 94 percent lower. These differences can be accounted for by the length of the production cycles involved in the research; that is, field crops, which have an annual production cycle, offer higher IRRs, whereas investments in forestry and fisheries, which have much longer production cycles, offer significantly lower rates of return (Alston et al. 2000b). However, returns to investment in tree crop, livestock, and unspecified RDE were statistically insignificant. In most cases, the possibility of spillover effects was not considered in the individual studies that inform the meta-analysis. Consequently, the coefficients for the consideration of spill-ins and spill-outs of research effects were statistically insignificant.

Of the 292 studies Alston et al. (2000b) analyzed, only 25 were performed by the private sector; these 25 studies contributed 90 observations to the regression analysis. There was no statistically significant difference in the rate of returns from research performed in the private sector versus that performed in the public sector.

Alston et al. (2000b) included a number of explanatory variables related to the characteristics pertaining to the research or researcher, including, for example, the affiliation of the paper's first author. The statistical significance of such variables indicates the likelihood of some bias in the estimates. As with Evenson (2001), Alston et al. (2000b) cautioned that the broad range of estimates poses difficulty to any effort in distinguishing meaningful patterns in the data.

A 2010 update on the Alston et al. (2000b) meta-analysis brings in additional global analyses, as well as a review that focuses on returns to R&D in the United States. In this update, Alston (2010) found that the global rate of return to R&D has been consistently high, with average and marginal benefit–cost ratios much greater than 1. These findings have significant policy implications. For example, a marginal benefit–cost ratio greater than 1 implies that public investment is socially efficient; thus, the 65 years of data and studies indicate that the ratios are usually much greater than 1, which suggests a substantial underinvestment in R&D across countries and time.

The meta-analyses also make transparent some of the methodological limitations to the analyses in the returns to RDE investment literature, as well as in the compilation of systematic reviews of this literature (Alston et al. 2000b; Evenson 2001). These caveats include limitations to data availability; differences in the measurement of costs and returns across studies; differences in data collection and terms across studies and data sources; problems of attribution of impact due to time lags, spatial distribution, and limited information on private R&D investment and potential spillovers to the public sector; and the likelihood of upwardly biased estimates due to the selection bias inherent in a review of papers on the impact of investment. Thus, successful ex post evaluations are more likely to be published than are those that find no impact.[38]

In summary, despite technical caveats, the review of the substantial body of work on public investments in RDE strongly suggests that returns to RDE are significant. Trends emerging from these comprehensive reviews and recent analyses indicate that higher returns are found in R&D for agricultural endeavors with shorter production cycles, such as field crops; higher

[38] Alston et al. (2000b) offered statistical evidence of this type of bias in the literature insofar as ex post studies are concerned.

returns have been found in R&D in Asia and developed countries; and R&D is associated with higher returns than extension and combined RDE. These findings are robust across countries, through time, and across studies, reviews, and methodology. The policy implication of these high returns is that governments have significantly underinvested in agricultural RDE.

It is worth noting that this underinvestment corresponds with a period of growing public and private investment. However, neither public nor private growth has been uniform across countries or regions (Pardey et al. 2006). Global public investment in agricultural research grew by 51 percent between 1981 and 2000. Among developing countries, public agricultural investment grew at an average rate of 3.31 percent per year; at the same time, public spending in developed countries grew at an average rate of 1.09 percent per year. Between 1991 and 2000, public agricultural R&D spending in developed countries fell by an average of 0.37 percent per year. Meanwhile, privately funded research in developed countries grew by 5.2 percent per year between 1981 and1991 and by 2.1 percent per year between 1991 and 2000. In 2000, only 6 percent of developing country agricultural R&D was private; whereas in developed countries, the share of privately funded R&D was 54.3 percent (Pardey et al. 2006).

This divergence between public and private funding in developing and developed countries could put developing countries at a disadvantage: technologies developed by private research institutions in countries with effective intellectual property rights are not as available or affordable for transfer as are publicly developed technologies. However, public–private collaboration can serve as an effective way to facilitate the sharing of private-sector intellectual property with other, including public, research institutions (Binenbaum, Pardey, and Wright 2001).

A 2001 study finds evidence of growing public–private collaboration in the biotechnology and seed industry in Brazil, China, and India (Pray 2001). In the case of Brazil, the public–private collaboration entails collaboration between state and private-sector research institutes for basic research, private-sector employment of public-sector scientists and labs or facilities, applied research collaboration (between, for example, Monsanto and a state research institution) for the development of new technologies such as seeds, and technology transfer from the public to the private sector. In the case of China, public–private collaboration includes the partnership between a private U.S.-based rice company and a Chinese university-based research institute for the development of hybrid rice; cooperation between multinational seed companies and local research institutes to identify potential cultivars; and technology transfer via the private-sector type operation of the public-sector research institutes—that is, they are expected to earn their income through commercial activities, such as sale of improved seeds. In the case of India, private funds have supported public-sector research in hybrid rice development, and both private and public funds support nonprofit research institutes. Without rigorous impact evaluation, it is difficult to know what effect these collaborations have had on agricultural R&D; however, Pray (2001) found that their contributions have been generally positive. He also found that public–private agricultural R&D research collaboration is more likely where both the public and private sectors have strong research programs with sufficient funding and where there is political support for such collaboration.

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