WIDER Working Paper No. 2013/060

Prioritizing rural investments in Africa

A hybrid evaluation approach applied to Uganda

Karl Pauw[1] and James Thurlow[2]

May 2013

Abstract

Prioritizing public investments requires information on relative returns that are difficult to derive from disparate evaluation studies. This paper presents a 'hybrid' approach that combines ex post evaluation data with an economy-wide model for experimenting ex ante with alternative investment portfolios within a consistent, structural framework. The approach is used to evaluate rural investments in Uganda. Agricultural research and extension services are found to be much more effective at promoting economic growth and poverty reduction than either rural feeder roads or irrigation infrastructure. This suggests that the government's recent shift in emphasis from extension services to irrigation is potentially misguided.

Keywords: rural investment, impact evaluation, agricultural growth, poverty
JEL classification: O13, O21, O22

---

[1]International Food Policy Research Institute, Lilongwe; [2]UNU-WIDER, corresponding author
email: thurlow@wider.unu.edu

This study has been prepared within the UNU-WIDER project on Development under Climate Change, directed by Channing Arndt, James Thurlow, and Finn Tarp.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme from the governments of Denmark, Finland, Sweden, and the United Kingdom.

ISSN 1798-7237 ISBN 978-92-9230-637-3

The World Institute for Development Economics Research (WIDER) was established by the United Nations University (UNU) as its first research and training centre and started work in Helsinki, Finland in 1985. The Institute undertakes applied research and policy analysis on structural changes affecting the developing and transitional economies, provides a forum for the advocacy of policies leading to robust, equitable and environmentally sustainable growth, and promotes capacity strengthening and training in the field of economic and social policy-making. Work is carried out by staff researchers and visiting scholars in Helsinki and through networks of collaborating scholars and institutions around the world.

www.wider.unu.edu *publications@wider.unu.edu*

UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

Typescript prepared by Lisa Winkler at UNU-WIDER.

1 Introduction

Many view rural development as necessary if Sub-Saharan Africa (SSA) is to substantially reduce poverty (Diao et al. 2009). There is also general agreement on the kinds of rural investments that are needed, such as agricultural research, extension services, education and rural roads (Dorward et al. 2004). These investments are now more often supported by rigorous project monitoring and evaluation. Yet, for governments facing resource constraints, knowing that specific projects can generate positive returns does not necessarily address the broader question of which interventions should be prioritized over others. Ranking interventions and allocating public funds across competing needs is an unavoidable complexity in the planning process.

One way to inform prioritization is to broaden the scope of traditional project-based impact evaluations to cover sector-wide interventions. This is the approach proposed by Elbers et al. (2009), who use school level panel data to statistically estimate the impact of different components of Zambia's education program. A similar approach is presented in a series of studies by Shenggen Fan and his coauthors, who use district time series data to simultaneously estimate the impact of different public investments on agricultural incomes (see, for example, Fan et al. 2000; Zhang and Fan 2004; Fan and Zhang 2008). Both approaches can estimate marginal returns to specific investments that can be used to prioritize spending across a range of spending options so as to raise the overall effectiveness of a sector-wide intervention.

Despite their advantages, sector-wide statistical approaches have certain limitations. First, they are constrained by data requirements, particularly in Africa, where a lack of spatial and time series data often prevents *simultaneous* analysis of different investments. Second, ex post analysis is restricted to evaluating past policies, i.e., they cannot consider new kinds of investments. For instance, if a government has not previously invested in irrigation then there is no historical data that can be used to estimate and compare returns. Third, there are concerns about using long-run returns to prioritize current investments, given possible changes in policy design and implementation. For instance, a government may improve its agricultural extension system over time and thus long-run returns may underestimate current returns. Given these limitations, African governments will probably continue to design their investment plans using disparate project evaluations (or without the support of empirical evidence). What is needed is a consistent framework for combining information from different evaluation studies.

There are at least two other factors, beyond measuring direct impacts, that complicate prioritizing investments. First, it is difficult to account for indirect impacts. Rural roads, for example, are not intended to benefit only the transport sector, but can benefit farmers and rural towns alike. Second, there are competing sets of policy goals. Not all investments have the same impact on different outcomes, such as agricultural production, poverty and regional equity. The 'optimal' allocation of funds depends not only on the relative efficiency of investments, but also on how policy goals are ranked by decision-makers. Ideally, sector-wide programs should be informed by evidence that not only measures the direct returns to investments, but also captures indirect impacts and identifies trade-offs between policy goals.

This paper presents a 'hybrid' approach to evaluating and prioritizing rural investments – one that utilizes the findings from different kinds of evaluation studies in order to assess future investment plans. At the core of our approach is an economy-wide model that measures both the direct and indirect impacts of rural investments on three policy goals: economic growth, poverty reduction and regional equity. The model is calibrated to Uganda, which has characteristics similar to other low-income African countries. The model includes rural investment functions that are calibrated to information from project evaluations and sector studies. This hybrid approach combines the strengths of ex post empirical analysis with a consistent economy-wide framework for experimenting ex ante with alternative investment portfolios. It complements project and sector-wide evaluation methods and directly addresses the prioritization problem.

The paper is structured as follows: We first introduce our case study country and describe the hybrid evaluation approach. We then present the findings from our investment analysis for Uganda, which includes changes in rural investment priorities and efficiencies. We conclude by summarizing our findings and discussing areas where the hybrid approach can be usefully applied and extended.

2 Uganda case study

Uganda has much in common with other poor economies in Africa (see Table 1). Most of the population lives in rural areas where they rely on subsistence agriculture. Population density is high by African standards and, as a result, most farmers are smallholders with an average 1.7 hectares of cultivated land. Per capita GDP is low – in the bottom quartile of African countries – and a third of the population lives below the national poverty line, which is set at approximately a dollar a day after adjusting for cost of living (GOU 2008a). Uganda is urbanizing, with people migrating to cities where poverty is lower (Dorosh and Thurlow 2012). However, cities' ability to absorb migrants is limited, and so rural development remains one of the country's main strategic goals (see GOU 2010b).

Although Uganda is an agrarian economy, its farm sector did not perform well during the 2000s, with per capita agricultural GDP declining throughout the decade (GOU 2012). This was reflected in a slowdown in poverty reduction after the successful post-reform period of the 1990s (Benin et al. 2012). Food crops generate most of agriculture's GDP and are mainly grown by smallholders who rely on traditional technologies and achieve low yields. The coverage of extension services and irrigation is quite limited and farmers often live far from decent roads and markets. Despite agriculture's poor performance, Uganda still relies on traditional exports, particularly coffee, which generates a third of export earnings.

Uganda is divided into four sub-national regions, each of which contains about a quarter of the population. These regions have quite different characteristics. Per capita GDP in the central region is nearly twice the national average and the poverty rate is relatively low. This region is more urbanized and contains most of Uganda's industry and services. In contrast, the northern region is the poorest and most remote, with the highest rural population share and lowest population and road densities. Farmers in this region rely on food crops and livestock. In fact, most export crops, with the exception of cotton and tobacco, are grown in other regions.

Within this context, Uganda's rural development strategy has three fundamental goals (GOU 2010a; 2010b). First, accelerate agricultural growth to around 6 percent per year by raising farmers' productivity through improved access to inputs and markets. This is consistent with the growth target that Uganda committed to under the Comprehensive African Agriculture

Development Program (CAADP) (Benin et al. 2012). Second, reduce poverty rates faster than population growth, thereby reducing the absolute number of poor people. Since over 90 percent of the poor live in rural areas, this implies a large reduction in rural poverty. Finally, encourage greater regional equity by promoting agricultural growth in the northern region. There is clear overlap between these three goals, as well as potential trade-offs (see Bahiigwa et al. 2005).

Uganda's National Development Plan (NDP) identifies various 'core projects' that are intended to promote rural development (GOU 2010a; 2010b). The three main expenditure items are irrigation infrastructure, research and extension services, and district feeder roads. Past public spending on these items has been low, particularly for irrigation. In 2007, for example, total spending on agriculture and irrigation was only 3 percent of the government's budget, and spending on district roads was 1 percent.[1] Under the current NDP, public expenditure on agriculture is forecasted at 5 percent of total spending. This is still well below the 10 percent agricultural budget share targeted under CAADP, even when donor spending is included and under a broad definition of spending on agriculture, i.e., one that includes rural roads.[2] It is also below the funding requirements estimated by the line ministries themselves (see GOU 2008b; 2010a; 2011). Of course, achieving Uganda's rural policy goals does not only depend on funding levels, but also on the efficiency in which funds are allocated and investments are implemented (Benin et al. 2012).

In summary, Uganda has three rural policy goals: agricultural growth, poverty reduction and regional equity. The NDP identifies three main investment areas: irrigation, research and extension and rural roads. However, current spending in these areas is low and agriculture's performance is poor. So to achieve its policy goals, Uganda's government will have to increase funding for rural investments and/or improve spending efficiency. In the next section we describe the framework that we use to estimate the impact of increasing the level and efficiency of public spending. In our analysis, we simulate the 10 percent agricultural budget share targeted under CAADP and examine which investment portfolios are best at achieving the three policy goals.

3 Measuring impacts

The impact of rural investments is modeled in two stages. First, a set of equations are specified that capture the impact channels through which public spending affects productivity levels. Parameter estimates are drawn from project and sector evaluations. Second, these equations are integrated within an economy-wide model in order to measure impacts on regional growth and poverty.

3.1 Impacts on productivity

The impact of investments on productivity is modeled using a set of nested linear equations. The economy-wide model contains a production function for each sector within Uganda's four sub-national regions. The equation below is a production function in which producers combine labor L, land N and capital K in order to produce total output Q in time period t.

---

1 Section 3 and Table A1 in the appendix describes the public spending data used in our study.

2 The CAADP target refers to 'public investment in agriculture' and not spending on the Agricultural Ministry. In Uganda, extension services, irrigation and rural roads fall under the Ministry of Agriculture, Ministry of Water and Environment, and Ministry of Works and Transport, respectively.

$$Q_t = \alpha_t F(L_t, N_t, K_t) \quad (1)$$

In our specification, rural investments affect the shift parameter α, which can be interpreted as a measure of total factor productivity (TFP). The investment equation is as follows

$$\frac{\dot{\alpha}_t}{\alpha_{t-1}} = \beta_0 + \beta_1 \frac{\dot{R}_t}{R_{t-1}} + \beta_2 \frac{\dot{I}_t}{I_{t-1}} + \beta_3 \frac{\dot{E}_t}{E_{t-1}} \quad (2)$$

where R is the density of feeder roads (measured in kilometers per square kilometer), I is the share of farm land under irrigation, and E is the share of rural farmers receiving extension services. The coefficients β_1, β_3 and β_3 show the percentage change in TFP resulting from a 1 percent change in investment outcomes. Productivity growth is determined by changes in investment, as well as a fixed time trend rate of technical change (β_0).

The right-hand terms in the investment equation refer to outcome variables, e.g., road density or irrigation coverage. Changes in these variables are derived from public expenditures and estimates of unit costs. The road stock equation is

$$R_t = \frac{(1-m)R_t^e}{r \cdot A} \quad (3)$$

where R^e is government spending on feeder roads, *m* is the share of spending devoted to maintaining existing roads, *r* is the unit cost of building one kilometer of new feeder road, and *A* is total regional land area. An increase in road investment R^e increases the amount of new roads built and, given fixed land areas, increases the density of the road network. Similar equations exist for irrigation and extension services

$$I_t = \frac{I_t^e}{i \cdot C_t}; \; E_t = \frac{E_t^e}{e \cdot H_t} \quad (4)$$

In this instance I^e and E^e are spending on irrigation and extension; *i* is the irrigation cost per hectare and *e* the extension cost per rural farm household; *C* is the total crop land area; and *H* is the number of rural farm households. Unlike the road stock equation, where land area *A* is fixed, *C* and *H* increase over time as farm land expands and population grows. Investment spending must match land and population growth in order to maintain productivity levels.

Table A1 in the appendix reports the base year values and sources of the parameters used to calibrate the investment functions. Government spending on agriculture, roads and water in 2007 was taken from the Statistical Abstract (GOU 2012). Detailed information from sector investment plans was used to isolate spending on research and extension (GOU 2010a), district feeder roads (GOU 2008b), and irrigation (GOU 2011). Regional spending levels (i.e., E^e, R^e, I^e) were derived from district level estimates for extension (GOU 2003), rural roads (Fan and Zhang 2008), and irrigation (GOU 2011). The same sources provided base year stocks (i.e., *E*, *R* and *I*). Magidu et al. (2010) report the share of annual spending on district roads devoted to routine and periodic maintenance (i.e., *m*). Finally, unit costs (i.e., *e*, *r* and *i*) were derived from project evaluations for roads (AfDB 2011) and extension (GOU 2003), and from the irrigation master plan (GOU 2011).[3] We assume that extension and road

3 Irrigation unit costs assume that new investments are evenly distributed across all areas with irrigation potential, including permanent and seasonal wetlands where unit costs are low (see GOU 2011). Excluding wetlands raises national average unit costs from US$3,182 to US$5,646 per hectare.

unit costs are the same across regions. We will examine changes in investment efficiency by raising or lowering unit costs.

Elasticities (i.e., β_1, β_2, β_3) are drawn from different kinds of impact evaluations. Table 2 shows national average elasticities. The National Agricultural Advisory Service (NAADS) (see GOU 2003) estimates that providing extension to smallholder farmers increases their agricultural incomes by 67.8 percent. This is close to the 67.0 percent average increase estimated by Benin et al. (2011) in their recent evaluation.[4] Based on current extension coverage, we derive a national elasticity of 0.171, i.e., a 1 percent increase in extension coverage causes total agricultural incomes (or productivity) to increase by 0.171 percent. This is similar to the 0.189 elasticity in Fan and Zhang (2008). Although these authors estimate their elasticity using a sector-wide statistical approach, we decided to use the more recent evaluation data to derive our extension elasticity. Our bottom-up approach also allows us to estimate region-specific coefficients, which vary according to initial coverage rates (see Table A1). We conduct sensitivity analysis using a 20 percent confidence interval around baseline elasticities. Finally, based on GOU (2003), we assume that advisory services are directed towards food crops and livestock.[5]

The elasticity for rural roads is taken from Fan and Zhang (2008), who use district time series data to econometrically estimate the returns to road investments. They find that reducing households' average distance to the nearest feeder road by 1 percent causes agricultural incomes to increase by 0.139 percent. Raballand et al. (2009) also find a significant and positive relationship between agricultural incomes and rural road density in Uganda. We therefore adopt a road elasticity of 0.139, thus assuming a strong relationship between road density and households' access to roads. Rural feeder roads are assumed to benefit food and export crops, livestock, as well as agro-processers and traders.

Finally, Inocencio et al. (2007) review past irrigation projects in SSA and conclude that, on average, these projects generated positive returns. In the past there has not been much public investment in irrigation infrastructure in Uganda and this may explain why there are no local evaluation studies that can be used to estimate the irrigation elasticity. While studies in neighboring countries confirm the positive impact of irrigation on household welfare, they do not explicitly measure its effects on agricultural productivity or revenues (see, for example, Van Den Berg and Ruben 2006). We therefore draw on a study by Dillon (2011), who, using a farm survey from Mali, finds that small-scale irrigation raises farmers' agricultural revenues by 72.8 percent. This is larger than the average 50 percent income gain identified by Hussain and Hanjra (2004) in their review of the empirical evidence. Using Dillon's impact estimate and Uganda's current irrigation coverage rates, we derive an average irrigation elasticity of 0.009. The elasticity is low because only 1.4 percent of crop land is irrigated in Uganda, and so a 1 percent increase implies only a small change in irrigated land area (and requires a relatively small increase in investment spending). Sensitivity analysis on the irrigation elasticity is essential since we are drawing on an impact evaluation from another country. Accordingly, we broaden the confidence interval around this particular elasticity to

---

[4] Agricultural income gains were found to range from 39.2 to 94.8 percent depending on model specification.

[5] Given that we assign TFP changes to only a subset of agricultural subsectors, we scale the elasticities in Table 2 using subsector GDP shares so that the effect on *total* agricultural income implied is maintained. Our choice of affected subsectors does not change the overall gain in total agricultural productivity, but it does influence distributional outcomes depending on which subsectors different farm households are engaged in.

40 percent. Being able to draw on external project evaluations when new kinds of investments are being considered is an advantage of the hybrid approach.

3.2 Impacts on growth and poverty

Changes in sector productivity are translated into changes in regional growth and poverty using a recursive dynamic computable general equilibrium model (see Diao and Thurlow 2012). This class of economy-wide models simulates the workings of a market-based economy in which the interests of detailed economic agents are mediated through factor and product prices, subject to resource constraints and macro-economic consistency.

Our model separates Uganda's economy into 50 sectors and four sub-national regions.[6] Representative producers in each sector and region combine factors of production, i.e., land, labor and capital, using a constant elasticity of substitution function and under constant returns to scale. Crop land is regional and labor is divided into six categories, i.e., primary, secondary and tertiary educated within rural and urban areas.

The model is run over the period 2007-17. Land and labor are mobile across sectors, but not regions, and their total supply grows over time based on historical trends. Past investment determines new capital stocks, which are allocated to sectors according to their relative profitability. Once invested, capital becomes immobile and earns sector-specific returns. This endogenous investment process excludes public spending on rural roads, irrigation and extension services, which instead determines productivity rates in the affected sectors. Elsewhere, the rate of technical change is exogenous such that the baseline replicates historical growth patterns.

There is imperfect substitution between domestic and foreign goods. Producers' decision to supply export markets and consumers' decision to buy imported goods are based on changes in domestic prices relative to fixed world prices. All domestic, import and export prices include relevant indirect taxes. The current account balance is maintained through changes in the real exchange rate.

The model separates Uganda's households into 20 groups within each region. These groups include farm and non-farm households within rural and urban areas, separated into per capita consumption quintiles. Representative households receive incomes based on their factor endowments, and then pay taxes, save and consume goods. The latter is determined by a linear expenditure system with income elasticities estimated using the 2005/06 national household survey (GOU 2008a). A top-down micro-simulation module measures changes in poverty (see Arndt et al. 2012). Each household in the model is linked to its corresponding survey households. Changes in real consumption spending are passed down from the model to the survey, where total per capita consumption levels are recomputed and compared to the official poverty line to determine whether a person should be classified as 'poor'.

The government receives direct and indirect taxes and foreign aid, and uses these revenues to pay for recurrent spending and investment. Private, public and foreign savings (i.e., capital inflows) are pooled and used to finance domestic investment. We initially assume that public spending grows in line with recent trends and that the fiscal deficit adjusts in order to equate

[6] The main database for the model is a regional extension of the social accounting matrix described in Thurlow (2012). Regional disaggregation uses data from GOU (2008a, 2012) and Dorosh and Thurlow (2012).

revenues and expenditures. Households' savings rates are fixed and investment demand adjusts so that it equals savings in equilibrium.

In the investment analysis below we exogenously increase public spending on a portfolio of extension services, irrigation infrastructure and rural feeder roads, and then allow the investment function to determine changes in productivity. All other public investments are held constant at baseline levels in order to isolate the effects of rural investments. Increased public spending crowds-out private investment. This is potentially a 'worst-case' scenario, since additional foreign aid or new oil revenues could be used to increase agricultural spending (see Wiebelt et al. 2011).[7] Our integrated economy-wide model and investment functions allow us to experiment with alternative rural investment portfolios, and to measure trade-offs across a range of policy goals, including growth, poverty and regional equity.

4 Investment analysis

4.1 Baseline

We first establish a baseline for the period 2007-2017. The baseline assumes that Uganda continues along current economic and demographic trends. Population, labor and capital supplies grow at 3 percent per year. Farm land expands at only half a percent each year reflecting high population density and rising land pressures. The baseline also tracks recent public investment levels and patterns. Government spending grows at 3.5 percent per year in real terms, implying a gradual increase in spending per capita. The share of the budget allocated to agriculture and rural roads increases slightly from 4.2 percent in 2007 to 4.5 percent in 2017. Public investment leads to improved rural outcomes by 2017, as shown in Table 3, i.e., the share of rural farm households receiving extension services rises from 22.9 to 26.7 percent; the share of cultivated land under irrigation increases from 1.4 to 1.6 percent; and the density of rural feeder roads increases from 11.4 to 14.5 kilometers per square kilometer.

Productivity growth is determined by public investment outcomes as well as exogenous technical change. We assume that there are no exogenous productivity gains in agriculture given the sector's recent poor performance. As a result, agricultural GDP grows at an annual rate of 3.4 percent, which is only slightly above population growth. Total GDP grows at 5.2 percent per year as a result of faster non-agricultural growth. Rising GDP per capita reduces the national poverty headcount rate from 31.0 percent in 2007 to 23.6 percent in 2017.[8] This rate of decline is consistent with observed poverty-growth elasticities.[9] Growth and poverty reduction are slowest in the northern region and fastest in the central region, reflecting a widening north-south divide.

The baseline is not intended to predict future economic growth and poverty reduction, but rather to provide a counterfactual for our investment analysis. Nevertheless, while the choice

---

7 Foreign aid and oil revenues have opportunity costs, i.e., if they are not used to finance agricultural investment, then they can be used for other purposes. Ideally an economy-wide impact evaluation should compare rural investment portfolios to investments in other sectors or programs.

8 The poverty headcount rate is the share of the population with per capita consumption below the official poverty line.

9 Uganda's per capita GDP grew at 4.3 percent per year during 2005/06-2009/10, while the poverty headcount rate fell from 31.1 to 24.5 percent (i.e., a 5.8 percent annual decline). This implies a poverty-growth elasticity of 1.34. Given the pattern of baseline growth, our model generates a poverty-growth elasticity of 1.26.

of baseline does not significantly influence our findings, it does represent a plausible 'business as usual' scenario for Uganda. In the next section we increase rural investments, resolve the model over the ten-year simulation period, and compare the new outcomes to those from the baseline.

4.2 Increasing rural investments

Figure 1 shows the share of the government budget allocated to agriculture and rural roads. Although public spending rises in the baseline, it is still well below the 'planned' investment levels identified in ministerial master plans (GOU 2008b; 2010a; 2011). The figure shows the planned increase in the share of the budget allocated to extension services, irrigation and rural roads, assuming that all other expenditure items remain at baseline levels. The gap between baseline and planned spending is largest for irrigation, which has received little funding in the past but is now a 'core project' in Uganda's NDP. Based on ministerial master plans, irrigation would become the largest expenditure item in the rural investment portfolio.

We simulate three investment scenarios that increase spending on agriculture and rural roads such that they account for 10 percent of the budget by 2017. This implies an increase in the growth rate of total government spending from 3.5 to 4.1 percent per year, and is equivalent to meeting the CAADP budget target under a broad definition of agricultural spending, i.e., one that includes rural roads. The investment scenarios differ in the way that the additional public funds are allocated. In the Extension, Irrigation and Roads scenarios we distribute half of the additional funds according to baseline allocations, while the remaining half is allocated entirely to extension, irrigation or rural roads, respectively. Note that the funding allocation in the Irrigation scenario is similar to that of the ministerial master plans (see 'Planned' in Figure 1), while the Extension scenario more closely resembles current allocations. The scenarios therefore allow us to compare Uganda's current and planned investment portfolios, albeit at higher spending levels.

The final three columns in Table 3 report the results from the investment scenarios. In each case, greater public spending leads to improved rural outcomes. In the Extension scenario, for example, 84.7 percent of rural farm households receive extension services by 2017, which is a substantial increase over the 26.7 percent achieved under baseline spending levels and patterns. There is a smaller increase in extension coverage in the Irrigation and Roads scenarios, since fewer additional funds are allocated to extension services. Similarly, the largest increase in irrigation coverage occurs in the Irrigation scenario, where the share of cultivated land under irrigation more than doubles relative to the baseline, i.e., to 3.8 percent by 2017. Since only about a tenth of arable land in Uganda is irrigable (see GOU 2011), this scenario is equivalent to irrigating 37.5 percent of all irrigable land, including wetlands. Finally, national feeder road density rises to 20.4 kilometers per square kilometer in the Roads scenario, which is more than a third higher than in the baseline.

The impact of public spending differs across investment portfolios. We begin with the Extension scenario. Agriculture's annual GDP growth rate increases by 2.3 percentage points relative to the baseline, i.e., to 5.7 percent per year. Food crops and livestock are the main beneficiaries of the expanded research and extension system. Higher productivity levels encourage farmers to reallocate their resources towards food crops and livestock and away from export crops. Non-agricultural GDP also increases, because higher agricultural production and lower prices benefit downstream agro-processers and higher rural incomes generate new demand for non-farm products. Despite these indirect or off-farm benefits, spending on extension primarily benefits farmers, with four-fifths of the gain in total GDP occurring within agriculture. It is not surprising then that the rural poverty rate declines by more than the urban poverty rate, since urban households benefit only indirectly via higher wages and lower food prices.

Investing in irrigation infrastructure generates a smaller increase in agricultural GDP than investing in extension services. This is *not* due to differences in farm level impacts, since both irrigation and extension raise farmers' agricultural incomes by about 70 percent (see Section 3). Rather it is because irrigation has higher unit costs, i.e., a once-off US$3,182 capital investment per hectare compared to an annual cost of US$28 per hectare for extension services (or US$282 over the ten-year simulation period). Even over a 20-year lifespan, irrigation infrastructure costs almost six times more per hectare than extension services. Irrigation does, however, benefit higher value crops, as well as crops with stronger linkages to non-agricultural sectors. Sugarcane, for example, is a high-value export crop that provides raw inputs to downstream sugar refineries, thereby raising non-farm employment and wages. These indirect impacts explain why agriculture accounts for a smaller share of the increase in total GDP than in the Extension scenario. It also explains the slightly stronger bias towards urban poverty reduction, although overall poverty reduction is smallest in the Irrigation scenario.

Investing in feeder roads increases agricultural GDP by 1.5 percentage points relative to the baseline, which lies between the GDP gains in the Extension and Irrigation scenarios. Feeder roads *directly* benefit crops and livestock as well as downstream agro-processors and traders. Accordingly, only 69.5 percent of the increase in total GDP occurs within agriculture. Of the three investment scenarios, rural roads are the most beneficial for export crops and this leads to broader-based agricultural growth. Higher productivity amongst traders benefits farmers by reducing transaction cost margins and raising farm gate prices. Expanding agro-processing also stimulates demand for raw agricultural inputs, thereby reducing demand constraints and supporting farm gate prices when agricultural production expands. Given these farm/non-farm linkages, rural feeder roads favor rural rather than urban poverty reduction, although poverty declines in both areas by more than in the Irrigation scenario.

In summary, public investments in extension, irrigation and rural roads all promote rural development, but the prioritization of these investments crucially determines overall outcomes. Directing funds towards research and extension is most effective in accelerating agricultural growth and poverty reduction, while investment in rural roads promotes broader-based economic growth. This is consistent with the findings from Fan and Zhang (2008) and Wiebelt et al. (2012). In contrast, irrigation infrastructure is a much less effective investment option, leading to more modest gains in both agricultural growth and poverty reduction. Our findings suggest that irrigation's prominent role in Uganda's NDP is overstated and that the current investment portfolio that favors research and extension services is more appropriate. In the remainder of this section we compare the returns to different investment portfolios and then consider how changes in efficiencies influence outcomes.

4.3 Comparing investment portfolios

Our hybrid approach combines information from evaluation studies in order to measure the impact of different investment portfolios on various policy goals. We consider three rural policy goals for Uganda: agricultural growth, poverty reduction and regional equity. Table 4 provides summary statistics on the returns to each investment scenario or portfolio.

The top panel in the table shows the additional public spending per capita in each region. We do not allocate funds on a per capita basis. Instead, extension investments are allocated according to the number of rural farm households; irrigation investments are allocated based on irrigable land in each region that is not currently irrigated; and feeder road investments are allocated according to road maintenance transfers to local governments (see Table A1 in the appendix). These allocations lead to regional differences in per capita spending in each scenario. For example, household sizes are largest in the northern region and so per capita extension spending is lowest for this region in the Extension scenario. In contrast, irrigable land and road stocks are disproportionately located in the north, given their population share, and so this region receives above-average public investment per capita in both the Irrigation and Roads scenarios. Given these regional differences in the allocation of public funds, it is necessary to 'normalize' the impacts reported in Table 3 by controlling for investment costs.

The middle panels in the table report the increase in total and agricultural GDP for every US$1 invested. These are average 'benefit-cost ratios' (BCRs) measured across the ten-year simulation period. The national BCR is 6.8 in the Extension scenario, implying that for every US$1 spent on this investment portfolio there is a US$6.8 increase in total GDP. This represents a high return on investment, although it is lower than the marginal returns estimated in Fan and Zhang (2008). The BCR is also positive but much lower for the Roads and Irrigation portfolios for the reasons discussed earlier. The gap between total and agricultural BCRs is determined by the economic structure of each region. For example, most of the benefits from extension investments in the central region occur outside of agriculture, since this is the region where downstream agro-processing is most established. The lower panel in the table reports the number of poor people lifted above the poverty line for every US$1,000 spent. Again, the Extension portfolio is more cost-effective than either the Irrigation or Roads portfolios. This means that prioritizing extension over irrigation and rural roads is consistent with Uganda's policy goals of accelerating agricultural growth and poverty reduction.

Returns vary by region. The returns on public spending are lowest in the northern region in terms of the gain in GDP, but highest in terms of poverty reduction. This is because poverty is high in the northern region and most of its farmers grow cereal and root crops for subsistence. Increasing the productivity of these low-value crops does not generate as large a gain in agricultural GDP, but it does directly benefit this region's large poor population who rely on these food crops. Directing public funds towards the northern region is consistent with promoting poverty reduction and regional equity, but is inconsistent with maximizing agricultural growth. However, the returns to public investments in all regions are highest in the Extension scenario, suggesting that expanding the agricultural research and extension system is still the most effective means of *jointly* promoting agricultural growth, poverty reduction and regional equity.

4.4 Efficiency (sensitivity) analysis

Our findings, like those in Benin et al. (2012), suggest that CAADP's 10 percent budget target is inconsistent with its 6 percent agricultural growth target, at least in the case of Uganda. The Extension scenario comes close to reaching the CAADP target at 5.7 percent agricultural growth, but the Irrigation and Roads scenarios fall short at only 4.4 and 4.8 percent, respectively. This suggests that reallocating public spending towards investments with higher returns is one way of improving policy outcomes. Increasing investment efficiency is another. Table 5 reports the returns to investments under different assumptions of investment function elasticities and unit costs. We apply a 20 percent confidence interval around the Extension and Roads elasticities and a 40 percent interval around the irrigation elasticity (see Table 2). We also raise and lower unit costs by 10 percent. Note that the central column in the table shows the same returns from Table 4.

Under the most optimistic efficiency levels, i.e., high elasticities and low unit costs, the Extension scenario generates higher agricultural GDP growth of 6.5 percent per year, which is 0.8 percentage points higher than the agricultural growth rate achieved using base efficiencies and unit costs. Conversely, under the most pessimistic efficiency levels, i.e., low elasticities and high unit costs, agriculture's growth rate drops to only 5 percent per year. There is also a wide dispersion in other outcomes under pessimistic and optimistic efficiency levels. For example, the increase in total GDP per US$1 spent on extension ranges from US$4.7 to US$9.4, and the number of poor people lifted out of poverty per US$1,000 spent ranges from 6.2 to 10.1. This suggests that raising the efficiency of extension investments is almost as effective as is improving the prioritization of planned investments. Achieving Uganda's rural policy goals will require both a continued prioritization of public investment in agricultural research and extension services as well as greater efficiency in the way these funds are spent.

Changing efficiency levels is also a form of sensitivity analysis. Table 5 shows that there are only a few cases where there is a change in the optimal investment strategy for Uganda. For example, when road investment efficiencies are at their most optimistic levels *and* extension investments are at their most pessimistic efficiency levels, then road investments become a more effective investment option for accelerating agricultural growth and poverty reduction. There are no cases in which irrigation investments are preferable to investments in either extension or rural roads. Our conclusion for Uganda – that extension is the optimal investment option – is robust across a wide range of efficiency levels and model parameters.

5 Conclusion

Prioritizing public investments requires information on the *relative* returns to interventions that are sometimes difficult to derive from disparate project evaluations. This has led some to advocate for sector-wide approaches that statistically evaluate portfolios of investment rather than individual projects. Despite their advantages, however, the scope of statistical studies is often limited to estimating the returns to long-standing investments. As an alternative, this paper presented a hybrid approach to evaluating and prioritizing investments – one that combines information from different types of project and sector studies. By integrating empirically-calibrated investment functions within an economy-wide model, our approach can measure both the direct and indirect impacts of investment portfolios on a range of policy goals.

The hybrid approach was used to evaluate rural investments in Uganda, including public spending on agricultural research and extension, irrigation infrastructure, and rural feeder roads. Our findings indicate that, while all three investments promote rural development, Uganda's new emphasis on irrigation is overstated. The government should rather continue to invest primarily in extension services, since this generates the best returns in terms of agricultural growth, poverty reduction and regional equity, i.e., promoting development in the northern region. Results suggest that extension investments are about twice as effective at accelerating growth and poverty reduction as irrigation investments, even though the latter generate more indirect benefits beyond agriculture. Rural road investments also lead to broader-based economic growth, but are a less effective investment option than extension services. Our findings are robust across a plausible range of parameter values and efficiency levels. Finally, we find that the CAADP's 10 percent budget target is insufficient to meet its 6 percent agricultural growth target in Uganda unless investment funds are prioritized optimally *and* investment efficiency is improved.

The Uganda case study demonstrated the usefulness of the hybrid approach for national planning. Although we considered only three investment options, there are others that could also be evaluated, such as input subsidies, farmer co-operatives, and education and health programs. Of course the hybrid approach is not a substitute for rigorous project evaluations, since estimates of direct impacts are needed for the investment analysis. Detailed evaluations could also permit more elaborate specifications of the investment functions, such as lagged effects and diminishing returns. One of the advantages of the hybrid approach is that it can incorporate new information once it becomes available. In Uganda, for example, the irrigation elasticity was drawn from a foreign study. This parameter could be updated using local or more recent evaluation data, although, in this case, sensitivity analysis indicated that it would not alter our conclusion. Overall, the hybrid approach complements standard evaluation studies and is an advance over the 'log frames' that are often used to design public investment plans (see Elbers et al. 2009). A hybrid approach provides an explicit and consistent structural framework for prioritizing public investments.

Appendix

Table A1. Investment function parameters

	Central	Eastern	Northern	Western	Uganda	Units	Source
R	8,941	4,946	6,920	6,693	27,500	km	GOU (2008b)
I	50	81,908	180	440	82,578	Hectares	GOU (2011)
E	152,264	267,832	92,629	313,892	826,617	Households	GOU (2003; 2008a)
m	0.728	0.728	0.728	0.728	0.728	Share	Magidu et al. (2010)
R^e	5,357	5,260	4,969	6,285	21,872	US$1000	GOU (2008b; 2012)
I^e	1,678	1,913	1,648	1,282	6,521	US$1000	GOU (2011; 2012)
E^e	7,169	12,611	4,361	14,780	38,922	US$1000	GOU (2011; 2012)
r	10,452	10,452	10,452	10,452	10,452	US$/km	AfDB (2011)
i	2,956	3,545	2,736	3,375	3,182	US$/ha	GOU (2011)
e	47	47	47	47	47	US$/hh	GOU (2003)
A	61,403	39,479	85,392	55,277	241,550	km^2	GOU (2012)
C	1,163,687	1,663,823	1,591,673	1,615,920	6,035,104	Hectares	GOU (2012)
P	860,524	1,020,925	645,518	1,084,548	3,611,515	Households	GOU (2008a)
B_1	0.13900	0.13900	0.13900	0.13900	0.13900	Elasticity	Fan and Zhang (2008)
B_2	0.00003	0.03278	0.00008	0.00019	0.00933	Easticity	Dillon (2011)
B_3	0.13735	0.19097	0.11435	0.20661	0.17078	Elasticity	GOU (2003)

References

African Development Bank (AfDB). (2011). Community agricultural infrastructure improvement programme, Project 3 (CAIIP-3): Project appraisal report. Tunis, Tunisia.

Arndt, C., Hussain, M.A., Jones, E.S., Nhate, V., Tarp, F., and Thurlow, J. (2012). Explaining poverty evolution: The case of Mozambique. *American Journal of Agricultural Economics*, 94(4): 854–872.

Bahiigwa, G., Rigby, D., and Woodhouse, P. (2005). Right target, wrong mechanism? Agricultural modernization and poverty reduction in Uganda. *World Development*, 33(3), 481–496.

Benin, S., Nkonya, E., Okecho, G., Randriamamonjy, J., Kato, E., Lubade, C., and Kyotalimye, M. (2011). Returns to spending on agricultural extension: the case of the National Agricultural Advisory Services (NAADS) program of Uganda. *Agricultural Economics*, 42(2): 249–267.

Benin, S., Thurlow, J., Diao, X., Kebba, A., and Ofwono, N. (2012) Uganda. In Diao, X., Thurlow, J., Benin, S., and Fan, S. *Strategies and priorities for African agriculture: Economywide perspectives from country studies*. Washington DC, USA: International Food Policy Research Institute.

Diao, X., Hazell, P., and Thurlow, J. (2009). The role of agriculture in African development. *World Development*, 38(10), 1375–1383.

Diao, X., and Thurlow, J. (2012). A recusive dynamic computable general equilibrium model. In Diao, X., Thurlow, J., Benin, S., and Fan, S. (eds.) Strategies and priorities for African agriculture: Economywide perspectives from country studies. Washington DC, USA: International Food Policy Research Institute.

Dillon, A. (2011). Do differences in the scale of irrigation projects generate different impacts on poverty and production? *Journal of Agricultural Economics*, 62(2): 474–492.

Dorosh, P., and Thurlow, J. (2012). Agglomeration, growth and regional equity: An analysis of agriculture- versus urban-led development in Uganda. *Journal of African Economies*, 21(1): 94-123.

Dorward, A., Kydd, J., Morrison, J., and Urey, I. (2004). A policy agenda for pro-poor agricultural growth. *World Development*, 32(1): 73–89.

Elbers, C., Gunning, W.J., and De Hoop, K. (2009). Assessing sector-wide programs with statistical impact evaluation: A methodological proposal. *World Development*, 37(2): 513–520.

Fan, S., Hazell, P., and Thorat, S. (2000). Government spending, growth and poverty in rural India. *American Journal of Agricultural Economics*, 82(4): 1038–1051.

Fan, S., and Zhang, X. (2008) Public expenditure, growth and poverty reduction in rural Uganda. *African Development Review*, 20(3), 466–496.

Government of Uganda (GOU). (2003). National Agricultural Advisory Services (NAADS) programme: Facts and figures. Kampala, Uganda: Ministry of Agriculture, Animal Husbandry and Fisheries, Republic of Uganda.

GOU (Government of Uganda). (2008a). National Household Survey, 2005/06. Kampala, Uganda: Uganda Bureau of Statistics, Republic of Uganda.

——. (2008b). Transport master plan, 2008-2023. Kampala, Uganda: Uganda National Roads Authority, Republic of Uganda.

——. (2010a). Agriculture sector development strategy and investment plan, 2010/11-2014/15. Kampala, Uganda: Ministry of Agriculture, Animal Husbandry and Fisheries, Republic of Uganda.

——. (2010b). National Development Plan, 2010/11-2014/15. Kampala, Uganda: National Planning Authority, Republic of Uganda.

——. (2011). National irrigation master plan for Uganda, 2010-2035. Kampala, Uganda: Ministry of Water and Environment, Republic of Uganda.

——. (2012). Statistical Abstract, 2012. Kampala, Uganda: Uganda Bureau of Statistics, Republic of Uganda.

Hussain, I., and Hanjra, M.A. (2004). Irrigation and poverty alleviation: Review of the empirical evidence. *Irrigation and Drainage*, 53: 1–15.

Inocencio, A., Kikuchi, M., Tonosaki, M., Maruyama, A., Merrey, D., Sally, H., and De Jong, I. (2007). Costs and performance of irrigation projects: A comparison of Sub-Saharan Africa and other developing regions. Colombo, Sri Lanka: International Water Management Institute.

Magidu, N., Alumai, J.G., and Nabiddo, W. (2010). Public expenditure tracking on road infrastructure in Uganda: The case study of Pallisa and Soroti districts. Kampala, Uganda: Economic Policy Research Center.

Raballand, G., Macchi, P., Merotto, D., and Petracco, C. (2009). Revising the roads investment strategy in rural areas: An application for Uganda. Policy Research Working Paper 5036. Washington DC, USA: The World Bank.

Thurlow, J. (2012) Replication data for: A 2007 social accounting matrix for Uganda. Washington DC, USA: International Food Policy Research Institute. Available at: http://hdl.handle.net/1902.1/18662 (accessed 31 March 2013).

Van Den Berg, M., and Ruben, R. (2006). Small-scale irrigation and income distribution in Ethiopia. *Journal of Development Studies*, 42(5): 868–880.

Wiebelt, M., Pauw, K., Matovu, J.M., Twimukye, E., and Benson, T. (2011). Managing Future Oil Revenue in Uganda for Agricultural Development and Poverty Reduction. IFPRI Discussion Paper 1122, Washington DC, USA: International Food Policy Research Institute.

Zhang, X., and Fan, S. (2004). Public investment and regional inequality in rural China. Agricultural Economics, 30: 89–100.

Table 1: Uganda's regional characteristics, 2007

	Uganda	Central	Eastern	Northern	Western
Population (% of total)	100.0	29.2	25.2	19.7	25.9
Rural share (% of region)	84.6	70.6	92.2	85.7	92.4
Poor population (% of total)	100.0	15.4	29.0	38.5	17.0
Poverty headcount (% of region)	31.1	16.4	35.9	60.7	20.5
GDP per capita (US$)	454.5	833.4	308.6	297.8	287.8
Total GDP (% of region)	100.0	100.0	100.0	100.0	100.0
Agriculture	21.7	10.6	33.0	36.2	34.7
Food crops	11.7	4.0	18.7	17.6	25.2
Export crops	2.8	1.5	3.9	1.9	6.4
Livestock	1.3	0.5	1.6	3.8	2.0
Industry	28.7	30.5	24.9	30.2	25.5
Services	49.6	58.9	42.1	33.6	39.8
Population density (people/km^2)	112.4	129.3	173.2	62.8	127.1
Average farm size (hectares)	1.7	1.4	1.6	2.5	1.5
Road density (km/km^2)	11.4	14.6	12.5	8.1	12.1
Irrigation coverage (% of cropland)	1.4	0.0	4.9	0.0	0.0
Extension coverage (% of farmers)	22.9	17.7	26.2	14.3	28.9

Notes: Poverty headcount is the share of the population below the national poverty line. GDP per capita is in unadjusted US$. Irrigation and extension coverage are shares of crop land and rural farm households, respectively. Farm size includes urban plots.

Source: Uganda social accounting matrix (see Thurlow 2012) and GOU (2008a).

Table 2: National average elasticities in the investment function

Investment type	Productivity-investment elasticity			Sectors affected by investment
	Low	Base	High	
Roads	0.111	0.139	0.167	Food and export crops, livestock, processing and trade
Irrigation	0.006	0.009	0.013	Rice, pulses, horticulture and sugarcane
Extension	0.137	0.171	0.205	Food crops and livestock

Source: Roads and extension elasticity from Fan and Zhang (2008) and GOU (2003), respectively. Irrigation elasticity based on estimated returns from Dillon (2011).

Table 3: Impacts in the baseline and investment scenarios

	Baseline scenario	Extension scenario	Irrigation scenario	Roads scenario
	Final density (km/km^2) or coverage (%), 2017			
Feeder road density	14.46	15.95	15.95	20.37
Irrigation coverage	1.65	1.80	3.88	1.80
Extension coverage	26.74	84.71	48.31	48.31
	Annual growth (%)	*Deviation from baseline growth rate, 2007-2017 (%-point)*		
Total GDP	5.17	0.56	0.27	0.41
Agriculture	3.36	2.30	1.08	1.46
Food crops	2.72	3.50	1.61	1.88
Export crops	5.24	-0.18	0.38	1.76
Livestock	3.99	3.05	1.23	1.38
Non-agriculture	5.63	0.13	0.08	0.15
Agriculture share (%)	-	81.53	76.62	69.46
	Final rate, 2017 (%)	*Deviation from baseline poverty rate, 2017 (%-point)*		
Poverty headcount	23.57	-4.95	-2.62	-3.65
Rural	26.05	-5.45	-2.84	-4.03
Urban	9.94	-2.16	-1.44	-1.58
Rural share (%)	-	93.30	91.58	93.34

Notes: 'Agriculture share' is the share in the increase in total GDP from baseline that occurs with agricultural sectors. 'Rural share' is the share of poor people lifted above the poverty line who live in rural areas.

Source: Results from the Uganda CGE model.

Table 4: Comparing investment portfolios

	Extension scenario	Irrigation scenario	Roads scenario
US$ increase in public spending per capita, 2017			
National	6.07	6.07	6.07
Central	5.10	6.05	5.89
Eastern	6.32	6.00	5.46
Northern	4.93	7.48	7.01
Western	7.20	5.35	6.27
US$ increase in total GDP per US$ spent, 2007-2017			
National	6.76	3.03	4.21
Central	8.23	3.35	4.61
Eastern	6.87	3.22	5.08
Northern	3.65	1.04	1.54
Western	7.05	4.07	4.84
US$ increase in agricultural GDP per US$ spent, 2007-2017			
National	5.42	2.30	2.94
Central	3.89	1.57	1.89
Eastern	5.94	2.62	3.79
Northern	2.68	0.78	1.04
Western	6.86	3.77	4.16
Poor people lifted above poverty line per US$1000 spent, 2017			
National	8.08	4.28	5.96
Central	5.40	2.62	3.84
Eastern	8.47	4.77	7.22
Northern	17.90	6.53	9.83
Western	5.47	3.45	4.02

Notes: Returns refer to outcomes and spending within each region.

Source: Results from the Uganda CGE model.

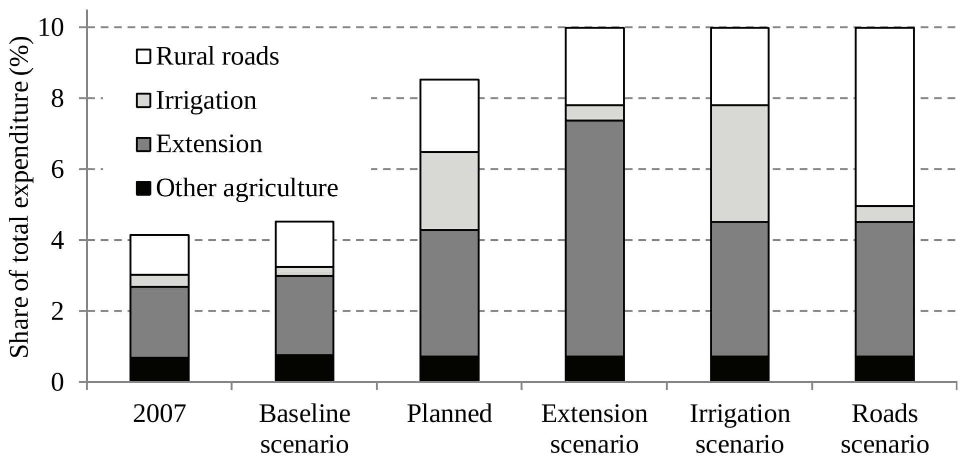
Table 5: Investment efficiency analysis

Elasticities	Low		Base	High	
Unit costs	High	Base	Base	Base	Low
Annual agricultural GDP growth rate, 2007-2017 (%)					
Extension	5.02	5.24	5.66	6.07	6.45
Irrigation	4.40	4.41	4.44	4.47	4.49
Roads	4.57	4.64	4.82	4.99	5.11
US$ increase in total GDP per US$ spent, 2007-2017					
Extension	4.68	5.48	6.76	8.02	9.41
Irrigation	2.94	2.95	3.03	3.10	3.13
Roads	3.39	3.61	4.21	4.82	5.22
Poor people lifted above poverty line per US$1000 spent, 2017					
Extension	6.16	6.74	8.08	9.43	10.12
Irrigation	4.05	4.10	4.28	4.43	4.52
Roads	4.78	5.11	5.96	6.68	7.31

Notes: Upper and lower bound unit costs assume a 10 percent confidence interval around baseline cost estimates. A 20 percent confidence interval was used for the extension and roads investment function elasticities, and 40 percent interval was used for irrigation.

Source: Results from the Uganda CGE analysis.

Figure 1: Public budget expenditure shares in the investment scenarios, 2017



Notes: ‘Planned’ is the baseline plus the additional funds requested in ministerial master plans (GOU 2008b; 2010; 2011).

Source: Results from the Uganda CGE model.