Distributional Effects of Public Investments in Mozambique

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Summary - In 2013, Mozambique's government proposed a five-year agricultural investment plan that raised spending and targeted new investment areas, including fertilizer subsidies and agricultural research and extension. Evaluating sector-wide strategies is difficult since they comprise multiple interventions with spillovers. Numerous ex post studies evaluate specific investments, but the time-series or spatial data needed to estimate sector-wide returns is often lacking. Moreover, when new interventions are planned, there is no historical evidence on which to base analysis. To overcome these limitations, we develop a mixed-methods approach to evaluating the distributional effects of Mozambique's investment plan – one that combines ex post analysis of specific investments with ex ante analysis of investment portfolios. We econometrically estimate investment impacts on farmer productivity, and then use these results to calibrate investment functions in a spatially-disaggregated CGE model. This permits experimentation with different levels and compositions of investments to evaluate how outcomes are improved. Econometric results (using propensity score matching) indicate farmers who use irrigation, receive extension advice, or use chemical fertilizers, have higher productivity. CGE analysis finds that the plan's benefit-cost ratio and poverty impacts justify implementation. However, returns are much larger if resources are reallocated to research and extension and away from the current emphasis on irrigation. Greater spending on fertilizer subsidies also improves outcomes, but to a lesser extent. These findings are robust to a range of assumptions about investment costs and efficiency. We conclude that research and extension should be afforded a greater role in Mozambican investment plans. Our mixed-methods approach also greatly enhances the usefulness of ex post evaluation studies for sector-wide planning.

1. Introduction

Even though Mozambique's economy grew at seven percent per year during the 2000s, the national poverty headcount rate remained virtually unchanged (GoM 2010; 2013). External shocks beyond the government's control reduced real incomes of the poor, including a spike in world food and energy prices (Arndt et al. 2008) and frequent droughts and floods (Arndt et al. 2011). However, while some of poverty's persistence can be attributed to external factors, part of the explanation lies in the failure of domestic policy to promote agricultural growth (Cunguara and Hanlon 2010). Arndt et al. (2012) found that slower-than-expected agricultural growth was almost as important as rising world energy prices in explaining stagnant poverty reduction. This is consistent with Diao et al. (2010), who find that agricultural growth is nearly twice as effective at reducing poverty tha non-agricultural growth in Mozambique. Agricultural growth is therefore essential for future poverty reduction, even with rapid nonagricultural growth and without external shocks.

The Government of Mozambique (GOM) has an ambitious agricultural investment plan – *Programa Nacional de Investmento do Sector Agrário* (PNISA) – intends to double public agricultural spending during 2013-2017 in order to accelerate agricultural growth and poverty reduction (GoM 2012a). It is technically challenging, however, to determine whether an investment plan can meet its objectives. Sector-wide strategies like PNISA comprise multiple interventions with potential spillovers and so require novel approaches to estimating joint impacts (see Elbers et al. 2009). While there are *ex post* studies that compare the returns to different agricultural investments (see, for example, Fan et al. 2000), there is often no consistent time series and/or spatial data to support this kind of analysis, particularly in Africa. Moreover, if new kinds of interventions are planned then there is no evidence on which to form expectations. This is the case in Mozambique, where past investments have focused on irrigation and extension (World Bank 2011), rather than on farm input subsidies, which is a core component of PNISA.

In order to overcome technical and data limitations, we adopt a mixed methods approach to evaluating PNISA – one that combines the strengths of *ex post* analysis of specific types of investments, with *ex ante* analysis of alternative investment portfolios, i.e., packages of interventions. More specifically, we econometrically estimate the impact of investments on farmer productivity using farm-level surveys, and then use these results to calibrate public investment functions within a detailed computable general equilibrium (CGE) model. The model allows us to experiment with alternative portfolios in order to determine whether adjusting the level and composition of PNISA significantly improves growth and poverty outcomes.

In order to establish a baseline for our evaluation of PNISA, Section 2 reviews Mozambique's past growth and investment patterns, taking into account concerns about the country's agricultural data. Section 3 describes our hybrid evaluation approach and Section 4 empirically estimates key investment function parameters. Section 5 presents our simulation results for different investment portfolios and the final section summarizes these findings and discusses their implications for Mozambique and for sector-wide impact evaluations more broadly.

2. Agricultural in Mozambique

In this section we consider whether Mozambique has achieved its CAADP growth and investment targets over the last decade, i.e., to maintain at least six percent annual growth in agricultural gross domestic product (GDP) and to allocate at least ten percent of the government's budget to agriculture. Unfortunately, this exercise is complicated by shortcomings in official agricultural statistics (Arndt et al. 2012) and by changes to public accounting systems (World Bank 2011). We attempt to provide a more accurate account of past agricultural growth and public investments in order to establish a more robust baseline for our forward-looking analysis of PNISA.

Re-estimating agricultural GDP

During the 2000s, the government undertook a systematic review of its agricultural information system (Kiregyera et al. 2008). This revealed shortcomings in the Ministry of Agriculture's crop forecasting survey, which relied on satellite imagery and crop cuttings to estimate cultivated land area and crop yields, respectively. As a result, the government switched to using its post-harvest farm surveys as the main source for agricultural statistics. This led to major revisions in the production levels of certain crops. Unfortunately, national accounts is based on the forecast data and so does not reflect the Ministry of Agriculture's revisions. Since agricultural GDP growth is a key outcome indicator for CAADP and PNISA, we re-estimate this data for the decade 2002-2012.

Table 1 illustrates the differences between FAOSTAT (2014), which is based on official statistics from the crop forecast surveys, and data from three of the post-harvest surveys (GoM 2002, 2008 and 2012b). The table shows Mozambique's two main staple food crops: maize and cassava. The maize series shows how production trends diverged between 2002 and 2008 and then re-converged in 2012 after the government started using the post-harvest surveys. For cassava, the divergence between data sources was not resolved by 2012, with FAOSTAT and official statistics continuing to report crop forecast data (Donovan et al. 2011). There are also persistent differences for other food crops, including rice, millet, sorghum and potatoes. As with cassava, FAOSTAT reports large production gains for these crops between 2002 and 2012 that are not corroborated by the post-harvest surveys. Since national accounts is based on the crop forecasts, it overestimates agricultural growth over the last decade.

[Insert Table 1]

In revising agricultural GDP, we substitute production quantities in FAOSTAT with estimates from the post-harvest surveys for cereals, roots, pulses, groundnuts and cotton. These are predominantly smallholder crops and are well-represented in the post-harvest surveys. We retain FAOSTAT data for other crops, including oilseeds (e.g., cashews), horticulture (i.e., fruits and vegetables) and traditional cash crops (e.g., sugarcane). These crops are not captured as well in the post-harvest surveys, either because they are concentrated in specific parts of the country or are grown on large-scale farms that fall outside the surveys' sampling frame.

Producer prices from FAOSTAT for 2003 are used to estimate the real value of crop production.[1] Input-output coefficients from the 2002 national social accounting matrix (SAM) are used to estimate crop value-added (i.e., value of crop production net of intermediate input costs) (McCool et al. 2009). These coefficients are consistent with those used to rebase national accounts in 2002. We estimate crop GDP and then add official estimates for livestock, forestry and fisheries in order to derive an estimate of total agricultural GDP for 2002, 2008 and 2012. We also retain official nonagricultural GDP estimates when estimating total GDP, including the agro-processing that occurs within the manufacturing sector.

Agricultural GDP growth, 2002-2012

Table 2 compares our revised GDP growth rates to those from national accounts. Using only FAOSTAT data, we produce an annual agricultural growth rate of 6.3 percent for the period 2002-2012, which is close to the official growth rate of 6.9 percent reported in national accounts. This would suggest that Mozambique exceeded its six percent agricultural growth target over the last decade. However, the agricultural GDP growth rate falls to 4.5 percent per year when we use the revised production estimates from the post-harvest surveys. Agricultural growth during 2002-2008 is slower than officially reported, which is consistent with the "slower-than-expected" agricultural growth discussed in Arndt et al. (2012). Our revised series also suggest that agricultural growth slowed down further during 2008-2012, which is consistent with national accounts.

[Insert Table 2]

It is worth noting that most of the decline in agriculture's growth rate is due to slower production growth for root crops, i.e., 6.4 percent per year in FAOSTAT and 1.9 percent per year in the post-harvest surveys. Root crops accounted for almost half of crop GDP in 2002, irrespective of the production data used. As such, slower root crop production growth greatly reduces overall agricultural GDP growth. There is of course considerable uncertainty surrounding root crop production data, particularly for cassava, which is harvested year round and is often treated as a food security crop (see Donovan et al. 2011). Dry and wet weight conversions may explain why production levels are always higher in FAOSTAT than in the post-harvest surveys, but it does not resolve the diverging production trends.

Table 3 decomposes total GDP growth during 2002-2012 using our revised estimates.[2] Agriculture grew more slowly than the overall economy, causing its share of GDP to fall over the decade. Nevertheless, agriculture is still one of the largest sectors and this meant that it still accounted for 16.1 percent of total GDP growth. Two-thirds of agricultural GDP is generated by crops, and in 2002, half of this was from root crops. However, it was horticulture that dominated the 2000s – it accounted for almost three quarters of total agricultural GDP growth. Much of this was probably the result of foreign investment in fruit exports after 2008, including bananas and pineapples. There was also vegetable production for local markets, particularly tomatoes and

[1] National accounts reports real GDP trends using constant 2003 prices.
[2] Table A1 in the appendix provides a detailed decomposition of crop GDP growth.

onions. In contrast, cereals performed very badly, growing at only 0.8 percent per year. As a result, the share of cereals and root crops in agricultural GDP fell by a third while the share of horticulture almost doubled. Finally, taken together, livestock, forestry and fishing accounted for only a quarter of agricultural GDP in 2002 and this share declined during the 2000s.

[Insert Table 3]

Land use data from the agricultural censuses for 1999/2000 and 2009/2010 provide supporting evidence for the slow expansion of cereals and the rapid growth in horticulture, particularly vegetables. Overall, the censuses report a rapid expansion of total cultivated land area, i.e., 3.9 percent per year over ten years. While maize land expanded slowly at only 1.0 percent year, the amount of land used for growing vegetables expanded at 7.2 percent per year. While the census does not report production quantities or yields, these trends in cultivated land area suggest strong horticultural growth. Although the censuses did not collect information on bananas or pineapples, export data from FAOSTAT (2014) indicates that banana exports increased from zero in 2002 to 49,300 tons in 2011.

In summary, the amalgamated agricultural data series suggests that horticulture was the main driver of agricultural growth during 2002-2012, with most other crops displaying modest growth. Our revised GDP estimates suggest that Mozambique not only fell short of CAADP's six percent agricultural growth target, but that the pattern of agricultural growth was concentrated in a few high-value, often export-oriented, crops. Moreover, Thurlow (2012) finds that export-oriented crops in Mozambique have weaker linkages to the rural poor. As such, our results suggest that Mozambique's dependence on horticulture-led agricultural growth may be consistent with the unchanged national poverty rate during 2002-2009. It also suggests that the upward pressure on rural poverty rates may have persisted during 2008-2012.

Decomposing agricultural growth

Agricultural growth can be decomposed into three components: (i) an expansion in total cultivated land area; (ii) a reallocation of land between lower and higher value crops; and (iii) an increase the land productivity of individual crops, e.g., an increase in value-added per hectare due to favorable weather patterns or greater use of improved technologies. In order to measure the contribution of each component we must first revise our estimates of cultivated land area so that they are consistent with revised production levels. We retain the crop yields reported in FAOSTAT and calculate the implied land area need to meet the revised production levels.[3] This produces a total cultivated land area of 5.4 million hectares in 2012, which is close to the 5.3 million hectare cultivated area reported in the 2009/10 Agricultural Census (GoM 2011). It is well below the 6.6 million hectares reported in FAOSTAT, mainly because we reduce the land allocated to cereals and roots to reflect lower production levels.

[3] Table A2 in the appendix provides the production, area and yield data used for the decomposition.

A major challenge for the decomposition is conflicting information on the area under cassava cultivation. This declined by 250,000 hectares during 2002-2012 according to FAOSTAT, but increased by almost 397,000 hectares during 2000-2010 according to the agricultural censuses. The two series implies strongly divergent trends in cassava yields. We take the average of the two data sources, implying a gradual increase in both cassava land area and yields. This is consistent with the gradual expansion of cassava production reported in the post-harvest surveys.

Table 4 reports the results of our decomposition of crop GDP growth. The table shows the percentage contribution of each crop and component to the real expansion in crop GDP during 2002-2012, i.e., the 4.8 percent annual growth reported in Table 3. Total cultivated land area grew at 1.7 percent per year over the decade. The second column of the table indicates that almost a third (i.e., 31.9 percent) of the increase in crop GDP is explained by this general expansion of cultivated land area (i.e., if we assume that each crop's cultivated land area expanded at the same 1.7 percent per year). Although this is a large component of overall growth, it is possible that we are underestimating the contribution of land expansion to agricultural growth. This is because FAOSTAT and the agricultural censuses report much larger rates of land expansion, i.e., three and four percent annual growth in cultivated land area, respectively. Of course FAOSTAT's rate land expansion is inconsistent with our slower-growing production levels, unless cereal and root crop yields declined dramatically.

[Insert Table 4]

The second component of our decomposition is the increase in crop value-added caused by reallocating land between lower- and higher-value crops. Taking maize as an example, we can calculate value-added per hectare by multiplying the price per ton of maize from FAOSTAT by ratio of maize's value-added to gross output from the SAM, and by maize's yield (i.e., tons per hectare). Following this approach, maize generated US$65 of value-added per hectare in 2002 compared to banana's US$2,188 per hectare (measured in 2003 prices). Therefore, during 2002-2012, the decline in the share of total cultivated land allocated to maize production and the increase in land allocated to bananas led to higher average value-added per hectare in Mozambique. Overall, this reallocation of land between crops generated almost two-thirds (i.e., 64.5 percent) of crop GDP growth during 2002-2012. This was entirely due to growth in share of the land area used to grow horticultural products, particularly bananas, pineapples, tomatoes and onions.

The third and final component of crop GDP growth is from increases in crop yields. As described above, higher crop yields leads to higher value-added per hectare, even without any land expansion or reallocation. Our decomposition suggests that almost none (i.e., 3.6 percent) of the crop GDP growth during 2002-2012 was caused by improved crop yields. While there was a marginal increase in value-added caused by rising cassava yields, this was offset by falling horticultural yields. One explanation for stagnant agricultural productivity in Mozambique is the fact that most farmers continue to rely on traditional farming practices rather than using improved technologies. According to the 2008 post-harvest survey, for example, only 8.3 percent of farmers used irrigation, 8.4 percent received advice from extension agents, and 5.2 percent used fertilizers (GoM 2008). Moreover, the two agricultural censuses suggest that fertilizer use declined over the 2000s, from 7.2 percent of farmers in 1999/2000 to 3.7 percent in 2009/2010 (GoM 2001; 2011). Low and declining adoption of improved technologies may therefore explain why there were very modest yield gains for most crops.

In summary, our decomposition provides a mixed assessment of the drivers behind agricultural growth over the last decade. One positive insight is that there may be some structural change occurring within Mozambique's crop sector, with lands reallocated from low to higher value crops, particularly in more recent years. To a large extent, agricultural growth in Mozambique over the last decade is due to the strong performance of just four crops: bananas, pineapples, tomatoes and onions. These crops accounted for two-thirds of crop GDP growth and almost a tenth of total GDP growth in Mozambique during 2002-2012. What remains unclear, however, is whether growth in such a narrow group of crops has benefited smallholder farmers and helped reduced rural poverty after 2008.

Finally, one unambiguously negative trend is that Mozambique has relied on expanding its cultivated land area rather than raising land productivity as a means to generating additional agricultural GDP. This probably reflects an expanding rural population without any increase in the provision of modern farm inputs. This process is consistent with a declining share of farm households using improved inputs, as well as the poor performance of staple food crops. It underscores the need for more productivity-enhancing investments in the agricultural sector.

Public agricultural spending, 2002-2012

Under CAADP, Mozambique set itself the target of allocating ten percent of its annual budget towards spending on the agricultural sector. There are many uncertainties surrounding this target, including how to define agricultural investments. Recognizing these difficulties, the World Bank (2011) recently conducted a public expenditure review for Mozambique's agricultural sector. The study concluded that the government has consistently allocated about 5.5 percent of its budget to agriculture over the last decade, which is well below the CAADP target (see Figure 1).

[Insert Figure 1]

If the rate of growth in public agricultural and nonagricultural spending during 2007-2011 continues, then the share of the budget allocated to agriculture will remain virtually unchanged until 2017. In contrast, PNISA would almost double agriculture's spending share during 2013-2017, from 5.5 percent under the business-as-usual projection to an average 10.2 percent per year. The projected budget for PNISA for 2013-2017 is US$3.7 billion (or an average US$789 million per year), thus implying US$1.9 billion in additional agricultural spending over and above what is already expected under the business-as-usual scenario.

Table 5 allocates PNISA spending across broad investment areas. Spending on research and extension is explicitly identified in PNISA's budget, and to this we add spending on livestock production. For irrigation, we combine spending on rice crops to the explicit irrigation line item in the budget. Finally, we treat all spending on food and cash crops (except rice) as spending on farm input subsidies. This is justified by PNISA's description of its planned interventions, which repeatedly highlights the provision of fertilizer and improved seeds as a means to raising crop yields. The plan also includes spending on rural feeder roads during the first two years of implementation, as well as "other spending" on an array of smaller expenditure items, including forest management, nutrition and food security programs, and ministerial reforms.

[Insert Table 5]

Overall, PNISA plans to spend an average US$43 per rural inhabitant per year during 2013-2017 (measured in unadjusted 2013 dollars), which is equivalent to 7.4 percent of total GDP per capita. Most of this is allocated to building irrigation infrastructure and providing agricultural research and extension services. Each of these investment areas accounts for almost a third of PNISA's budget. In addition, almost a tenth of the budget is assigned to providing fertilizer and improved seeds to smallholders via a farm input subsidy program. In our analysis we focus on these three investment areas, i.e., research and extension; irrigation; and input subsidies. This covers almost three quarters of PNISA's planned expenditures for 2013-2017, particularly those areas that lie within the responsibility of the Ministry of Agriculture.[4]

It is difficult to separate past spending into categories due to changes in the government's accounting systems (see World Bank 2011: 40). Nevertheless, since we are interested in quite broad categories, it is possible to provide a rough estimate of spending patterns in 2007, i.e., the final year reported in World Bank (2011) and the base year of our model. The first column of Table 5 shows per capita public agricultural spending in 2007. Spending levels were clearly much lower in that year than what is planned under PNISA. The allocation of the budget in PNISA also differs from 2007. Irrigation accounted for 22.1 percent of total agricultural spending in 2007, but is 30.9 percent of PNISA's budget. Similarly, spending on improved inputs was 5.0 percent in 2007 compared to 9.3 percent in PNISA. There is a small decline in the spending share for research and extension under PNISA. Instead, the largest reduction in spending shares is for "other spending", which includes livestock, mechanization, market access, natural resources, nutrition programs, and ministerial reforms. This category's share is 20.6 percent in PNISA, compared to 34.9 percent in 2007. There is clearly not only an increase in the level of agricultural spending, but also a shift towards irrigation and the provision of improved inputs. In the analysis that follows we will evaluate the implications of scaling-up spending on agriculture and of altering the allocation of spending across the three broad investment areas.

[4] Agriculture falls under both the Ministry of Agriculture and the Ministry of Fisheries.

3. Evaluation Procedure

PNISA is evaluated in two stages following the approach described in Pauw and Thurlow (2013). An investment equation is specified that captures the impact of public spending on agricultural productivity, and this is integrated within an economywide model in order to measure impacts on economic growth and poverty.

Measuring impacts on productivity

The impact of investments on agricultural productivity is modeled using nested equations. The model contains a production function for each sector in Mozambique's three sub-national regions. The equation below is a typical crop production function in which farmers combine labor *L*, land *N* and capital *K* in order to produce total output *Q* in time period *t*.

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

Public investment affects the shift parameter α, which measures crop-specific total factor productivity (TFP). The investment equation is as follows

$$\alpha_t = \bar{\alpha} \cdot \left(1 + s_t^i \cdot \beta^i + s_t^e \cdot \beta^e + s_t^f \cdot \beta^f\right) \cdot (1+g)^{t-1}$$

where s^i is the share of cultivated farm land under irrigation in period t, s^e is the share of rural farmers receiving extension services, and s^f is the share of farm land using chemical fertilizers and improved seeds. The coefficients β^i, β^e and β^f are the productivity gains achieved on lands that have irrigation, extension and fertilizer, respectively, relative to lands that do not use these technologies. The latter achieve productivity $\bar{\alpha}$, while the maximum attainable productivity level is $\bar{\alpha} + \beta^i + \beta^e + \beta^f$, which is achieved when all lands are irrigated, receive extension and use modern inputs (i.e., s^i, s^e and s^f are equal to one). Finally, productivity in a given time period is determined by investment outcomes, e.g., irrigation coverage rates, and by an exogenous rate of productivity growth g. The latter is determined by public policies and private investments that do not explicitly appear in the investment function.

Investment outcomes are derived from public expenditures and estimates of unit costs. The extension coverage rate is determined by the following equation:

$$s_t^e = \frac{E_t^e}{u^e \cdot H_t} + p^e$$

where E^e is public spending on agricultural research and extension, u^e is the unit cost of the government providing extension (with embodied research) to one farmer, and *H* is the total number of rural farm households. An increase in spending E^e increases the number of farmers receiving publically-provided extension services. If this exceeds the population growth rate then extension coverage rises, leading to higher average productivity. We assume that a fixed share p^e of farmers receive extension services from nongovernment organizations.

A similar equation exists for fertilizer and improved seed use:

$$s_t^f = \frac{E_t^f}{u^f \cdot C_t} + p^f;$$

where E^f is spending on subsidized fertilizer and seeds; u^f is the cost of the subsidy per hectare; and p^f is the share of land that uses privately-purchased inputs. As total crop land C increases, public spending must match this land expansion in order to maintain productivity levels.

Finally, we irrigation is treated as a capital stock rather than a flow, as shown below:

$$s_t^i \cdot C_t = \frac{E_t^i}{u^i} + s_{t-1}^i \cdot C_{t-1} \cdot (1 - \delta)$$

where again, the stock of new irrigation infrastructure is equal to current spending E^i divided by the unit cost per hectare u^i. This is added to the previous period's capital stock after applying a fixed rate of depreciation δ.

Measuring impacts on growth and poverty

Changes in sector productivity are translated into growth and poverty outcomes using a recursive dynamic computable general equilibrium model (see Diao and Thurlow 2012). The model separates Mozambique's economy into 56 sectors and 3 subnational regions.[5] Producers in each sector and region combine factors of production using a constant elasticity of substitution function under constant returns to scale. Crop land is regional and labor is divided into four categories, i.e., uneducated and primary, secondary and tertiary educated.

The model is run over 2007-2017, although we will focus on the post-2012 PNISA period. Land and labor are mobile across sectors, but not regions, and their total supply tracks historical trends. Past investment determines new capital stocks, which are allocated according to sectors' relative profitability. Once invested, capital is immobile and earns sector-specific returns. This endogenous investment process excludes public spending on irrigation, extension and modern inputs, which instead affects productivity in agriculture. Elsewhere, the rate of technical change is exogenous such that the baseline replicates historical growth patterns.

Domestic and foreign goods are imperfect substitutes, with producers' decision to supply export markets and consumers' decision to buy imported goods based on changes in relative prices.

[5] A 2003 version of the database is described in McCool et al. (2009).

All domestic, import and export prices include relevant indirect taxes, and the current account balance is maintained through changes in the real exchange rate.

The model separates households into ten groups within each region, i.e., rural and urban households 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 2008/09 national household survey (GoM 2010). 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 revenues and expenditures. Households' savings rates are fixed and investment demand adjusts so that it equals savings in equilibrium.

In our analysis we will exogenously increase public spending on a portfolio of agricultural investments, and the investment functions then determine changes in crop- and region-specific productivity. All other public spending is held constant at baseline levels in order to isolate the effects of investments in irrigation, extension and farm inputs. Nevertheless, raising public agricultural spending crowds-out private investment relative to the baseline. Overall, by combining a structural model with empirically-calibrated investment functions, we can experiment with alternative investment portfolios and measure impacts on a wide range of policy goals, including growth, poverty and regional equity.

4. Estimating Investment Function Parameters

Spending levels and unit costs

Table 6 reports base-year parameter values for the public investment functions. Total spending in 2007 is allocated to irrigation, research and extension, and input subsidies using information from World Bank (2011) (see Table 5). Base-year stocks (I, E and S) are drawn from the 2008 post-harvest survey, which captures the share of farmers who reported using irrigation or fertilizer or who received a visit from an extension agent (GOU 2008). Total spending levels (I^e, E^e, S^e) are disaggregated across subnational regions using base-year stocks, which assumes that the same cost structure applies throughout the country.

[Insert Table 6]

Unit costs (i.e., *i*, *e* and *s*) are derived from various studies. You et al. (2011) estimate the average cost per hectare of small-scale irrigation infrastructure in Mozambique. PNISA and GoM (2007) project total costs for Mozambique's agricultural research and extension system, as well as the number of households expected to receive extension services. From this we derive the average cost of providing extension (and research) to one farm household. Finally, PNISA intends to provide fertilizer and improved seeds to smallholders via an input subsidy program. This is a new intervention and so there is no unit cost estimates available for Mozambique. We therefore use the 2011/12 impact evaluation of Malawi's farm input subsidy program to estimate the cost per hectare of providing subsidized fertilizer and improved seeds (Chirwa and Dorward 2013: 91 and 122).

Impact coefficients

A key set of parameters in the investment function are the coefficients β^i, β^e and β^s, which give the percentage change in TFP resulting from a one percent change in investment outcomes (i.e., adoption or coverage rates for irrigation, extension and improved inputs). In order to estimate the value of these coefficients, we follow the approach described in Cunguara and Darnhofer (2011) and Cunguara and Moderc (2011). These studies used the 2005 post-harvest survey and propensity score matching (PSM) to estimate the impact of improved agricultural technologies and extension services on household incomes in Mozambique. Since 2005 was a drought year, we replicate the analysis using the 2008 post-harvest survey (GoM 2008). We also estimate impacts on production values, as opposed to total incomes, for different types of crops (i.e., cereals, roots, pulses, horticulture, and cash crops).

In the absence of a randomized trial, PSM addresses selection bias by comparing farmers that use improved technologies with farmers who do not use these technologies but are as similar as possible in all other respects. Propensity scores, which are used to identify the comparison group, were estimated using a Logit model and information on asset endowments, demographic characteristics, labor availability, and access to information, credit and road infrastructure (see Cunguara and Darnhofer 2011). Both the comparison of normalized differences and the distribution of propensity scores for treatment and control groups suggest that the overlap assumption is reasonable.[6]

Table 7 reports results for the doubly robust estimator by crop groups and subnational regions.[7] Results suggest that production values (or sales in the case of horticulture) are often, but not always, significantly different between treatment and control groups. For example, the production value of cereals in the Northern region is 28.2 percent higher for those farmers receiving extension services than similar farmers who do not receive these services. Impacts on cereal production values are highest in the Southern region and lowest in the Central region,

[6] Detailed results from the PSM analysis are provided in supplementary materials.
[7] Consistent results were obtained using a matching and regression approach.

although the latter is only significant at the 0.15 level. For some regions and crops there are too few observations on which to estimate impact coefficients. For example, the survey suggests that farmers rarely irrigate root crops, and so there are no estimates reported in the table.

[Insert Table 7]

In order to compare our findings with those from other studies, we use regional production values from the social accounting matrix to calculate the weighted average coefficients for crops in each region. On average, providing extension services to farmers in Mozambique increases their crop revenues by 26 percent. This is higher than the 12 percent gain estimated by Cunguara and Darnhofer (2011) using the 2005 post-harvest survey, although these authors include livestock values. Conversely, extension in Mozambique has a relatively small impact compared to in Uganda, where Benin et al. (2011) estimate a 67.0 percent average agricultural income gain. Similarly, we find that irrigation increases farmers' crop revenues by 8.6 percent, which is lower than the 73 percent gain estimated by Dillon (2011) in Mali. Variation across studies for Mozambique underscores the importance of sensitivity analysis, while variation across countries suggests that there may be scope to improve the efficiency of public spending.

For the investment functions in the CGE model, we apply a low threshold for significance, i.e., at the 0.2 level. We assume that changes in production values reflect changes in TFP. We also use significant national coefficients when there are too few observations for a particular crop and crop (as indicated in Table 7).

Table 8 reports the baseline values for β^i, β^e and β^s. These are marginal changes in TFP derived from the estimated coefficients and base year coverage rates in Table 6. For example, a one percent increase in the share of total cultivated land that is irrigated leads to a 0.045 percent increase in total farm revenues. We will conduct sensitivity analysis on all coefficients using a 20 percent confidence interval around baseline elasticities.

[Insert Table 8]

5. Simulating Alternative Investment Portfolios

Baseline scenario

We first establish a baseline growth path for the period 2007-2017, which assumes a continuation of economic and demographic trends from 2002-2012. Population and labor grow at 2.5 percent per year, farm land expands at 1.6 percent each year, and capital supplies increase at 4.0 percent per year. The baseline assumes that past public investment patterns and trends continue until 2017 (see Figure 1). Total public spending grows at 9.1 percent per year (in real terms), and agriculture's share remains constant at 5.4 percent. This leads to modest improvements in investment outcomes by 2017, as shown in Table 9. The share of cultivated land under irrigation increases from xxx in 2012 to xxx percent in 2017, and the share of rural farm households receiving extension services rises from xxx to xxx percent. However, the provision of subsidized fertilizer and seeds is not enough to reverse the current decline in adoption rates, with the share of crop land using improved inputs declining from xxx to xxx percent.

[Insert Table 9]

Productivity growth is determined by public investment outcomes as well as exogenous technical change. We adjust the rate of exogenous productivity growth to match the historical baseline described in Section 2, i.e., agricultural GDP grows at an annual rate of 4.5 percent and total GDP grows at 6.5 percent per year. Rising GDP per capita reduces the national poverty headcount rate from 54.7 percent in 2007 to 44.5 percent in 2017. This baseline provides a counterfactual for our evaluation of PNISA. While the choice of baseline does not significantly influence our findings, it does represent a plausible "business as usual" scenario. In the next section we increase agricultural investments during 2013-2017, re-solve the model, and compare the new outcomes to those from the baseline.

Increasing agricultural spending

Figure 2 shows the share of the government's budget allocated to agriculture. This is 5.4 percent in the baseline, but rises to 11.0 percent in the "planned" PNISA scenario. We simulate the impact of PNISA as well as three alternative investment scenarios that differ in the way the additional PNISA funds are allocated. In the Irrigation, Extension, and Subsidies scenarios we distribute a two-thirds of PNISA funds as planned, while the remaining third is allocated entirely to irrigation, extension or input subsidies, respectively. This allows us to assess whether reprioritizing PNISA would improve some or all of its outcomes.

[Insert Figure 2]

To be completed

Reprioritizing the spending portfolio

To be completed

Sensitivity to investment efficiency

To be completed

6. Conclusion

To be completed

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Appendix

[Insert Tables A1, A2 and A3]

Table 1. Revised production series for selected crops

		Production (1000 tons)		
		2002	2008	2012
Maize	FAOSTAT	1,115	1,676	1,177
	Post-harvest survey	1,115	1,214	1,171
Cassava	FAOSTAT	5,925	4,055	10,051
	Post-harvest survey	3,446	3,839	4,099

Source: FAOSTAT (2014) and GoM (2002, 2008 and 2012b)

Table 2. Official and revised GDP growth trends

	Average annual growth (%)		
	2002-12	2002-08	2008-12
Agricultural GDP			
National accounts	6.87	7.34	6.17
FAOSTAT data	6.26	5.83	6.91
Revised data	4.46	4.54	4.33
Total GDP			
National accounts	7.45	7.86	6.82
FAOSTAT data	7.29	7.47	7.02
Revised data	6.86	7.14	6.43

Source: Own estimates using FAOSTAT (2014) and GoM (2002, 2008, 2012b and 2013).

Table 3. Decomposing total GDP growth, 2002-2012

	Share of total GDP (%)		Annual growth rate, 2002-12 (%)	Contribution to growth, 2002-12 (%)
	2002	2012		
Total GDP at factor cost	100	100	6.9	100
Agriculture	27.7	22.1	4.5	16.1
Crops	19.9	16.4	4.8	12.6
Cereals	3.0	1.7	0.8	0.3
Roots	9.4	5.9	1.9	2.1
Pulses, oilseeds	2.0	1.3	2.2	0.5
Horticulture	3.8	6.3	12.4	9.0
Traditional cash crops	1.6	1.2	3.4	0.7
Livestock	2.4	1.8	3.9	1.2
Forestry	3.3	2.3	3.0	1.2
Fishing	2.0	1.6	4.4	1.2
Industry	23.8	23.9	6.9	24.0
Of which, agro-processing	8.5	6.1	3.4	3.6
Services	48.5	54.0	8.0	59.9

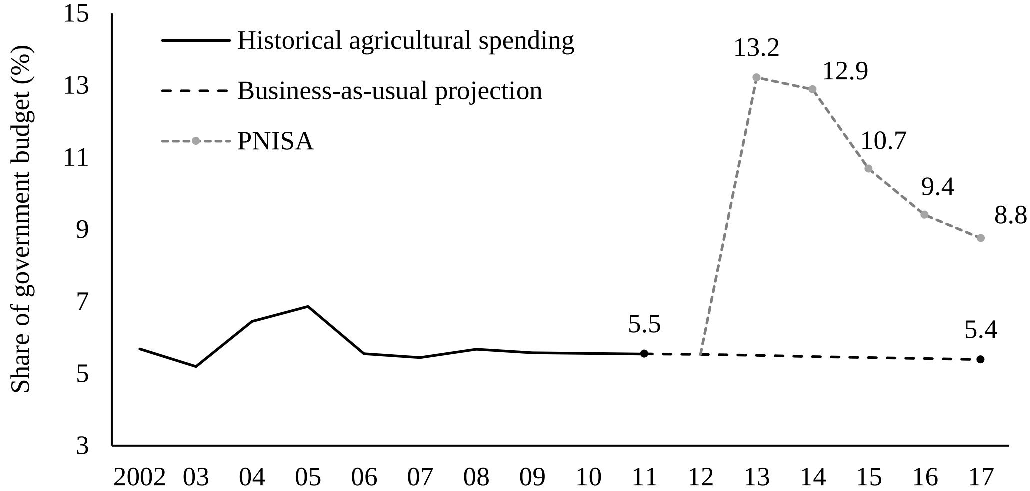
Source: Own estimates using FAOSTAT (2014) and GoM (2002, 2012b and 2013).

Table 4. Decomposing crop GDP growth, 2002-2012

	Contribution to total crop GDP growth (%)			
	Combined components	Land expansion	Land reallocation	Land productivity
All crops	100	31.9	64.5	3.6
Cereals	2.2	4.8	-2.9	0.3
Roots	16.7	15.1	-3.8	5.4
Pulses and oilseeds	5.5	3.7	1.2	0.6
Horticulture	71.5	6.1	69.1	-3.6
Traditional cash crops	4.1	2.1	1.0	0.9

Source: Own estimates using FAOSTAT (2014) and GoM (2002, 2012b and 2013).

Figure 1. Past and planned public agricultural spending, 2002-2017



Source: Own calculations using World Bank (2011), Mogues and Benin (2012), and GoM (2012a).
Notes: The "business-as-usual projection" maintains the 2007-11 growth rates in agricultural and nonagricultural public spending.

Table 5. Base year and PNISA spending per rural inhabitant, 2007 and 2013-2017

	US$ per rural inhabitant (constant 2012 prices)						
	Base, 2007	Planned spending under PNISA					
		2013	2014	2015	2016	2017	Average
Total spending	11.0	43.6	45.1	38.8	35.9	35.3	39.7
Research and extension	3.3	11.4	11.8	11.2	10.5	12.0	11.4
Irrigation	2.4	11.8	13.6	13.2	12.5	10.2	12.3
Farm input subsidies	0.5	3.3	3.0	3.6	4.0	4.4	3.7
Fisheries	0.8	3.3	4.5	4.8	4.0	4.1	4.2
Rural roads	n/a	7.5	5.9	0.3	0.3	0.3	2.9
Other spending	3.8	6.3	6.3	5.8	4.6	4.3	5.4

Source: Own calculations based on GoM (2012a).
Notes: Rural population is assumed to grow at 2.5 percent per year after 2012. Rural roads are not treated as an agricultural investment area in World Bank (2011).

Table 6. Investment function parameters, 2007

	North	Center	South	National	Units	Source
C	1,320,947	1,888,347	511,408	3,720,701	hectares	GoM (2008)
H	1,315,476	1,692,327	599,135	3,606,938	households	GoM (2008)
s^i	4.87	6.85	22.84	8.34	% hectares	GoM (2008)
s^e	9.57	8.78	4.96	8.44	% households	GoM (2008)
s^f	4.31	5.69	5.64	5.19	% hectares	GoM (2008)
p^e	2.58	2.37	1.34	2.27	% households	Own derivation
p^f	3.69	4.87	4.83	4.45	% hectares	Own derivation
E^i	7,524	15,128	13,668	36,320	US$1000	GoM (2012)
E^e	20,663	24,390	4,881	49,934	US$1000	GoM (2012)
E^f	2,428	4,581	1,230	8,239	US$1000	GoM (2012)
u^i	2,670	2,670	2,670	2,670	US$/ha	You et al. (2011)
u^e	225	225	225	225	US$/hh	GoM (2007)
u^f	298	298	298	298	US$/ha	Chirwa and Dorwood (2013)
β^i	2.33	4.10	35.36	9.26	elasticity	GoM (2008)
β^e	27.29	30.07	6.42	25.05	elasticity	GoM (2008)
β^f	25.54	27.84	28.75	27.38	elasticity	Chibwana et al. (2012)
δ	5.00	5.00	5.00	5.00	%	Assumed 20-year lifespan

Notes: Privately-provided extension is the difference between total and publically-provided extension, i.e., $s^i \cdot H - E^e/u^e$. Similarly, privately-purchased fertilizer is $s^f \cdot C - E^f/u^f$.

Table 7. Impacts of Extension and Irrigation on Production Values, 2008

	Percentage increase in production value relative to matched farmers not receiving extension or using irrigation (p-value in parentheses)		
	North	Center	South
Extension services			
Cereals	28.2 (0.010)	15.2 (0.149)	40.2 (0.067)
Roots	27.1 (0.042)	59.4 (0.005)	23.2 (0.217)
Pulses and groundnuts	24.5 (0.072)	37.1 (0.072)	6.2 (0.810)
Traditional cash crops	62.7 (0.083)	47.9 (0.056)	n/a
Irrigation use			
Horticulture	n/a	41.9 (0.160)	103.4 (0.000)

Source: Own calculations using the 2008 post-harvest survey (GoM 2008).
Notes: Not available (n/a) or not shown in table implies too few observations (e.g., few farmers in the survey use irrigation on root crops and so no results are shown).

Table 8. Weighted national TFP-investment elasticities

Investment type	Productivity-investment elasticity			Sectors affected by investment
	Low	Base	High	
Irrigation	0.0359	0.0449	0.0539	Rice, pulses and horticulture
Extension	0.0178	0.0222	0.0267	Food crops (excl. fruits), cash crops and livestock
Subsidies	0.0168	0.0210	0.0252	Maize, rice, roots, pulses and vegetables

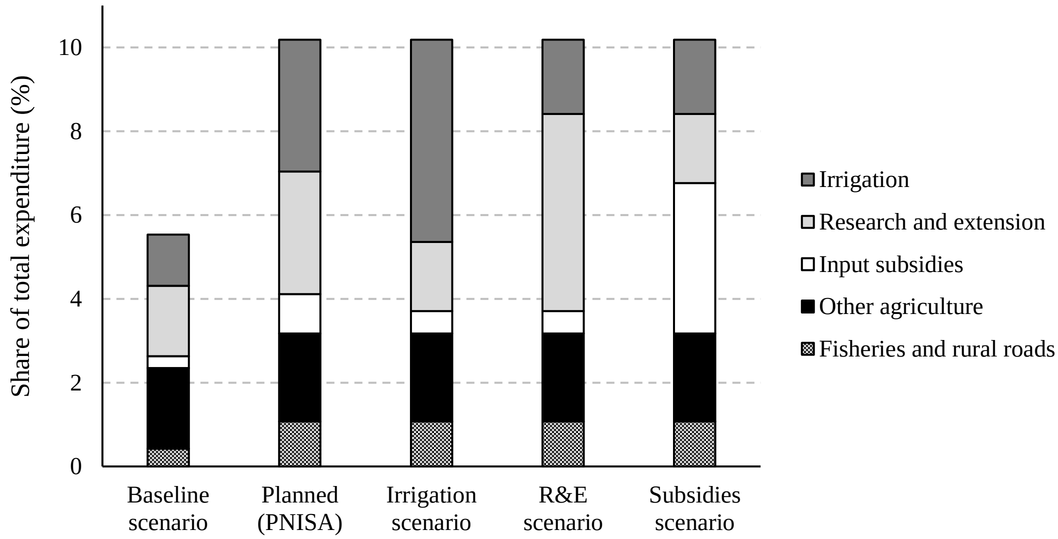
Source: Own estimates using 2008 post-harvest survey (GoM 2008), weighted using crops' gross output value shares from Thurlow (2012).

Table 9. Impacts in the baseline and investment scenarios, 2012-2017

	Baseline scenario	Planned scenario	Irrigation scenario	Extension scenario	Subsidies scenario
	Final coverage of hectares or farmers, 2017 (%)				
Irrigation coverage	9.90	14.49	18.39	11.32	11.32
Extension coverage	17.07	29.34	17.54	45.82	17.54
Improved input use	6.40	11.41	8.38	8.38	30.97
	Annual growth (%)	*Deviation from baseline growth rate, 2012-2017 (%-point)*			
Total GDP	6.86	0.22	0.11	0.34	0.24
Agriculture	4.45	0.85	0.44	1.27	0.90
Non-agriculture	7.62	0.03	0.01	0.06	0.04
Agriculture share (%)	-	88.06	93.28	86.71	88.45
	Final rate, 2017 (%)	*Deviation from final baseline poverty rate, 2017 (%-point)*			
Poverty headcount	33.75	-1.28	-0.66	-1.86	-1.34
Rural	36.35	-1.35	-0.62	-2.00	-1.39
Urban	27.81	-1.12	-0.77	-1.54	-1.21
Rural share (%)	-	73.28	64.89	74.80	72.42

Source: Results from the Mozambique model.
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.

Figure 2. Public budget expenditure shares in the investment scenarios, 2013-2017



Source: Results from the Mozambique CGE model.
Notes: “Planned” is expenditure level and composition from PNISA (GOM 2012a). Baseline is the planned portfolio scaled back to match historical agricultural spending growth for 2002-2012.

Table 10. Comparing investment portfolios

Scenarios	Mozambique	North region	Center region	South region
US$ increase in public spending per capita, 2017				
Planned	16.1	16.1	16.1	16.1
Irrigation	15.0	11.7	18.6	14.6
Extension	17.4	16.1	18.0	19.7
Subsidies	15.3	22.2	9.3	11.7
US$ increase in total GDP per US$ spent, 2007-2017				
Planned	1.07	1.16	0.92	1.24
Irrigation	0.46	0.21	0.60	0.61
Extension	0.94	0.56	1.13	1.44
Subsidies	2.14	2.64	1.06	1.71
Poor people lifted above poverty line per US$1000 spent, 2017				
Planned	1.73	1.33	1.82	2.41
Irrigation	1.43	1.12	1.38	1.04
Extension	1.76	1.43	1.81	2.84
Subsidies	2.07	1.35	3.10	3.44

Source: Results from the Mozambique CGE model.
Notes: Returns refer to outcomes and spending within each region.

Table 11. Investment efficiency analysis

Elasticities	Base	Base	Base	+15%	+30%
Unit costs	Base	-15%	-30%	-15%	-30%
Annual agricultural GDP growth rate, 2007-2017 (%)					
Planned	5.29	5.48	5.74	5.64	6.11
Irrigation	4.89	5.02	5.20	5.11	5.42
Extension	5.72	5.98	6.33	6.20	6.84
Subsidies	5.35	5.54	5.81	5.71	6.20
US$ increase in total GDP per additional US$ spent, 2007-2017					
Planned	0.35	0.41	0.50	0.47	0.62
Irrigation	0.17	0.20	0.25	0.23	0.30
Extension	0.55	0.64	0.76	0.72	0.96
Subsidies	0.38	0.44	0.52	0.50	0.66
Poor people lifted above poverty line per additional US$1000 spent, 2017					
Planned	0.72	0.76	0.83	0.79	0.98
Irrigation	0.37	0.41	0.37	0.40	0.40
Extension	1.05	1.14	1.29	1.28	1.53
Subsidies	0.75	0.78	0.85	0.82	0.95

Source: Results from the Mozambique CGE model.
Notes: Upper and lower bound unit costs assume a 20 percent confidence interval around baseline cost estimates or investment function elasticities.

Table A1. Decomposing agricultural crop GDP growth, 2002-2012

	Share of crop GDP (%)		Annual growth rate, 2002-12 (%)	Contribution to growth, 2002-12 (%)
	2002	2012		
All crops	100	100	4.8	100
Cereals	15.2	10.4	0.8	2.2
Maize	12.8	8.4	0.5	1.1
Sorghum and millet	1.6	1.1	0.9	0.2
Rice	0.8	0.6	0.8	0.1
Wheat and barley	0.1	0.3	22.3	0.8
Roots	47.4	36.0	1.9	16.7
Cassava	37.7	28.2	1.8	12.1
Potatoes	9.7	7.8	2.5	4.7
Pulses and oilseeds	10.1	7.9	2.2	4.2
Pulses	1.0	1.2	6.7	1.5
Groundnuts	2.4	1.6	0.8	0.3
Cashews	1.3	1.1	2.6	0.6
Oilseeds	5.4	4.0	1.7	1.7
Horticulture	19.1	38.6	12.4	71.5
Vegetables	3.9	13.9	18.9	30.8
Fruits	15.2	24.7	10.0	40.7
Traditional cash crops	8.2	7.1	3.4	5.4
Leaf tea	3.3	3.6	5.7	4.1
Tobacco	2.3	0.7	-6.6	-1.9
Sugarcane	1.0	1.3	7.9	1.8
Cotton	1.5	1.4	4.3	1.3
Other crops	0.2	0.1	0.7	0.0

Source: Own estimates using FAOSTAT (2014) and GoM (2002 and 2012b).

Table A2. Crop production data, 2002 and 2012

	Production (1000mt)		Cultivated area (1000ha)		Yield (mt/ha)	
	2002	2012	2002	2012	2002	2012
Cereals						
Maize	1,115	1,171	1,578	1,563	0.71	0.75
Sorghum and millet	151	161	272	375	0.55	0.43
Rice	93	102	206	306	0.45	0.33
Wheat and barley	3	20	3	12	1.04	1.68
Roots						
Cassava	3,446	4,099	863	953	3.99	4.30
Potatoes	456	587	105	135	4.33	4.33
Pulses and oilseeds						
Pulses	144	274	429	688	0.33	0.40
Groundnuts	102	110	330	379	0.31	0.29
Cashews	50	65	65	80	0.77	0.81
Oilseeds	366	420	326	511	1.12	0.82
Horticulture						
Vegetables	147	546	30	106	4.82	5.15
Fruits	337	811	59	124	5.72	6.55
Traditional cash crops						
Leaf tea	13	22	7	13	1.75	1.69
Tobacco	43	21	40	21	1.07	1.01
Sugarcane	1,586	3,394	35	46	45.32	73.91
Cotton	103	157	214	113	0.48	1.39
Other crops	5	5	10	10	0.50	0.53

Source: Own estimates using FAOSTAT (2014) and GoM (2002 and 2012b).

Table A3. Mozambique's regional characteristics, 2007

	National	North	Center	South
Population (% of total)	100	32.9	43.1	23.9
Rural share (% of region)	69.6	73.6	79.0	47.2
Poor population (% of total)	100	28.0	47.0	24.9
Poverty headcount (% of region)	54.7	46.5	59.7	56.9
GDP per capita (US$)	311.7	210.5	249.7	562.5
Total GDP (% of region)	100	100	100	100
Agriculture	27.7	37.7	42.5	10.8
Food crops	19.4	23.8	31.2	7.7
Export crops	1.2	1.2	2.5	0.0
Livestock	2.0	2.4	2.9	1.1
	5.1	10.3	5.8	1.9
Industry	26.0	26.2	21.3	28.9
Services	46.4	36.2	36.2	60.3
Average farm size (hectares)	1.03	1.00	1.11	0.85
Irrigation coverage (% of cropland)	8.52	4.97	7.00	23.34
Extension coverage (% of farmers)	13.66	15.50	14.22	8.04
Improved input use (% of farmers)	5.88	4.88	6.44	6.39

Source: Mozambique social accounting matrix (Thurlow 2013) and GoM (2008).
Notes: Poverty headcount is the share of the population below the national poverty line. GDP per capita is in unadjusted dollars.