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DETERMINANTS OF CROP INCOME IN RURAL MOZAMBIQUE, 2002-2005

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DIRECÇÃO DE ECONOMIA

Série de Relatórios de Pesquisa

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ACRONYMS

DE	Directorate of Economics (DE)
INE	National Statistics Institute
IIAM	National Agronomic Research Institute
GIS	geographic information system
MINAG	Ministry of Agriculture (*Ministério de Agricultura*)
MSE	Micro-small Enterprise
MSU	Michigan State University
NGO	Non-governmental Organization
NRE	Natural Resource Extraction
SIMA	Agricultural Market Information System of Mozambique (*Sistema de Informação de Mercados Agrícolas*)
TIA	National Agricultural Sample Survey (*Trabalho do Inquérito Agrícola)*

EXECUTIVE SUMMARY

Crop income is the predominant source of income for most rural Mozambican households, accounting for 73% of rural household income on average in 2002, and greater than 80% of the total income of the poorest 40% of rural households. While the Government of Mozambique recognizes the need to improve agricultural productivity, there is little empirical evidence to date suggesting what mix of public and private assets would best foster improved agricultural productivity in rural Mozambique. This paper aims to better understand the determinants of household crop income in rural Mozambique, by using the TIA panel household survey of 2002-2005 to measure the impact of various private and public assets on crop income. We build upon Walker et al.'s (2004) analysis of TIA02 crop income by utilizing the econometric advantages of panel econometrics to obtain improved estimates of the impact of various private and public assets on crop income. Our principal focus is to measure the effect on total household net crop income of factors which are assumed to have a positive effect on crop productivity and profitability, including: private assets such as landholding; household use of improved inputs (fertilizer, animal traction) and diversification into tobacco or cotton; and access to public goods such as extension advice, market price information, and farm association membership.

While our analysis focuses on a few specific private and public assets, we control for many additional household and spatial factors which may affect household crop income, including drought, flood, and crop disease shocks. Although we do not find significant effects on crop income from village-level flood and crop disease shocks, we find that an additional *day of drought* during the principal growing season results in an average 5.5% loss in crop income in the south, and a 2.0% loss in crop income in the north. These results highlight the extreme sensitivity of crop income to weather shocks, and thus the potential value of: a) promotion of smallholder access to low-cost methods of irrigation and/or conservation farming techniques to reduce the impact of drought -- in contrast to the recent emphasis of heavy investment in formal perimeter irrigation schemes; and b) investment in development and dissemination of drought-tolerant maize varieties as well as varietal improvement in traditionally drought-resistant crops such as cassava and sweet potato.

We find large significant effects of increased landholding on crop income, as a 5% increase in *total landholding* significantly increases crop income by 1.9% in the north, 2.1% in the center and 1.2% in the south. An important constraint to increased landholding could be the low use of animal traction in the center, and virtual non-existence of it in the north (attributed to trypanosomiasis spread by the tsetse fly). We investigate the determinants of landholding using regression analysis and find that adoption of animal traction use increases total landholding by 13.8% in the center and 18.5% in the south.

We also find that *animal traction use* significantly increases crop income by 29.7% in the Center. Given that the crop income regression controls for total landholding separately, the return to animal traction use is likely due to improved soil productivity. The evidence of significant, large positive effects of animal traction use on both productivity (in the Center) and total landholding (in the Center and South) suggest that promotion of animal traction use could lead to increased crop income both through increased landholding and improved productivity. Public investment could potentially increase adoption of animal traction in the North by alleviating disease constraints to animal traction via medicinal subsidies and/or eradication of the tsetse fly. Because oxen ownership represents a high investment cost, support for rural financial services might help to address household financial constraints to financing traction rental. Given the lack of tradition of maintaining oxen in these areas, livestock extension could also play a valuable role in promoting oxen ownership or rental. While cost-benefit studies may be required to evaluate the expected ex ante rate of return to some of these investments, the high farm-level benefits which we find from animal traction use suggest that such investments could have large aggregate returns, and could help foster the emergence of more commercial farmers.

Diversification into cotton or tobacco resulted in very large and significant increases in total net household crop income. Central households which grew tobacco had 55% higher crop income than that of non-growers, while cotton grower income was 194% higher than that of non-growers. Northern cotton growers had 43% higher crop income relative to non-growers; the effect of growing tobacco in the north was positive but not significant. While these crops have historically offered high returns, the option of growing such crops is only available for households which live within a reasonable distance from concession areas, and previous research has suggested that there appear to be landholding thresholds below which household participation is unlikely. Thus, tobacco and cotton are unfortunately not a panacea for widespread poverty reduction among smallholders due to these existing barriers to participation.

We also find evidence that some *non-farm income* sources may reinforce and multiply growth in the agricultural sector. Fishing/charcoal resource extraction activities have a significant positive association with crop income in the north and center (24% and 43%), while high-return medium-small enterprise activities such as trading and construction are associated with 22% higher crop income in the North. On the other hand, skilled nonfarm income in the center appears to compete for family labor, as it has a rather large and significant negative association (-40%) with crop income. What is surprising about these results is while non-farm income opportunities are most viable in southern Mozambique -- where crop potential is limited and demand for labor from South Africa is a reality -- there are no significant associations between non-farm income sources and crop income in that region. This suggests that non-farm income is not reinvested into agriculture in the South. Although we find a significant association between some non-farm income sources and crop income in the Center and North, policymakers should bear in mind that the types of non-farm activities available in the Center/North are largely dependent upon growth in agriculture.

We find that *household receipt of market price information* significantly increased crop income by 22% in the center and 31% in the south. There are several potential policy implications from these results. First, considering the size of these farm-level benefits of market information, and the widespread receipt of market price information (MPI) by rural households (40% of rural households in 2005), it is likely that the rate of return to SIMA investments to date is quite large, and would justify the restoration of SIMA funding to previous (higher) levels. Second, these results suggest that there would also be large returns to investments which increase household access to market price information. Given that radio is the predominant and lowest-cost (per household) method of dissemination price information (74% of households receiving price information received it via radio), there appear to be at least three ways to increase household-level access to MPI via radio broadcasts.

One means to do this would be to expand radio coverage to areas previously not served (19% of households live in villages which do not report receiving SIMA radio broadcasts).

However, the number of households which live in villages which receive MPI, yet did not personally receive MPI in 2005 (32% of households) is actually larger than the total number of households living outside these areas (20% of the rural population). Thus, it would appear that the principal constraint to increased household access to MPI is not necessarily a lack of radio coverage in rural Mozambique. Low frequency of broadcasts may explain why we observe that 45% of households which own a radio (and live in a village which receives price information via radio) said that they did not receive MPI. Thus, within areas already receiving radio coverage, another option to increase the number of household which receive MPI would be to increase the number of SIMA broadcasts in a given area of the country, using existing radio stations.

Another potential constraint to increased household use of MPI may be related to the appropriateness of the content of the SIMA price information relative to the marketing needs of farmers in specific areas of rural Mozambique. For example, SIMA could able to deliver price information in local languages, report on all the major crops on a provincial basis. In addition, SIMA could perhaps add some analytical content to their messages, such as price forecasts and trends, or potential markets and transport costs. Addressing these types of constraints would require additional investments to set up provincial SIMA units (SIMAPS) that collect, analyze and disseminate more province-specific market information on a broader range of products than the national SIMA – which are specifically targeted to the needs of the radio audience in that province.

Because some extension advice may only result in improved productivity over time, we created extension variables to measure the possibility that an extension visit has an immediate impact on crop income (that season) or an impact which is realized over time. We also constructed separate extension variables for tobacco/cotton growers because of the advantage those growers have in terms of net returns as well as access to credit, fertilizer, etc. With respect to non-tobacco/cotton growers, we find no significant effects of *the number of cumulative extension visits* on crop income in any region, but we find that households in the South which received an *extension visit in 2002* had 78% higher crop income in 2005 than other households. The results from these two extension variables suggest that extension messages do not improve a household's crop income in the year in which the visit is made, but that, in the South, this advice led to an increase crop income over time. One policy implication of these results is that caution may be warranted prior to substantial increases in extension funding without a better understanding of what kinds of extension are working well and which are not, why impacts are only found over time (and only in the South).

With respect to tobacco/cotton growers, we find that an increase in the *number of cumulative extension visits* improves crop income by 35% in the North, while the effect of an *extension visit in 2002* over time is significant leads to a 73% increase in crop income over time in the Center. A policy implication from these tobacco/cotton extension results is that it is possible for extension advice to result in higher crop income in both the year of receipt and over time. This extension effect for tobacco/cotton farmers might derive from higher returns to their cash crops, or it could be that these farmers are better able to implement extension recommendations due to better input access. Further investigation is therefore needed to discover whether the tobacco/cotton extension result is driven by increases in tobacco/cotton income or by increases in income from other crops.

We find that *farm association membership* is associated with a 22% increase in crop income in the North, yet had no significant effects elsewhere. A policy implication of this result is that caution may be warranted prior to substantial increases in funding to assist farm associations, without a better understanding of why associations in the north have had a significant effect on crop incomes, while those in the center and south have not.

In order to measure the effect of market access on crop income, we use road density and village remoteness as proxies of market access. Because these variables are only observed in 2002, they drop out of our panel regression model, thus we run a separate regression (pooled OLS) to measure the effect of these variables on crop income. Given the methodological shortcomings of these road variables as well as the conflicting results from them, we consider the results on these market access variables to be inconclusive.

Finally, this study suggests ways to improve the effectiveness of the TIA survey to serve as an instrument to monitor the contribution of the agricultural sector to poverty reduction. These include collecting additional information on: agricultural technology use; the specific activities of farm associations in each village; the nature of extension advice received by households and the organizational affiliation of the extensionist; and market access, preferably based on the satellite coordinates of interviewed communities, overlaid with a grid of roads in a GIS format.

1. Introduction

Crop income is the predominant source of income for most rural Mozambican households, accounting for 73% of rural household income on average in 2002 (Table 1), and greater than 80% of the total income of the poorest 40% of rural households. Crop income was also responsible for much of the increase in total rural household income from 1996-2002 for the poorest 60% of Mozambicans (Boughton et al, 2006). However, some analysts believe that much of the growth in agricultural production and crop income in rural Mozambique since 1994 has primarily come from agricultural extensification (increasing area cultivated) and very little from intensification (increased productivity via higher levels of inputs and/or shifting area into higher-return cash crops) (World Bank, 2007). Given that levels of fertilizer and animal traction use remain very low in rural Mozambique (Mather et al, 2008), it seems doubtful if continued area expansion by manual cultivation will continue to generate growth in crop income over time, without some increase in the adoption of improved inputs and/or increased production of higher-value crops. While there was some increase in adoption of improved inputs and increased production of higher-value crops from 1996 to 2002 (Boughton et al, 2006), this positive trend did not continue from 2002 to 2005 (Mather et al, 2008). History suggests the necessity of productivity increases in agriculture for sustained poverty reduction: except in the cases of a handful of city-states, there are virtually no examples of mass poverty reduction since 1700 that did not start with sharp rises in employment and self-employment income due to higher productivity in small family farms (Lipton, 2005). While the Government of Mozambique (GOM) recognizes the need to improve agricultural productivity, there is little empirical evidence to date which measures the effect on crop income of various private and public assets.

This paper aims to better understand the determinants of household crop income, by using the TIA panel household survey of 2002-2005 to measure the impact of various private and public assets on crop income. We build upon Walker et al's (2004) analysis of TIA02 crop income by utilizing the econometric advantages of panel econometrics to obtain improved estimates of the impact of various private and public assets on crop income. Our principal focus is to measure the effect on household crop income of factors which are assumed to have a positive effect on crop productivity and profitability, including: private assets such as landholding; household use of improved inputs (fertilizer, animal traction) and diversification into tobacco or cotton; and access to public goods such as extension advice, market price information, and farm association membership.

2. Data

2.1 Survey

This study uses a 3-year panel of rural household-level surveys known as the TIA (Trabalho do Inquêrito Agícola), which were implemented in 2002 and 2005 by MINAG staff from the Directorate of Economics (DE) in collaboration with colleagues from Michigan State University (MSU). Employing standards from the National Statistics Institute (INE), the TIA 2002 (TIA02) used a stratified, clustered sample design[1] that is representative of rural small- and medium-

Table 1 Household shares of components in total net household income by income quintile, 2002

Quintiles of Total net HH income/AE, 2002	Crop income	--- Components of Crop Income --- Retained food crops	Food crop sales	High-value crops	Livestock sales	Unskilled farm labor	Non-Farm income
	------------- shares of income component in total net HH income (%) ------------						
1-low	82.5	73.8	4.5	3.7	3.8	1.4	12.0
2	80.8	72.6	4.3	3.9	2.5	1.6	15.1
3-mid	78.3	70.0	4.9	3.4	2.6	2.2	16.8
4	71.2	61.9	4.8	4.4	2.4	2.9	23.6
5-high	51.3	42.8	3.9	4.7	2.1	1.9	44.7
total	72.8	64.2	4.5	4.0	2.7	2.0	22.4

Source: TIA02

holders[2] at the provincial and national levels, and includes 4,908 households from 80 districts (out of 128) across the country. To construct a panel data set and yet also have a sample that remains representative at national and provincial levels, MINAG statisticians and its collaborators designed the TIA 2005 (TIA05) sample to include all TIA02 households (which could be re-interviewed) and yet also includes new households for TIA05 so as to retain a representative sample of the population.[3]

Both the TIA 2002 and TIA 2005 survey instruments covered a range of aspects: agricultural and livestock production, land use, and income sources and services. The survey instruments also included several demographic sections, to capture the characteristics of each current member of the household, and to document new arrivals, departures, deaths, and prolonged illness of household members.

[1] The TIA 02 sample was drawn from the sampling frame prepared for the year 2000 agricultural "census" (covering approximately 22,000 households) with the intention that TIA 02 data can be analyzed at the provincial level and by agro-ecological zone.

[2] Medium scale farmers (based on criteria using land and livestock holdings and horticultural production) were expressly over-sampled, to ensure sufficient observations for analysis.

[3] The full TIA 05 sample includes all TIA 02 households which could be reinterviewed from the 80 TIA 02 districts (i.e. the panel households), replacement households for attrited TIA 02 households, as well as households from 16 additional districts which were not sampled in TIA 02.

2.2 Panel income dataset

This paper uses a panel household income dataset which was constructed by DE/MSU from the TIA panel data, using methods which are described in detail elsewhere (Mather et al, 2008). This paper uses the crop income variable from that dataset for 2002 and 2005, the composition of which is largely consistent with earlier work on TIA income data (Walker et al, 2004; Boughton et al, 2006). The variable *crop income* used in this paper includes the retained and sold value of food crops (grains, beans, oilseeds, roots/tubers), retained and sold value of cashew and coconut, sales of field cash crops (such as tobacco and cotton), and sales of horticultural and fruit crops. Costs of seed and chemical fertilizers and herbicides are netted out from gross crop income. The price we use to value crop production depends upon the type of crop and whether it was sold or retained. We value the sales of some crops (maize, rice, beans, groundnuts, and cassava) using the farmer's reported sale price for that crop.[4] The prices of these crops are all broadcast via radio by the *Sistema de Informação de Mercados* (SIMA), thus we use actual household sale prices of these crops to value the sales of a selling household, in the event that receipt of market information enabled that household to negotiate a better sales price. For sales of other food crops, we value sales by using the median district-level TIA household farmgate sales price.[5]

In previous TIA work, food production retained for household consumption is valued at the same price used to value that which is sold – the median district or provincial farmgate sales price. By contrast, in this paper (as well as in Mather et al, 2008), we value retained food crop production using the annual average retail price of that product from the nearest rural retail market with price data reported by SIMA.[6] For traditional cash crops, horticultural crops and fruit, we use the farmer's reported sale price to value their sales, given that price variation across farmers for these crops might well be due to varying quality.[7]

2.3 Panel attrition

Given that over time, some households move away from a village and others dissolve as part of a typical household life-cycle, panel household surveys typically have to contend with at least some sample attrition over time. In the three-year TIA panel, n=804 households (17.3% between the two surveys, or 5.8% per year) out of the n=4908 TIA02 households were unable to be re-interviewed (Mather and Donovan, 2007). Overall, the rate of attrition in this sample is relatively low, as compared to other African country surveys described in Alderman et al (2001) and elsewhere (Chapoto, 2006, for rural Zambia). However, if households which fall out of the sample (i.e. are not re-interviewed) are a non-random sub-sample of the population, then using the re-interviewed households to estimate the means of variables during the 2nd time period (or the change in the variable between the two panels) may result in biased estimates. Using standard diagnostic techniques, Mather and Donovan (2007) found

[4] We cap the reported household sale price (most likely sold at the farmgate) at the retail price of that crop reported by the nearest SIMA rural retail market.
[5] We compute this price at the district level where there are at least 10 household price observations for a given crop, otherwise at the provincial level.
[6] Since non-farm income is typically reported in cash terms, sold crops represent cash income, and cash income is an indicator of household consumption potential, then valuing retained food production at retail (rather than farmgate) prices better approximates the 'consumption' value to the household of food production which is retained. In sum, we feel that this valuation method improves the ability of household income to serve as a welfare indicator.
[7] We cap farmer-reported prices of field cash crops at the 20% and 80% marks (i.e. recode the top 20% of prices to the 80 percentile price; the bottom 20% of prices at the 20 percentile price).

evidence of attrition bias in various household characteristics such as demographics, total household income, and asset levels. All panel household analysis in this paper uses sampling weights which have been corrected for attrition bias, using Mather and Donovan's (2007) attrition correction for the TIA panel income dataset.[8]

2.4 Other panel data issues and adjustments

Prices between the two panels were adjusted so as to inflate 2002 values to 2005 MTN, based on rural price deflators constructed from available secondary data as described by Mather et al (2008).[9] Mather et al (2008) contains details on adjustments made to the raw TIA data on cassava production and landholding.

[8] Mather and Donovan (2007) used the inverse probability weight (IPW) method (Wooldridge, 2002) to correct for attrition bias. The method involves the estimation of a reinterview (probit) model and then using the inverse of predicted probabilities of reinterview to adjust sampling weights for attrition bias. In short, this results in larger weights for households which were more likely to have dropped out of the sample, which in the case of the TIA panel tended to be households with somewhat lower total income and livestock assets in 2002.

[9] While the Meticais da Nova Familia (MTN) was not introduced until 2006, all values in this report are reported in MTN for the convenience of readers, and converted at the rate of 1000 meticais (adjusted to constant 2005 values) = 1 MTN.

3. Methods

3.1 First difference model

In this section, we use multivariate regression analysis to determine the effect of various household and village factors on total household crop income in 2002 and 2005. The dependent variable in these regressions is the change in the natural log of total net crop income[10], which includes all crops produced by the household, and nets out costs for fertilizer, pesticides/herbicides, and seed.

We use data from the TIA panel households in a first-difference regression model, in which the value of each variable (dependent and independent) in the first time period is subtracted from the value in the following period, as described below in more detail. With a few exceptions, each variable in the model is thus the change in that variable over time (the 2002 value subtracted from the 2005 value for each household). Any variable which does not vary over time for at least some households is thus differenced out of the model (drops out of the model). However, we can still estimate coefficients for time-invariant variables which are interacted with a time dummy. Because we only have two time periods, our first difference model will yield the same results and coefficient interpretation as a household fixed-effect (within estimator) model (Wooldridge, 2002). We use the first-difference (FD) rather than the fixed-effect (FE) regression model because it is considerably easier to program in the regression analysis software (STATA) for use with complex sample weights.

We specify a first-difference model as follows:

$$Y_{it} = \beta_0 + \beta_1 T + \gamma_d Dist_d + \psi_d Dist_d{*}T + \varphi_p X_i^{02} + \tau_p X_i^{02}{*}T + \beta_k X_{it} + c_i + \varepsilon_{it} \quad (1)$$

Where: $i = 1$ to n TIA panel households
- $t = 0$ to 1 time periods
- $d = 1$ to 79 TIA districts common across TIA02 and TIA05
- $k = 1$ to m time-varying household, village, and district-level variables
- $p = 1$ to 8 household-level variables observed only in 2002
- $Dist_d = 1$ for households in District d, and = 0 otherwise
- T is a time dummy which =0 in year 2002, and =1 in year 2005
- X_i^{02} represents a household-level characteristic observed only in 2002
- X_{it} represents time-varying household, village, and district-level variables
- c_i represents time-constant household unobservables
- ε_{it} is the error term, assumed to have a mean of zero

The estimation model includes a separate district dummy for 79 of the 80 TIA panel districts (i.e. the TIA02 districts), and various household-level characteristics. To demonstrate more clearly how we derive the first-difference equation, we write out the crop income equation for each time period as follows: Equation (2) represents time period t=1 (i.e. year=2005), and equation (3) represents time period t=0 (i.e. year=2002).

$$Y_{i2} = \beta_0 + \beta_1 T + \gamma_d Dist_d + \psi_d Dist_d{*}T + \varphi_p X_i^{02} + \tau_p X_i^{02}{*}T + \beta_k X_{it} + c_i + \varepsilon_{it} \quad (2)$$

[10] In order to include cases of zero crop income, we add the value of 'one' to each case before taking the natural logarithm. There are a few cases of negative crop income, which we recoded to =1.

$$Y_{i1} = \beta_0 + \quad + \gamma_d \, Dist_d + \quad + \varphi_p \, X_i^{02} + \quad + \beta_k \, X_{it} + c_i + \varepsilon_{it}$$
(3)

Note that any term which is an interaction between a variable and the time dummy variable T drops out of equation (3) because T=0 in 2002. The first-difference (FD) equation which we estimate is derived by subtracting equation (3) from equation (2). This operation is represented in equation (4) which, once simplified, gives us the equation which we actually estimate (5).
That is, we subtract the equation for 2002 (3) from the equation for 2005 (2), which results in an equation which represents the change in each variable from 2002 to 2005 (4).

$$Y_{i2} - Y_{i1} = (\beta_0 + \beta_1 T - \beta_0) + [(\gamma_d \, Dist_d + \psi_d \, Dist_d{*}T) - \gamma_d \, Dist_d)] + \ldots$$

$$\ldots + [(\varphi_p \, X_i^{02} + \tau_p \, X_i^{02}{*}T) - \varphi_p \, X_i^{02}] + \beta_k (X_{i2} - X_{i2}) + (c_i - c_i) + (\varepsilon_{i2} - \varepsilon_{i1})$$
(4)

Note that any variable which does not change over time for at least some households is differenced out of equation (4) (i.e. it drops out). This includes the district dummies, the observed time-constant household characteristics X_i^{02}, and the unobserved time-constant household-level characteristics c_i (which is often termed the household fixed effect). However, the interaction between time-constant variables (district dummies and household 2002 characteristics) and the time dummy T is not differenced out, because the dummy T=0 in 2002 and T=1 in 2005, and thus the interaction between any variable and the time dummy T will vary over time. Therefore, the coefficient on time-constant variables in our model which are interacted with the time dummy T must be interpreted as the 'change over time in the dependent variable, given a change in the independent variable'.

$$\Delta Y_i = \beta_1 T + \psi_d \, Dist_d{*}T + \tau_p \, X_i^{02}{*}T + \beta_k \, \Delta X_{i2} + \Delta\varepsilon_i$$
(5)

Where:
- ΔY_i is the change in the crop income for household i
- β_1 is the intercept and represents the change in average district crop income for the base district
- ψ_d is a constant that represents the change in the average of crop income in district d
- τ_p is the change from 2002-05 in the effect of the time-invariant household-level characteristic X^{02} on Y
- β_k is the effect of a change in household characteristic X on Y
- $\Delta\varepsilon_i$ is the error term

If we were to ignore the c_i terms (the household fixed effect), equations (2) and (3) could be regressed together as pooled OLS. Relative to pooled OLS, the advantage of the FD model is that by subtracting the equation for one time period from the ensuing time period, we are able to difference-out the c_i term, and thus control for unobserved household-level characteristics which do not vary over the panel time period. These unobserved factors include such factors as the soil quality of the household's fields, the farmer's experience and farm management skill, the farmer's risk preferences, and the household's social connections. Such factors are unlikely to vary much over the three years of the panel, yet may play a significant part in determining crop income. Because these household factors are unobserved and undoubtedly vary non-randomly across households (i.e. some farmers are better farm managers than others; some farmers have better soils than others in the same village; etc), they could easily confound (i.e. overstate or understate) the measurement of returns to a variable such as *received agricultural extension*, *membership in farm association*, *fertilizer use*, *total land area*, etc.

For example, because extension agents are known to sometimes target farmers with more experience, more skill at farm management, or stronger social connections, the coefficient on returns to *household receipt of an agricultural extension visit* in a cross-sectional regression may include not only the true (assumed to be positive) effect of agricultural extension on crop income, but also any positive effects of unobserved variables which are correlated with agricultural extension receipt – but which also have a positive effect on crop income -- such as high farm management skill, good quality soils, and better social capital connections. Likewise, the measurement of returns to a variable such as returns to land could be confounded by unobserved soil quality (i.e. in terms of yield response, one hectare of land on good soil is not equivalent to one hectare of land with poorer soil).

The advantage of the FD model relative to a pooled OLS or a cross-sectional OLS is that it enables us to improve the consistency (i.e. reduce the bias) of our OLS estimate of the returns to observed variables such as *received agricultural extension* and *total landholding* while holding fixed over time the unobserved time-invariant household characteristics, which are specific to the given household and are likely to be correlated with these observed variables. Such correlation could result in biased estimation of these coefficients, due to a form of endogeneity termed omitted variable bias (Wooldridge, 2002). Because the FD model enables us to control for unobserved time-invariant household characteristics, we are able to estimate the effect on crop income of household access to a public good without concern for bias from this specific form of endogeneity (though others may remain). Any unobserved, time-invariant characteristics of households or villages (such as non-random program placement) are differenced out of the regression, and therefore do not bias the coefficient estimates of the impact of these programs on crop income.

The disadvantage of the FD model relative to a pooled OLS of two cross-sections is that we use half the number of cases, and thus we lose some precision in the estimate (i.e. coefficients from the FD model will likely have larger standard errors than those from pooled OLS). However, considering the large size of the TIA panel (n=4,143 households used in the regressions in this paper), loss of precision is not likely to be as problematic as the lack of consistency (increase in bias of coefficients) from pooled OLS.

We group the model variables conceptually as follows:

a) district- or village-level factors (meso-level) such as agroecological potential, rainfall, other shocks, road infrastructure, and input/output prices
b) household assets (micro-level): such as household farm assets (land, labor, livestock), marketing assets (bicycle, radio), human capital
c) household choice variables (micro-level): household cropping decision, non-farm livelihoods, and use of improved inputs (fertilizer, animal traction),
d) household access to public goods (micro-level): household access to agricultural extension, market price information, farmer association

Note that some of these variables relate to levels of household assets (land, labor, livestock, human capital) or community assets (agro-ecological potential). Other variables affect the returns to existing household and community assets, at the community level (prices, rainfall, shocks) or the household level (use of improved inputs, cropping decision, household access to agricultural extension, market price information, etc). Education of the head represents an asset level yet also serves as a proxy of farm management skill, which likely affects the returns to existing household and community assets.

3.2 District or village-level factors

3.2.1 Agro-ecological potential, rainfall and shocks

In our regression model, we control for rainfall and agro-ecological potential in various ways. First, we include an estimate of the *district-level days of drought* during the primary agricultural season (November/December to March/April, depending on the district), to control for variation in drought shocks across districts. The data and methods for creating this variable are explained in Mather et al (2008). It should be noted that relative to 2002, days of drought in 2005 were considerably higher in the north, though the same or worse in the center and south (Table 2). However, *both* years of the TIA panel experienced more drought days than the five-year average, with the exception of a favorable season in 2002 in the north. Poor rainfall in 2005 relative to 2002 is likely to be the principal cause of a 24% decline in median household crop income/AE from 2002 to 2005 (Mather et al, 2008). We also include village-level indices for the extent of flood and disease shocks *(% of households in the village affected flood,* and *% of households in the village affected by crop disease*), which come from a community-level survey implemented in conjunction with TIA02 and TIA05.[11]

The district-level rainfall and village-level flood and disease shock variables only control for one aspect of a given area's agro-ecological potential for a given point in time. For example, temperature, humidity, insect pressure, soil conditions, etc also are important aspects of agro-ecological potential in a given season. As we do not have measures of these variables, we control for these unobserved factors (common to a given area) using district dummy variables (district fixed effects) interacted with a time dummy. The district dummy variables are differenced out of the FD model, but the district*time interaction term is not. This captures the average *change in crop income* in the district from 2002-05, and thus captures the average effect of unobserved variables such as changes in prices and agro-ecological potential across the two years of the panel. In other words, the interaction of time*district helps us to control for the average effect of shocks common to households in a given district, etc.

3.2.2 Input and output prices

While crop income regressions typically include measures of input prices (such as wages or fertilizer prices) and output prices (farmgate food and cash crop prices), we do not include these for several reasons. With respect to input prices, we have too few observations on unskilled wages (farm and non-farm) at the district level to construct a variable to measure the costs of hired labor or the opportunity costs of farm labor. Likewise, we do not include a

[11] The community survey associated with both TIA02 and TIA05 asked the village head(s) if the village suffered from a flood during the previous agricultural year. If there was a flood, the village head was then asked whether the flood affected: less than half the household in the village; half; more than half; or all households in the village. We created a variable which =0.25 for less than half, 0.50 for half, 0.75 for more than half, and 1.0 for all. We created a similar village-level index for 'crop disease.'

fertilizer price because fertilizer price data is nonexistent for many areas (given that fertilizer is so infrequently used in many parts of the country). With respect to output prices, we have a reasonable number of observations on principal food crop sale prices (such as for maize), but there is little variation across districts in district median or mean food crop prices (and using household-level sale prices is not feasible as less than 20% of growers of a given food crop are sellers). We therefore rely upon the district*time dummies to capture changes in input/output prices over time.

3.3 Household physical and human capital assets

Each variable mentioned below is included in the FD model as a 'change (in that variable) from 2002 to 2005,' with the exception of those which are the 2002 value of a variable interacted with the *time* dummy. The two principal assets used in crop production are land and labor. The natural log of total *land access* (which includes the sum of area cultivated to annual and permanent crops, and the area in fallow) is included, along with its squared term to reflect the assumption of diminishing returns to land, when other production factors (e.g., labor) are in fixed supply. We use the *number of adults in agriculture* in the household (age 15 and above) as a proxy for available labor for cropping activities.[12] While recent research has shown that prime-age mortality in rural Mozambique often leads to significant negative effects on crop income (Mather and Donovan, 2007), we do not include mortality dummies here because such dummies would likely be highly correlated with changes in land area and changes in numbers of adults. However, we do include the *number of chronically ill prime-age adults* because a change in this variable would likely affect the household's available labor, and such a change would not likely be captured by changes in land or labor. Because retained food crop production accounts for much of the value of total crop income for a majority of rural households in Mozambique (Mather et al, 2008), we include variables for the *number of children age 0-4*, *children 5-14*, and adults *age 60+* to control for variation in food consumption requirements across with different demographics.

[12] The TIA demographic section asks if each adult is 1=principally engaged in agriculture, 2=secondarily engaged in agriculture; or 3=not engaged in agriculture. We define PA adult in agriculture to be those adults in the first two groups.

Table 2. Provincial average number of drought days during the primary maize growing season

Province	**1996**	1997	1998	1999	2000	2001	**2002**	2003	2004	**2005**	2006	average 1996-06	average 2002-06
Niassa	**51.8**	33.3	41.4	0.0	21.5	0.5	**3.1**	0.5	5.2	**22.5**	3.2	16.6	5.8
C.Delgado	**31.0**	15.8	18.6	0.9	7.3	4.4	**3.0**	4.4	3.4	**17.1**	3.0	9.9	5.9
Nampula	**18.6**	4.9	11.8	2.9	8.1	1.4	**1.6**	2.0	3.4	**24.4**	9.1	8.0	7.0
Zambezia	**5.4**	9.8	14.9	0.0	4.6	0.4	**14.0**	0.9	2.0	**43.1**	2.7	8.9	10.5
Tete	**32.4**	13.5	56.0	9.4	14.6	7.7	**44.2**	14.8	14.1	**45.5**	8.8	23.7	22.5
Manica	**6.2**	5.0	37.7	4.0	10.7	20.2	**56.5**	12.9	11.7	**63.4**	17.4	22.4	30.4
Sofala	**2.0**	3.7	15.6	0.3	17.5	14.1	**41.9**	4.5	8.0	**41.6**	2.4	13.8	18.7
Inhambane	**31.9**	27.7	53.8	7.1	18.1	9.5	**82.9**		36.5	**79.7**	17.5	36.5	45.2
Gaza	**17.4**	32.9	79.4	18.5	0.0	32.0	**105.9**	30.8	70.2	**112.9**	39.1	49.0	65.2
Maputo Prov	**66.0**	37.5	84.5	26.3	1.0	89.9	**73.4**	93.4	26.0	**93.8**	37.3	57.2	69.0

Source: FEWSNET dekadal rainfall estimates from satellite imagery; computations of drought days per dekadal described in Mather et al, 2008.

About 20% of households employ temporary labor for land preparation, and 2% employ permanent labor for land preparation (with a high of 5% in the center). We also include *number of temporary laborers in land preparation and seeding/transplant* and *number of permanent laborers in agriculture.* We do not include temporary laborers hired for other tasks such as weeding or harvest, as these are likely to be endogenous to crop income (i.e. more labor will likely be hired for weeding and harvest when rains are good and crops develop well). We also do not include permanent workers for livestock activities.

Another important set of productive assets includes owned farm equipment used for production (plough, sprayer, pump), processing (press, mill, thresher), and transportation (bicycle, cart, trailer, motorcycle, truck). We use the 2002 prices of these items from neighboring Zambia to value them for both TIA02 and TIA05, and inflate the values using the rural price index we created. Thus, we include the natural log of farm equipment value to control for other types of physical capital. We do not include a measure of livestock holdings because we include a variable for use of animal traction (below), and because it would be problematic to include the change in livestock holdings because of there were considerable losses of chickens in 2004/05 due to Newcastle disease in various parts of the country. While TIA includes data on household numbers of productive cashew and coconut trees, we do not include this in the models because there is very little change in this variable over the three-year gap between panel surveys (not surprisingly).

Human capital variables include *head's education, 2002*TIME*, and the *maximum education of adults in the household*. *Bike ownership* is relevant to crop income as it should reduce marketing costs and therefore improve the farmer's sale price. *Head's age in 2002*TIME* and its square are included to capture potential lifecycle and experience effects.

3.4 Household cropping, livelihoods and input use

We also include several livelihood choice variables.[13] The first group of choice variables are related to crop choice (separate dummies for 1=household grows tobacco, and 1=household grows cotton). While we would expect commercially-targeted vegetable and fruit production to also increase total net crop income, TIA does not provide enough information on vegetable and fruit production to include such a variable for horticultural production.[14] A second group of choice variables is related to the household's non-crop activities, which we include as a proxy for cash availability.

There is evidence from some African countries that non-farm income is an important source of investible capital, which can enable households to generate the cash necessary (i.e. alleviate credit constraints) to purchase improved inputs such as fertilizer, improved seeds, etc. or hiring of labor or labor substitutes such as animal traction (Reardon et al, 1994).

[13] Household-level 'choice' variables such as input use are considered to be potentially endogenous, either because they may be simultaneously (or previously) determined along with the dependent variable, or because they may be correlated with unobservable household characteristics. Our use of first-differencing controls for the second type of endogeneity, and we do not include household choice variables which may reflect decisions taken after crop income is already largely determined.

[14] For horticultural products, TIA only collects information on the value of sales, and the sale decision for many of these crops is endogenous to crop income since it may well be made after other food crops have been harvested. By contrast, tobacco and cotton are not produced for home consumption, thus planting these crops indicates a livelihood choice which was made at the beginning of the season.

While the evidence for this occurrence is mixed and conditional on various factors, it is typically found in the situation of rural credit market failure.[15] These non-farm income dummies include: 1=household has skilled wage income;[16] 1=household has a higher return natural resource extraction SME activity (such as fishing or charcoal production); 1=household has a non-resource extraction SME activity; and 1=household has remittance income. We do not include indicators for unskilled farm or nonfarm labor, or for low-return natural resource extraction SME activities, because such activities might be undertaken in response to drought (in which case, crop income would already be largely determined, and such responses would be endogenous to crop income).[17] The indicator for remittance income might suffer from the same endogeneity, if household migration is undertaken in response to a drought.

So far we have considered levels of rural household assets, and the extent to which these levels have changed over time. In the following two sections, we consider factors which can significantly increase the returns to existing household assets: household use of new and improved technologies, and household access to public goods. With respect to improved inputs, we include variables for *use of animal traction* (owned or rented), and the natural log of *total fertilizer cost*. Animal traction is expected to result in increased crop productivity due to improved soil aeration and weed control, while fertilizer use should improve crop yields (assuming timely and sufficient rainfall).

We include an additional cropping-related variable to control for potential changes in crop income due to our imputation of cassava production for some growers in 2002. [18] About one-third of cassava growers in TIA02 reported growing the crop but did not report production (many of these were in Nampula). Because crop income for these growers could potentially change over time due solely to our use of imputed cassava production for these growers in 2002 but their actual cassava production 2005, we include a dummy variable which =1 for households with imputed cassava production in 2002.

3.5 Household access to public goods

3.5.1 Agricultural extension

There are some goods (commodities) that, once produced, the benefits of which can be enjoyed by every person in the village (or beyond), regardless of whether or not that person pays for access to the good. Such a good is considered to be *non-excludable* by economists. A good is considered to be *non-rival* in consumption if one person's use of it diminishes others' use. Goods which are both non-excludable and non-rival are considered by economists to be *pure public goods.* The private sector has no incentive to incur the costs of producing such a commodity, given that they are unable to force those who benefit from the good to pay for access to it. Therefore, such goods are typically either provided by governments (i.e. the public) or not at all.

[15] Market failure is defined by de Janvry et al (1991) as a situation in which the general benefit of using the market is less than the transaction costs of using it, or where access constraints makes the net benefit of participation negative for some households.

[16] See Appendix A-4 for a definition of some specific activities included in each non-farm category.

[17] Our variables take the value =1 if the household engaged in that activity in the previous 12 months. Further analysis might diminish the potential for endogeneity of some of these activities by using information from TIA on the specific months in which the household pursued that activity.

[18] See Mather et al (2008) for details regarding TIA02 cassava imputation.

For example, agricultural extension represents a mechanism by which new and improved agricultural technologies and better management practices can be transmitted to farmers, as well as providing a means by which farmers can provide feedback to the agricultural researchers about their needs, constraints, and preferences regarding technology development. Messages delivered by agricultural extension agents have public good characteristics, given that an extension agent who gives a specific farmer advice on crop management practices such as crop rotation, line sowing, soil management, etc. would face high costs of excluding that information from other neighboring farmers. Thus, even assuming that farmers would be willing and able to pay for such advice, a private firm would have trouble selling such extension information to farmers given that only one farmer per village would likely pay for it, because the others could avoid paying the fee and just ask the farmer later what the extensionist had said.

The same logic also extends to the research cost which is required to discover which set of crop management practices make the most sense by economic and agronomic criteria for farmers in a given area (which often entails research using on-farm trials). The costs of such research would not likely be undertaken by a private firm, because the firm would not be able to exclude non-paying farmers from obtaining the information about the recommended crop management practices, once a few paying customers had received it. Nevertheless, the benefits of agricultural extension messages are only realized if farmers adopt the new input or management technique and it proves to be financially viable and appropriate to the farmers' agro-ecological and market access environment.

The empirical evidence of the impact of agricultural extension in developing countries is rather mixed, though conventional wisdom holds that public agricultural research and extension plays a critical role in improving agricultural productivity. Birkhaeuser et al (1991) reviewed 15 studies of the impact of agricultural extension (typically defined as farmer contact with an extension agent) on crop productivity or value, each of which used multivariate regression methods. These studies provided 26 estimates of extension impact, 11 of which were significant and positive, with the largest being 27%. However, the authors caution that many of the studies they reviewed did not control for the two most common statistical challenges in evaluating the impact of agricultural extension – non-random targeting of farmers and/or agro-ecological zones by extension agents (or participation by farmers). Besides those specific methodological concerns, there are many reasons that we might expect to find highly variable results in comparing extension impacts across crops, regions, and countries. First, from a methodological perspective, attributing crop productivity improvements to extension contact is a notoriously difficult task, and typically there are significant methodological differences across studies. Second, from an empirical perspective, extension programs often vary widely by crop/region/country in terms of their organizational structure or model, by the human and financial capacity available to carry out their responsibilities within that model, and by the appropriateness and financial feasibility of technologies and practices available to the agents for promotion to farmers.

A recent study using panel household data from Zimbabwe across 4 years enables the authors to apply 'best practice' impact evaluation methodologies, and thus to control for potential endogeneity of agricultural extension at the household and village level (Owens et al, 2003). They find that one or two visits by an extension agent significantly improved crop productivity by 15% (even when controlling for 'farmer ability'). However, their results also caution against extrapolating too far from the impact results based on one year of data, especially if that one year is not a 'normal' year in terms of climate and prices. For example, when they looked at year-by-year findings using cross-sections, they found that extension visits in non-drought years had a positive and significant effect on crop productivity, while 1-2 extension visits in drought years had a negative effect, while 3+ visits had a positive effect.[19]

The results of existing studies of the impact of agricultural extension in Mozambique are mixed. Walker et al (2004) used TIA data to run a cross-sectional multivariate regression of crop income on many of the household and community variables that we use below. They found that neither household access to agricultural extension nor community-level presence of extension visits had a significant effect on crop income (and the sign of the household agricultural extension term was negative). They concluded that agricultural extension impact is constrained due to lack of location-specific adapted technologies and/or household-level constraints on access to existing technologies. By contrast, another study used the same TIA02 data on crop income but found a significant effect of 8% on crop income (World Bank, 2005), most likely because they had a much smaller number of controls relative to Walker et al (and their adjusted R-squared was only 0.24, compared with Walker's 0.50). A more recent study (ECON Analysis, 2005) collected its own survey data (in 2004) and found a positive and significant effect of agricultural extension on household crop income. However, neither the Walker nor the ECON Analysis studies addressed the potential endogeneity of household receipt of extension, and the ECON study's sampling procedures appear to be highly problematic.[20]

The TIA data show a positive correlation between extension access and household income (Table 3). However, as in the case of road density, we have to consider the challenging methodological issue of the direction of causality – are extension workers targeting the wealthier farmers (who would tend to have higher crop income), or does the extension advice result in higher incomes for households which meet with an extension agent? There is considerable evidence from other developing countries that extension is often targeted to wealthier farmers, often for a variety of reasons. First, if extension programs target the most favorable regions in terms of agroecological potential and/or market access, then households in those regions will likely be wealthier (and have higher crop income) than households from other regions. Second, even within a given region, if wealthier farmers are more likely to live closer to accessible roads,

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[19] Owen et al's (2003) explanation for this is that in that year in question, the drought hit in the middle of the growing season, thus farmers who had only received 1-2 visits at the beginning of the season had followed extensionists' advice to apply fertilizer – but then when the drought hit, they had higher input costs than other farmers yet similar yields (due to the drought). However, farmers who received 3+ visits (and thus received at least one visit later in the season, after the drought had already taken hold) were able to follow the advice of extensionists to make adjustments to their usual crop management routine so as to prepare for the inevitability of lower yields.

[20] The sampling for the ECON study appears to be quite problematic for the purposes of evaluation, in our opinion, given that the prevalence of household receipt of extension advice in Nampula (60%) in the ECON survey in 2004 was four times higher than the rate found by TIA (16%) just two years before in 2002. If such a big improvement in extension access in Nampula occurred, it could not have come from an increase in expenditure for government extension, given that PROAGRI spending dominated the MINAG budget, that only about 50% of PROAGRI expenditures went to provinces in 2002-2003, and that PROAGRI expenditure on extension fell from 7.6% of their budget in 2002 to 2.2% in 2004 (Table 4.10 from World Bank, 2008). Thus, unless there is evidence of a massive increase in NGO extension activity in 2003-2004, the ECON survey results do not appear to be credible relative to those from TIA. This suggests that the ECON survey's selection of districts and villages was not random and/or village-level samples of households were not random – either of which could substantially bias the statistical results.

extension agents with severe transportation budget constraints may target wealthier farmers simply because it costs less in terms of time and fuel to reach them. Third, targeting extension to wealthier farmers is sometimes an intentional strategic decision of the extension program, as wealthier farmers are more likely to be able to adopt the extension recommendations, and may intentionally be used as 'model' or 'demonstration' farmers, which can play a valuable role serving as a local example for other farmers who are less able to take the initial risk of adopting a new technology or technique. Our intention here in discussing these issues is not to judge the efficiency or equity of targeting public goods to wealthier farmers – it is simply to recognize that if public goods are not targeted randomly across households, then evaluating the impacts of these public goods must account for the inherent statistical challenges posed by non-random distribution.

Although our regression model below of the determinants of crop income contains many of the same variables used by Walker et al (2004), we have the advantage of panel data with which to analyze the impact of extension. The TIA panel data enables us to control for initial levels of not only observable wealth (landholding, livestock, human capital, etc) but also unobservable, time-invariant household characteristics such as soil quality, social capital connections, farm management skill, etc., all of which might be correlated with both extension access and higher crop income.

The TIA survey instruments asked households in both 2002 and 2005 if they received an extension agent within the previous 12 months. Unfortunately, the question does not ask the respondent to distinguish between different types of extension agents – such as those from government, NGOs, and firms.[21] TIA data show that 13 percent of households received extension in 2002, and 14.8 percent in 2005 (Table 3). However, the percent of households which receive extension advice in a given year may not tell us the 'extension coverage' over the 3-year panel period, if different households are visited in the two years, and if the benefits of an extension visit are not exclusive to the year of the visit. That is, if an extension visit in 2002 results in a farmer adopting a new crop management technique, or a new input purchased from a private input dealer or output firm, then it is possible that the farmer will continue with that new technique or input in following years, regardless of whether the farmer receives another extension visit.[22] The TIA panel data show that 26% of households received an extension visit in either or both years,[23] while 74% did not receive an agent in either year.

[21] The TIA05 questionnaire asked the respondent about the content of the extension advice (i.e. was the extension visit related to crop production, livestock, etc).

[22] Whether or not an extension visit results in a change in the farmers' input decisions in subsequent years depends upon the nature of the technology and whether or not the extension agent offered a subsidy for adoption in the first year which is not offered in subsequent years.

[23] The TIA panel data show that 10% of households received an extension visit in 2002 yet none in 2005, 12 percent received a visit in 2005 but not in 2002, 3.6% received a visit in both 2002 and 2005.

Table 3 Rural household farm input use and access to public goods, TIA 2002 and 2005

Quintiles of total net HH income/AE, 2002 & 2005	HH used animal traction (%)		HH used chemical fertilizer (%)		HH has non-manual irrigation system (%)[a]		HH hired temporary labor (%)	
	2002	2005	2002	2005	2002	2005	2002	2005
1-low	8.4	6.2	1.5	1.7	0.4	0.4	4.6	6.5
2	10.3	7.6	3.1	3.0	1.1	0.7	8.3	9.5
3-mid	9.1	7.6	2.3	4.0	1.7	1.1	13.9	14.6
4	9.7	9.0	4.2	3.1	0.7	1.3	18.5	21.1
5-high	18.6	16.1	7.5	6.7	2.2	2.0	32.2	36.3
total	11.2	9.3	3.7	3.7	1.2	1.1	15.5	17.6

Quintiles of total net HH income/AE, 2002 & 2005	Total road density (km roads per 1000 km^2)[b]		HH received price information (%)		HH received extension visit (%)		HH belongs to farm association (%)	
	2002	2005	2002	2005	2002	2005	2002	2005
1-low	48.5	49.1	24.0	28.0	8.7	10.5	1.5	4.1
2	48.9	49.0	29.5	36.6	12.3	11.0	2.4	4.6
3-mid	50.1	50.7	36.8	42.3	14.1	14.6	5.1	7.0
4	51.1	50.2	41.6	46.2	15.8	18.8	3.7	8.2
5-high	53.1	52.8	40.7	48.4	16.8	18.8	5.7	8.0
total	50.3	50.3	34.5	40.3	13.5	14.8	3.7	6.4

Source: TIA02 & TIA05. Notes: a) Non-manual irrigation = HH owns pump equipment or gravity irrigation system; b) Total roads is a district-level measure of both primary (year-round) and secondary roads

The benefits to crop income related to a visit by an extension agent in rural Mozambique will likely derive not from free fertilizer or improved seeds a farmer receives from the agent, but rather from information from the agent regarding crop management, improved inputs and techniques, etc. If we assume that a farmer who receives this information in 2002 proceeds to follow it in 2002 and 2005, then we would not expect that farmer to lose the 'benefit' of the 2002 visit over time (i.e. by 2005), in the event that the extension agent did not visit again in 2005. In other words, because the benefit derived from the visit is assumed to be improved farmer knowledge (a better understanding of how to improve crop production and management), the household would only lose this benefit if for some reason that advice became irrelevant or if the farmer left the household for some reason since 2002. For this reason, we do not construct a variable for the FD model which is the 'change in receipt of extension.' Were we to do so, a household which received extension in 2002 but not 2005 would have a change in extension = -1 – i.e. an expectation that in 2005, the household had a 'reduction in knowledge' relative to 2002. Therefore, we construct an extension variable which is *change in cumulative extension visits from 2002 to 2005*. Note that a household which receives a visit in 2002 but not one in 2005 has a change in cumulative extension visits which equals zero.

An alternative (but not competing) argument could be made that farmers who receive an extension visit might improve their productivity over time as they test the extension recommendations and adjust them for their local situation. To test the proposition that extension promotes farmer learning (and thus improved productivity) over time, we interact the variable *receipt of extension* with the time dummy. This interaction terms captures the potential effect on crop income of learning (over time) from the initial visit. If the farmer uses the recommended crop management technique or input in both 2002 and 2005, it is possible that he as 'learns' how to apply this technique over time, this technique could have a higher return in 2005 than in 2002.[24] In order to differentiate the effects of potentially different extension agents and different farmer financial and cropping situations, we create separate extension variables for tobacco/cotton and non-tobacco/cotton growers.

3.5.2 Market price information

Similar to the knowledge content of agricultural extension messages, basic market price information also has the qualities typically associated with a public good. Once the cost of collecting the market price information is paid and the information is disseminated to buyers, it would be prohibitively costly for the seller of such market price information to try and prevent any given buyer from sharing the information with their neighbors. This is especially true in the case of Mozambique, where the lowest-cost method (cost per household reached) of delivering such information is via radio, in which case, any household which lives within range of public radio broadcasts and owns a radio (or knows someone who does) can access such information, regardless of whether or not they pay for it. Thus, the costs of collecting basic market information would not likely be incurred by a private firm, as they could not be assured of earning revenue sufficient to cover their costs (and make a profit).

Measuring the total net benefit of a system of market price information is very difficult because such information can improve market efficiency (and thus the input and output prices faced by rural farmers) in various ways, some of which are inherently difficult to observe. First, it can lower the entry costs for traders/assemblers, thereby increasing their numbers, which would help reduce the ability of small groups of traders (oligopolies) to collude in such a way as to depress prices paid to farmers below prices which would prevail under a scenario of perfect competition (i.e. costless information for all participants, and large numbers of both buyers and sellers). Second, price information could reduce information asymmetry between farmers and traders about prevailing market prices, and thereby enable farmers to negotiate for higher prices than they would have obtained in the absence of publicly-available market price information (because otherwise, these farmers would incur search costs for price information, which often may be prohibitive).

Third, market price information theoretically enables farmers to better adjust their cropping systems so as to maximize crop income (whether for sale or for home consumption), by improving their expectations regarding future farmgate and retail prices. Responses from TIA05 households to questions regarding the role of market price information in their household's decisions about area cultivated and crop choice suggests that, in fact, receipt of market price information does influence these decisions.[25] For example, among respondents who had received market price information (40% of TIA05 households), 23% said that

[24] This discussion highlights the inherent difficulty in measuring the benefits of the transfer of knowledge and information (which in this case derive from agricultural extension). If a household adopts fertilizer due in part to extension advice, and a regression controls for both extension advice and fertilizer use, then the extension advice coefficient will not necessarily reflect the 'change in crop income' due to the advice, assuming that fertilizer use has a positive and significant partial effect on crop income. Future research on extension impacts could focus on the productivity impacts of specific inputs and management techniques, and the extension impact could be derived from the improved probability of farmer use of such inputs and techniques.

[25] The first question asked: How relevant was receipt of market price information to your household's decision regarding cultivated area? The second question asked: How relevant was receipt of market price information to your household's decision regarding the crops you planted?

receipt of price information was “highly relevant” to their decision regarding cultivated area, while 27% said that the information was “moderately relevant” (Table 4). With respect to crop choice, 22% said that receipt of price information was “highly relevant’ to their decision regarding which crops to plant, while 28% said that the information was “moderately relevant”.

Table 4 Respondent opinion of relevance of receipt of market price information for household decision regarding cultivated area and crop choice, 2005

Response of households which had received market price information in 2005	How relevant was receipt of market price information to your household's decision regarding cultivated area?	How relevant was receipt of market price information to your household's decision regarding which crops to plant?
	---------- % of households -----------	
Highly relevant	23.0	21.5
Moderately relevant	28.0	27.7
A little relevant	21.8	20.0
Not relevant	22.5	26.5
Don't know	4.7	4.4
	100.0	100.0

Source: TIA05

We include the variable *household received market price information* in our model, acknowledging that the available data and our chosen method do not enable us to specifically attribute increases in crop income due to receipt of market price information to any one of the scenarios given above. While market price information is a ‘knowledge’ variable similar to receipt of agricultural extension, a key difference for modeling purposes is that market price information received in 2002 is not likely to be of much use in 2005 because market price information tends to be very time-specific. Thus, we treat ‘receipt of market price information’ as a change variable similar to other inputs.

The potential for household access to market price information is relatively widespread in rural Mozambique, as 91.8% of TIA 2005 households lived in a village in which at least one respondent received market price information (either via radio, newspaper, an extension agent, a farmer association, or another source) (Table 5). However, the actual percentage of TIA households which report receipt of market price information is considerably less (40% in 2005, up from 34% in 2002). We will discuss the potential household constraints to accessing price information in more detail in the results section.

There are several potential econometric concerns regarding the potential endogeneity of receipt of market price information to crop income. First, while receipt of price information might be correlated with household wealth (which also is assumed to be positively correlated with crop income), we control for household wealth through observables such as landholding and farm equipment value. Second, receipt of market price information might be correlated with unobserved household characteristics such as the farmer’s management skill, entrepreneurial ability, social ties, etc., which are unlikely to vary during the panel period. The FD model controls for this source of endogeneity.

Table 5 Household and village access to market price information, rural Mozambique, 2005

Source	% of all TIA05 HHs which live in village in which at least one HH received price information (from this source)	% of all TIA05 HHs which received market price information (by source)	Among TIA05 HHs which received price information: % of HHs which received market price information from a given source[1]
	-------- % of TIA05 households	---------	
Radio	81.7	29.9	74.3
Extension agent	31.4	5.7	14.1
NGO	19.6	3.3	8.3
Newspaper	23.0	3.6	8.9
Farmer association	20.2	3.5	8.7
Other (neighbor)	42.8	8.9	22.2
Any source	91.9	40.3	

Source: TIA05. Notes: 1) the third column does not add up to 100% because some households received market price information from more than one source.

Third, receipt of price information could be endogenous to crop income if some farmers decided to incur costs of searching for market price information only after first discovering that they were going to enjoy an abundant harvest. Because the TIA instrument does not ask the farmer *when* he/she received price information, we do not know if the farmer decided to search for price information only after first discovering that they would have a bountiful harvest and therefore have some surplus crop production to sell. Thus, for some observations, it is possible that 'receiving price information' would be a function of crop income (i.e. associated with high yields) and/or be simultaneously determined, and thus be endogenous if used as an independent variable. However, this problem is not likely to be widespread considering that 75% of households which received price information in 2005 received it via radio. Thus, households which receive price information via radio would very likely have received it throughout the entire year, and therefore prior to planting and/or harvest. In addition, another source of market price information is extension, which is already included in the model.

The way in which we constructed the dependent variable 'crop income' should enable us to capture various ways in which market price information could potentially improve crop income. First, because receipt of market price information could improve the sales price for a food crop (whose price is reported by SIMA) sold by a household which received market price information, we valued these sold food crops at the household-reported sale price. Second, receipt of market price information could improve total household crop income (our dependent variable) through cropping choices based on better price information. Third, receipt of market price information (which is at the retail level) throughout the growing season could potentially help net buyer households to better anticipate retail food prices in the lean season, and thus make better household-specific decisions regarding how much food to retain. Thus, by valuing retained food crop production at retail prices, while sales are valued at sale (farmgate) prices, we may capture the effect of market price information on a household's decision regarding how much of a given food crop to retain.

3.5.3 Farmer associations

Household membership in a farmers' association is considered by economists to be a 'club good', in which benefits are obtained through collective action but accrue only to members (i.e. the club can exclude non-members from enjoying the benefits). A typical example would be a cooperative in which members join together to obtain financing and better prices for inputs and outputs (both by reducing transaction costs and offering enough volume – as buyers or sellers - to give them more market power than they would have as individual farmers). Outgrower arrangements and farmer cooperatives are two such forms of farmer associations that have been tried in Africa, with varying levels of success (Dorward, Kydd, and Poulton, 1998; Bingen et al, 2003).

Some have argued that farmer associations provide a key to improving farmer access to new and improved technology (inputs such as improved seed, fertilizer, animal traction; and management practices) and output markets. Perhaps with these goals in mind, some farmer associations in Mozambique have received financial assistance from the government and/or training assistance provided by non-profit organizations such as CLUSA and World Vision. Rural household participation in farmer associations was 6.4% in 2005, though this percentage varied widely by province, ranging from 3.6% in Inhambane to 17.6% in Maputo Province (Mather et al, 2008). Participation increased from 3.9 to 6.4% nationally from 2002 to 2005, although a few provinces accounted for much of this increase: Niassa (3.2 to 12.9%), Gaza (3.5 to 11.2%) and Maputo Province (12.4 to 17.6%) (ibid, 2008). Similar to the other public goods, the TIA data show a positive correlation between membership in a farmers' association and household income. Yet, such a correlation cannot tell us the direction of causality between membership and income – that is, whether joining a farmer association results in higher income (or not), or whether wealthier households are more likely to join farmer associations to begin with. Our FD model enables us to control for initial household wealth levels, and thus test whether or not membership in a farmer association has a significant effect on crop income.

Our model variable for 'farm association membership' takes the value=1 if the household enjoyed membership in 2002 (=0 otherwise), and takes the value=1 if in 2005 (=0 otherwise). In the FD model, the estimated coefficient is of the 'change in farm association membership'. We assume that the benefits which accrue to farm association members (such as improved prices for inputs/outputs, improved access to credit, etc) is not likely to be of much use in 2005.[26] Thus, by modeling farm association as a 'change' variable, we expect that a household which gains membership in 2005 (without membership in 2002) would enjoy an increase in crop income, while a household which previously enjoyed membership in 2002 but loses it in 2005 would see a decrease in crop income.

3.5.4 Market access

Market access plays an important role in fostering market development and household market participation by driving down the costs of trade across villages, districts, provinces, and countries. Thus, rural roads are a classic public good because the costs of excluding potential users of the road are often prohibitive. Road infrastructure in the district and at the village-level is expected to influence rural household crop income because transport costs and road

[26] This assumption would not be appropriate if the benefit from farmer association membership were access to a new technology in 2002 (such as an improved management technique), which the farmer could continue to use in 2005 even if they were no longer a member.

reliability affect the input and output prices faced by farmers in the village, as well as the extent of market access (i.e. number of input sellers and output buyers). While prices are not the only factors which determine farm participation in input and output markets,[27] we would expect farmers who live in villages which are relatively close to a good road would face lower input costs and higher output prices and thus be more likely to participate in input (fertilizer) and output (cash crops, maize, etc) markets – both of which are integral to intensive agricultural production.

Our measures of market access include both district- and village-level variables which proxy for market access. The district-level variables include two measures of road density: *kilometers of roads per thousand square kilometers* and *kilometers of roads per thousand people.* The roads data is from the Administração Nacional de Estradas, and the rural population data is from CAP in 2000. While we think that the road data was measured in 2002, this could not be confirmed.[28] We expect both of these variables to be positively correlated with crop income, as higher road density should be associated with lower input costs and higher output prices for farmers in either 2002 or 2005. While there are good reasons to think that higher road density may be associated with higher crop incomes, road construction in many countries has been shown to have been targeted to areas which are wealthier and/or of higher agroecological potential. In order to test for the direction of causality between road density and crop income, we would need observations of road density for more than one point in time – which we have unfortunately not been able to find to date. Because the road density variable we have is only for one year, this variable is time-invariant and thus drops out of the first-difference model. Therefore, we only consider this variable in a pooled OLS model, which we run specifically to investigate the effect of road infrastructure (one of our proxies for market access) on crop income.

The village-level market access proxies include *distance from village to the district capital, 2002, distance from village to the nearest public transport, 2002* (in kilometers), and *distance from village to the nearest paved road, 2002* (in kilometers). The first two variables were measured by the TIA 2002 community survey, while the latter was constructed with TIA village coordinates and a GIS map of paved roads (Nielson, 2009). Like the road density variables, none of these *distance* variables vary over time, thus they are differenced out of the FD model. Thus, we only include these variables in a pooled OLS model. Controlling for district-level road density and average district fixed effects, we would expect that expect the coefficients on these village-level distance variables to be negative, as farmers in remote areas theoretically should face higher input prices and lower output prices. One caveat for using these variables to proxy for market access is that the relevant market for some farmers in the north is the export market to neighboring countries, which may be in the opposite direction from the nearest primary road (which tend to be closer to large urban areas, which happen to be further from the higher agroecological potential zones), as well as the district capital.

[27] Other household-specific variables which influence household decisions regarding participation in input (fertilizer) or output markets would include credit availability, asset levels, risk preferences, etc; village-specific variables would include agroecological potential.

[28] This GIS road infrastructure data was obtained from the National Road Administration by an IFPRI researcher, but the ministry officials were unsure of the year of the data.

4. Estimation results

4.1 Estimation

Because of the wide range of agroecologies across Mozambique, we anticipate that the returns to both household assets and public goods may differ by region, thus we estimate four regressions: one using the national TIA sample, and one regression for each region - north, center, and south. The means of the variables used in our FD model are shown in Table 6, while the values of these variables in 2002 and 2005 are found in Appendix Table 1. Because the TIA uses complex sampling (stratification and clustering), statistical analysis at the provincial level or higher requires the use of complex sampling weights. We estimate the following regressions using STATA's survey sampling weights.[29] These weights are adjusted for panel attrition bias using a correction factor developed by Mather and Donovan (2007).

Of the total sample of TIA panel households (n=4,105), we drop cases which have missing data for crop income in one or both years (n=60), most likely due to lack of planting that year. We also drop cases which are households for which area cultivated (and total area) is either zero or missing in either 2002 or 2005 (n=136). Households in these two groups are not appropriate for our analysis because they apparently were not farmers in both of the two panel years.

After dropping these potential outlying cases, we nevertheless encountered a statistical challenge in that the dependent variable *change in ln(net crop income)* still has some very large positive and negative values. This occurs because there are some households which had zero (or close to zero) crop income in 2002, but had reasonable (positive) crop income in 2005, thus the change in crop income for such a household is a very large positive number. Likewise, a household with reasonable crop income in 2002 but zero (or very low) crop income in 2005 would have a change in crop income which was very large and negative. The result is that the distribution of the dependent variable, even when transformed by the natural log (which usually addresses problems of high skewness), has some very large positive and negative values.

The problem with including such cases is that OLS coefficients are quite sensitive to outlying observations. We address the problem by first running our national and regional regressions with and without the most egregious outlying cases (n=197).[30] These regressions demonstrate that the outlying cases do have a rather large influence on the coefficients. We therefore use the regressions without the outlying cases for inference (Table 7), and show the regression which includes the outliers in the appendix (Appendix Table 2).

[29] When we apply sampling weights to our OLS model, STATA automatically applies a heteroskedasticity correction to the standard errors.

[30] We define outlying cases as those which have 'excessive' leverage on the distribution of the dependent variable (using the Stata command *lv*) and are considered to be considerably outside of the normal distribution. Of the outlying cases, n=121 are from the south, n=51 from the center, and n=7 from the north.

Table 6 Means of variables in first-difference model of net household crop income, 2002-2005

Household and village covariates (variables without a year indication are changes in the variable from 2002-2005)	National (A)	North (B)	Center (C)	South (D)
Δ ln(Total net crop income)	-0.187	-0.281	0.029	-0.104
Δ district drought days	17.4	21.8	8.0	12.3
Δ % HHs in village which experienced extensive flooding	-0.087	-0.051	-0.164	-0.127
Δ % of HHs in village with extensive crop disease	0.208	0.196	0.246	0.206
1=cassava production imputed in 2002	0.280	0.393	0.086	0.093
1=HH headed by non-widow female in 2002 * TIME	0.148	0.154	0.131	0.145
1=HH headed by widow in 2002 * TIME	0.091	0.066	0.111	0.165
Δ no. of chronically ill PA adults	0.025	0.028	0.012	0.031
Head's age, 2002 (years) * TIME	41.9	39.6	43.1	49.2
Head's age squared, 2002 (years) * TIME	1973	1756	2088	2658
Head's education, 2002 (years) * TIME	2.2	2.1	2.3	2.3
Δ max education (years)	0.415	0.342	0.465	0.631
Δ no. of PA adults (age 15-59) in agriculture	0.096	0.113	0.178	-0.076
Δ no. of PA adults in agriculture squared	0.852	0.901	1.579	-0.269
Δ no. of children age 0-4	-0.037	-0.049	-0.060	0.040
Δ no. of children age 5-14	0.219	0.231	0.244	0.139
Δ no. of adults age 60+	0.037	0.041	0.022	0.044
Δ ln(total area (ha))	0.107	0.191	0.060	-0.154
Δ ln(total area squared (ha))	-0.015	0.000	0.049	-0.156
Δ ln(farm equipment value)	0.510	0.702	0.288	0.062
Δ 1=HH uses animal traction	-0.027		-0.078	-0.070
Δ ln(Value of fertilizer used) ('05 contos)	0.062	0.067	0.089	0.008
Δ ln(Value of fertilizer used squared) ('05 contos)	-14.1	-14.0	-14.0	-14.4
Δ no. of temporary laborers hired	0.111	0.023	0.356	0.137
Δ no. of temporary laborers hired, squared	-59.192	-97.758	8.119	2.353
Δ no. of permanent laborers hired	0.007	0.004	0.003	0.025
Δ no. of permanent laborers hired, squared	0.056	-0.036	0.249	0.159
Δ 1=HH grows tobacco	-0.013	-0.013	-0.014	
Δ 1=HH grows cotton	-0.017	-0.031	0.010	
Δ 1=HH has skilled nonfarm wage income	0.023	0.021	0.030	0.024
Δ 1=HH has MSE activity, NRE high (fishing/charcoal)	0.002	0.004	-0.002	-0.005
Δ 1=HH has MSE activity, non-NRE low cost activity	0.057	0.066	0.038	0.046
Δ 1=HH has MSE activity, non-NRE high cost activity	0.042	0.062	0.011	0.005
Δ 1=HH received remittances	0.038	0.037	0.037	0.042
Δ 1=HH member of farm association	0.029	0.029	0.018	0.043
Δ cumulative # of extension visits to non-tobacco/cotton	0.131	0.130	0.126	0.138
HH received extension visit, non-tob/cotton HH, 2002 *	0.112	0.106	0.154	0.080
Δ cumulative # of extension visits to tobacco/cotton HH	0.027	0.030	0.040	
HH received extension visit, tobacco/cotton HH, 2002 *	0.027	0.033	0.031	
Δ 1=HH received price information	0.055	0.031	0.022	0.186
Number of observations	3730	1678	1098	954

Source: TIA 2002, TIA 2005

4.2 Agro-ecological and district-level factors

We begin by considering variables which measure weather- and disease-related shocks at the district- and village-levels. First, the coefficients on *district days of drought, village flood,* and *village crop disease* in the national sample are not significant, though those of the first two variables are negative as expected (Table 7).[31] In the south, an additional *district day of drought* during the principal growing season results in a significant 5.5% loss in crop income, on average, while an additional day of drought in the north results in a 2.0% loss in crop income. The coefficient on days of drought in the center is positive but insignificant.[32] None of the coefficients on *village flood* are significant, though all have the expected negative sign. Surprisingly, the coefficient on the dummy for *village crop disease* is positive in the center and south, and significant in the center, which merits further inquiry.[33]

Second, we note that many of the district*TIME dummy coefficients are significant, although they are not presented in the tables. The interpretation of any given significant district*TIME coefficient is that the change in crop income over time in the given district was significantly higher than that of the base district, after controlling for observable household and village characteristics.[34] Therefore, these district intercept shifters capture the average effect of unobserved district-specific factors on household income. These unobserved factors include not only agro-ecological conditions but also input and output prices, which are similar among households within a district. Although the interpretation of district coefficients is inherently vague (i.e. we cannot determine specifically which factor(s) causes the district coefficient to be significant), they are nevertheless valuable for improving the coefficient estimates on the household-level variables in the model.

The coefficient on the dummy for 2002 cassava imputation is significant and suggests that our imputation of cassava production for some households in 2002 resulted in 10% higher income in 2002 relative to 2005. While this result may suggest that our imputation overestimated cassava production in 2002, most of the imputation was for Nampula households, a province which on average saw a large decline in crop income on average from 2002 to 2005.

[31] Although all of the time-varying variables in the FD model represent a 'change in X', the coefficient interpretation is the same as for a household fixed effect model (which does not use differenced variables). For this reason, we refer to the coefficient on a variable such as 'change in village flood' simply as 'village flood'.

[32] Our measure of district-level change in days of drought may be a poor predictor of changes in crop income for several reasons. First, changes in drought at the village level may vary considerably from our district-level measure. Second, drought is likely to result in lower crop yields, yet higher crop prices. Thus, days of drought may be a better predictor of crop production or crop yield. The district dummies will pick up the average effect of drought on both yield and prices (and the average effect of other unobserved factors).

[33] Within a context of low education and extension access levels, farmer-identified occurrence of 'disease pressure' is sometimes a problematic measurement because of the potential for misdiagnosis of the actual agronomic factor causing a yield loss, as well as the potential for only better-educated and/or experienced farmers to identify yield loss which is in fact caused by disease pressure (if better educated farmers tend to have higher crop income, then a dummy for 'disease pressure' might be positive if such a diagnosis is only reported by villages where crop income tends to be higher regardless of disease pressure).

[34] We chose the base district by first computing the mean change in crop income by district for all 80 districts, then ranking the district means, then finding the median value among the 80 districts and making that district the base. The choice of the base district does not affect household or village coefficients – only the other district dummies and district-level variables such as road density and days of drought.

4.3 Household assets

The combination of a positive coefficient on land and a negative coefficient on land squared indicate that landholding exhibits diminishing marginal returns, ceteris paribus (i.e. holding the level of other variables constant). This means that crop income increases in landholding at a decreasing rate. In other words, crop income increases as a farmer increases his landholding up until a certain level of landholding, after which additional increases in land – holding other factors constant – will not give a positive marginal return in crop income unless other inputs are also increased (such as labor, fertilizer, etc).

The results show that a 1% increase in *total landholding* significantly increases crop income by 0.38% in the north, 0.43% in the center and 0.24% in the south (Table 7).[35] In other words, a 5% increase in total landholding in the north increases crop income by 1.9%. These regional findings are generally consistent with variation in agroecological potential across the three regions, as the center and north regions contain some medium and high potential areas, while the south is entirely low and low-medium potential.

An obvious policy implication from this result would be to promote improved land access for rural households. Walker et al (2004) found that communities in which leaders said that it was easy to obtain more land in 2002 had significantly higher net crop and livestock income. These communities represented 72% of the TIA02 households, and 85% of TIA02 respondents said that 'it is not difficult to access additional land in their village'. Given the sizeable marginal returns to increases in *landholding* found here, this beg the question of why households do not increase their landholdings if it is easy to do so, and why Mozambique still has very few rural households which farm more than 10 hectares. Even in those parts of Mozambique where expanded access to land is feasible, the limited availability of animal traction often prevents its exploitation. A significant barrier to animal traction in the north is trypanosomiasis, which is spread by the tsetse fly. In addition, use of animal traction requires either a large fixed investment (for ownership) or financing for rental, yet the difficulty of both are compounded by the virtual absence of rural credit.

[35] The regression results report the actual change in the natural log of the dependent variable, not the percentage change; note that the actual percentage change in the dependent variable needs to be adjusted since the logarithmic transformation approximates small changes (those under 20%) well but larger changes less well (Wooldridge, 2002). The necessary adjustment is as follows: % change in y = [exp(B) – 1].

Table 7 First Difference regression of rural household crop income determinants, 2002-2005

Household and village covariates (variables without a year indication are changes in the variable from 2002-2005)	Change in ln(Household total net crop income)			
	National (A)	North (B)	Center (C)	South (D)
Δ district drought days	-0.008	-0.020*	0.007	-0.055**
	(1.40)	(2.53)	(0.82)	(19.85)
Δ % HHs in village which experienced extensive flooding	-0.152	-0.121	-0.129	-0.299
	(1.32)	(1.02)	(0.46)	(0.81)
Δ % of HHs in village with extensive crop disease	0.036	-0.041	0.150+	0.202
	(0.60)	(0.55)	(1.67)	(1.17)
1=cassava production imputed in 2002	-0.085+	-0.102+	0.112	0.023
	(1.69)	(1.80)	(0.67)	(0.18)
1=HH headed by non-widow female in 2002 * TIME	-0.008	-0.087	0.099	0.151
	(0.12)	(1.26)	(0.48)	(0.99)
1=HH headed by widow in 2002 * TIME	0.246**	0.058	0.334*	0.418**
	(2.75)	(0.35)	(2.31)	(4.76)
Δ no. of chronically ill PA adults	-0.015	0.107	-0.095	-0.259
	(0.19)	(0.90)	(0.60)	(1.60)
Head's age, 2002 (years) * TIME	-0.009	0	-0.011	-0.016
	(1.05)	(0.01)	(0.47)	(0.63)
Head's age squared, 2002 (years) * TIME	0	0	0	0
	(0.71)	(0.24)	(0.17)	(0.84)
Head's education, 2002 (years) * TIME	0.005	0.002	0.009	-0.001
	(0.38)	(0.12)	(0.24)	(0.02)
Δ max education (years)	0.006	0.019	-0.03	-0.016
	(0.46)	(1.36)	(0.92)	(0.40)
Δ no. of PA adults (age 15-59) in agriculture	0.074	0.13	-0.003	0.136
	(1.53)	(1.66)	(0.04)	(1.72)
Δ no. of PA adults in agriculture squared	-0.002	-0.013	0.008	-0.006
	(0.36)	(1.39)	(1.00)	(0.62)
Δ no. of children age 0-4	0.056*	0.037	0.107*	0.031
	(2.09)	(1.02)	(2.56)	(0.34)
Δ no. of children age 5-14	0.039*	0.060**	0.009	-0.029
	(2.07)	(2.88)	(0.18)	(0.45)
Δ no. of adults age 60+	-0.087	-0.121	-0.088	0.066
	(1.40)	(1.25)	(0.51)	(0.64)
Δ ln(total area (ha))	0.338**	0.345**	0.447**	0.257**
	(10.06)	(7.44)	(3.64)	(4.21)
Δ ln(total area squared (ha))	-0.035	-0.036	-0.072	-0.03
	(1.27)	(0.87)	(0.80)	(0.75)
Δ ln(farm equipment value)	0.018*	0.018	0.016	0.025*
	(2.34)	(1.62)	(1.09)	(2.43)
Δ 1=HH uses animal traction	0.023		0.296*	-0.13
	(0.19)		(2.12)	(0.81)
Δ ln(Value of fertilizer used) ('05 contos)	0.03	0.011	0.062+	-0.114
	(1.30)	(0.34)	(1.95)	(1.72)
Δ ln(Value of fertilizer used squared) ('05 contos)	0.009	0.024**	-0.026	0.047
	(0.98)	(2.67)	(0.96)	(1.18)

Δ no. of temporary laborers hired	0.016*	0.012	0.059**	0.013
	(2.05)	(1.54)	(3.18)	(0.49)
Δ no. of temporary laborers hired, squared	-0.000+	0	-0.001*	0
	(1.79)	(1.36)	(2.01)	(0.20)
Δ no. of permanent laborers hired	0.073	0.031	0.042	0.329
	(0.97)	(0.30)	(0.37)	(1.65)
Δ no. of permanent laborers hired, squared	-0.003	-0.001	-0.002	-0.023
	(0.70)	(0.13)	(0.27)	(0.79)
Δ 1=HH grows tobacco	0.315*	0.228	0.443+	
	(2.18)	(1.28)	(1.81)	
Δ 1=HH grows cotton	0.471**	0.360*	1.083+	
	(2.70)	(2.46)	(1.83)	
Δ 1=HH has skilled nonfarm wage income	-0.148	-0.099	-0.337+	0.023
	(1.51)	(0.65)	(1.86)	(0.14)
Δ 1=HH has MSE activity, NRE high (fishing/charcoal)	0.252**	0.217*	0.344*	0.226
	(2.95)	(2.03)	(2.18)	(0.66)
Δ 1=HH has MSE activity, non-NRE low cost activity	0.089*	0.077	0.117	0.077
	(2.05)	(1.48)	(1.22)	(0.77)
Δ 1=HH has MSE activity, non-NRE high cost activity	0.165**	0.213**	0.139	-0.014
	(3.11)	(3.08)	(1.20)	(0.10)
Δ 1=HH received remittances	-0.017	0.004	-0.032	-0.065
	(0.33)	(0.07)	(0.32)	(0.46)
Δ 1=HH member of farm association	0.157+	0.203*	0.189	0.072
	(1.93)	(2.18)	(0.85)	(0.35)
Δ cumulative # of extension visits to non-tobacco/cotton HH	0.041	-0.013	0.025	0.211
	(0.49)	(0.15)	(0.16)	(0.70)
HH received extension visit, non-tob/cotton HH, 2002 * TIME	0.038	-0.177	0.257	0.578*
	(0.40)	(1.49)	(1.35)	(2.68)
Δ cumulative # of extension visits to tobacco/cotton HH	0.259*	0.307*	0.032	
	(2.46)	(2.47)	(0.13)	
HH received extension visit, tobacco/cotton HH, 2002 * TIME	0.232+	0.107	0.549**	
	(1.87)	(0.70)	(2.94)	
Δ 1=HH received price information	0.113*	0.055	0.199+	0.273*
	(2.45)	(0.97)	(1.99)	(2.63)
Δ Constant	0.118	0.617+	-0.347	0.734
	(0.40)	(1.79)	(0.37)	(1.08)
District X time dummies	Yes	Yes	Yes	Yes
Number of observations	3730	1678	1098	954
R-squared	0.20	0.22	0.19	0.24

Source: TIA 2002, TIA 2005

Notes: *** Significant at the 1% level; ** Significant at the 5% level; + Significant at the 10% level. Numbers in parentheses are absolute t-ratios computed with linearized standard errors which account for complex sampling using STATA.

Given the importance of landholding in crop income, we further investigate the role of animal traction use in determining total landholding. Previous research on landholding access in Northern Mozambique has found that the principal determinants used by such village authorities for land allocation are typically the household's size (food consumption requirements) and ability to cultivate (adult labor and/or access to animal traction) (Marrule, 1998). Other factors which have a significant effect on landholding include social connections to village leadership and the political strength of the household's lineage, both of which are a function of the predominant lineage system in the area (matrilineal or patrilineal) (ibid, 1998). We ran a panel FD regression of the change in the log of landholding on household assets (PA adults in agriculture, tropical livestock units), livelihood choices, other household characteristics which might influence landholding (husband is native of village, wife is native of village, number of children, number of elderly adults, etc), and animal traction use. The results showed that adoption of animal traction use increases total landholding by 13.8% in the center and 18.5% in the south, and increases total area cultivated to annual crops by 17% in the center and 22.7% in the south. These results suggest that promotion of animal traction could help smallholders increase their landholding and thus crop incomes. Further research is warranted to investigate the determinants of land access in general, as well as the determinants of animal traction ownership and rental.

The return to farm equipment value is positive in each region, and is significant in the south, where a 10% increase in farm equipment value increases crop income by 2.5%. The coefficient in the north is very nearly significant (p=0.108), and indicates that a 10% increase in farm equipment value increases crop income by 1.8%. We also separated this equipment into those assets more related to production (ploughs, sprayers, pumps, threshers, etc.) and those more related to marketing (bicycle, cart, motorcycle, truck, etc) but surprisingly did not find significant effects from changes in either of these two asset groups.

None of the coefficients on *prime-age adults engaged in agriculture* (i.e. proxy for actual family labor used) are significant, suggesting that this variable may not be a good proxy for actual labor use in these areas. A more flexible functional form (such as a translog) might also be considered, in which land and labor are interacted. The coefficients on *number of temporary hired laborers* are positive in each region, and significant in the center, where adding an additional temporary laborer increases crop income by 5.7%. The coefficients on *number of permanent hired laborers* are insignificant in each region, though are all positive as expected. The coefficient for the south region is relatively close to significant (p=0.12) and suggests a rather large effect on crop income (38%) from an additional permanent hired laborer.

With respect to human capital, neither *head's education 2002*TIME* nor *maximum education in the household* has a significant effect on crop income. The policy implication of this result is not that education has no role to play in fostering agricultural growth, because evidence from other countries shows that education plays an important role in fostering adoption of improved inputs and management techniques (Foster and Rosenzweig, 1995). Rather, it is more likely that this results shows that returns to education for crop income in rural Mozambique are currently minimal, perhaps because positive returns are generally found in an environment in which improved inputs are readily available and higher-value crops are grown by many farmers. For example, when such analysis is restricted to crops whose production value is quite sensitive to crop management and input use (tobacco), positive and significant returns to education are found: Boughton et al (2007) found that head's education significantly improves tobacco sales revenue among tobacco growers in central and northern

Mozambique. They explain this result by noting that tobacco product quality is highly sensitive to crop management techniques, and prices paid by tobacco companies vary dramatically by product quality.

With respect to indicators of household vulnerability, the coefficients on the dummies for *non-widow female-headed household (2002)*time* are insignificant, though those for *widow-headed households (2002)*time* are surprisingly positive and significant in both the center and the south. The results show that widow-headed households in the Center and South enjoyed a 40% and 50% increase in crop income over time. These widow-headed dummies might be picking up the effect of targeted assistance from government or NGOs, though more investigation is warranted to better understand this result.

4.4 Household cropping and livelihood choices

Diversification into cotton and tobacco resulted in very large and significant increases in total net crop income. Central households which grew tobacco enjoyed crop income which was significantly higher (55%) than that of non-growers, as did cotton growers, whose crop income was 194% higher than that of non-growers. Northern households which grew cotton significantly higher crop income (43% higher) relative to non-growers. The coefficient on tobacco is insignificant in the north, but the magnitude is large (26%). Further investigation is needed to understand the lack of significant results in the north, though this result may have to do with the large increase in Northern farmer participation in tobacco between 2002 and 2005.[36] Dummies for cotton growing and tobacco growing are not included for the south as there are no concessions there.[37]

We included dummies to indicate use of non-farm livelihood income activities, anticipating that some of these might have positive effects on crop income in the event that nonfarm income facilitates financing of improved inputs. On the other hand, if non-farm activities compete with farming for family labor, this could reduce crop income (unless the household hires labor). The evidence of an influence of non-farm income on crop income is mixed and depends upon the type of non-farm activity and the region. For example, skilled nonfarm income in the center appears to compete for family labor, as it has a rather large (-40%) and significant negative effect on crop income. The coefficients for skilled nonfarm income are insignificant in the other regions. Since a household with skilled nonfarm income would likely have enough cash to hire labor, this result suggests that a household with skilled nonfarm income pursues crop production with less intensity than neighboring households, perhaps because they have less time to manage hired farm labor.[38] In addition, none of the

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[36] The insignificant tobacco result in the north might be related to the concurrent large increase in the number of households growing tobacco in Niassa in 2005 along with drought. In addition, our use of a binary measure of participation might not allow for differentiation between the expected low returns of new entrants and the higher returns expected from more experienced cash crop growers (thus one might use a continuous measure of participation such as area planted to tobacco or cotton).

[37] TIA does report a small number of cases of tobacco income from farmers in the South, which are likely growers who are selling small quantities of tobacco for chewing.

[38] We have defined each nonfarm activity as a 0/1 variable. Given the range of returns within each of these activity categories (as shown above), it is possible that our definition of a nonfarm activity as simply a 0/1 dichotomous variable is too simplistic. For example, it is possible that we have aggregated some skilled nonfarm income which is of a short duration with salaried workers with 10-12 months of employment.

remittance coefficients are significant, and those for the Center and South are negative (the regions with the most remittance income).[39]

By contrast, fishing/charcoal resource extraction activities seem to have a significant positive effect on crop income, as it is consistently positive across the regions, and significant in the north and center, where this activity is associated with 24% and 43% higher crop income, respectively. At the national level, non-resource extraction MSE activities with low costs/returns are associated with 8.9% higher crop income, though this coefficient is not significant in the regional regressions. Non-resource extraction MSE activities with higher costs/returns are associated with 22% higher crop income in the North. Further research is warranted to investigate in more depth the direction of causality of the associations between crop and non-farm activities, because only the skilled wage income and certain high-cost, non-NRE activities are likely to be occupations which the household undertakes with high intensity regardless of how crop production fares in a given season. It is interesting to note that while non-farm income opportunities are most viable in southern Mozambique –where labor demand from neighboring South Africa is strong -- there are no significant associations between non-farm income sources and crop income in that region. This suggests that non-farm income is not reinvested into agriculture in the South, which is perhaps not surprising given the region's low agroecological potential.

4.5 Use of improved inputs

Animal traction use is expected to increase crop income both by increasing total landholding and via productivity effects associated with improved soil aeration and weed control. Unfortunately, animal traction is limited to the south (44% of households use it) and center (18%), as disease constrains the spread of oxen to the north. Thus, we do not include the animal traction use variable in the North because there is only one household which used it. As noted above, use of *animal traction* significantly increases *total area cultivated* to annual crops by 17% in the center and 22.7% in the south. In the crop income regression, we find that *use of animal traction* significantly increases *crop income* by 29.7% in the Center. Because the crop income regression controls for total landholding separately, the benefit of animal traction use in this Central region regression appears to be due to improved soil productivity. The coefficient on animal traction use is negative yet insignificant in the south. One explanation for this could be that widespread drought in the south rendered the productivity benefits of animal traction to be less than the rental cost incurred (though animal traction use was still likely profitable via its indirect effect on crop income by increasing total landholding).

The evidence of significant, large positive effects of animal traction use on both productivity (in the Center) and total landholding (in the Center and South) suggest that promotion of animal traction use could lead to increased crop income both through increased landholding and improved productivity. Public investment could potentially increase adoption of animal traction by alleviating disease constraints to animal traction in the north via medicinal subsidies and/or eradication of the tsetse fly. Because oxen ownership represents a high investment cost, support for rural financial services might help to address household financial constraints to financing traction rental. Given the lack of tradition of maintaining oxen in

[39] While this variable could be endogenous if household migration is undertaken in response to a drought, this is probably unlikely given that such an individual should have been defined by the household as a member who works outside the village and earns wage income (as opposed to a non-member sending remittances).

these areas, livestock extension could play a valuable role in promoting oxen ownership or rental. While cost-benefit studies may be required to evaluate the expected ex ante rate of return to some of these investments, the high farm-level benefits which we find from animal traction use suggest that such investments could have large aggregate returns, and could help foster the emergence of more commercial farmers.

The results on fertilizer use are somewhat mixed. While the coefficients on fertilizer use in the North and Center are positive (as expected), they are only significant in the Center, where application of an additional 10% of fertilizer (measured in cost) would increase crop income by only 0.4%. Contrary to expectation, the coefficient on fertilizer use in the South is negative (and nearly significant), while the squared term is positive and significant (suggesting a U-shaped response). One explanation for this result in the South could be that low fertilizer doses are unprofitable if they get locked up in decomposition processes or are leached, whereas higher doses provide positive returns. Another explanation could be that, without sufficient water (i.e. rainfall), the net benefit of fertilizer is likely negative. Thus, as with animal traction use in the south, the negative effect of fertilizer may be due to the extreme drought in the south both 2002 and 2005. Further investigation may be warranted to try other functional forms and interaction terms with rainfall shocks.

4.6 Access to public goods

4.6.1 Market price information

We find that *household receipt of market price information* significantly increased crop income by 22% in the center and 31% in the south. The coefficient in the north is positive and of much smaller magnitude but is insignificant. This northern result is surprising considering that these provinces tend to have the highest percentage of maize, rice, and bean growers who sell these crops. For the case of Nampula, where 67% of farmers received market price information (MPI), it could be that receipt of price information does not have as large of a farm-level impact (that we could detect in this regression) in an area where most farmers have the information. However, in the other high population northern province, Zambezia, only 24% of households received market price information.

There are several potential policy implications from these results. First, SIMA has recently faced a decline in funds available to pay for radio broadcasts. Given the magnitude of these farm-level benefits of receipt of market price information estimated here for the Center and South, and the widespread receipt of price information by rural households (40% of rural households in 2005), it is likely that the rate of return to SIMA is quite large, and would justify the restoration of SIMA funding to previous (higher) levels.[40]

Second, the large farm-level benefits of receipt of MPI suggest that there would also be large returns to investments which increase household access to MPI. Household-level information from TIA05 on the source of MPI offers some clues as to how to increase household receipt of MPI.[41] According to TIA05, radio is the predominant form of dissemination of MPI, as

[40] Future research could estimate the rate of return to SIMA's price collection and dissemination activities, using a cost-benefit analysis which could compare the aggregate farm-level benefits of price information relative to the public investments in SIMA

[41] Future research using existing TIA data from 2005 onwards could further investigate the determinants of household receipt of price information. In addition, future TIA (or other) surveys could improve upon the

74% of households which received MPI in 2005 indicated that they had received it via radio (Table 5). In addition, 81% of TIA05 households live in a village in which at least one respondent received MPI via radio (Table 5). Thus, it would appear that the principal constraint to increased household access to MPI is not necessarily a lack of radio coverage in rural Mozambique.

However, our definition of the *radio-transmitted coverage* is not very precise, given that we have defined coverage simply as the receipt of MPI by one household in the village during the previous year. However, if the frequency of SIMA broadcasts varies significantly from one radio station to the next, then the extent of *effective coverage* will vary among areas which we have defined as having received at least a minimum number of broadcasts. Areas in which the frequency of SIMA broadcasts is low may explain why, within areas which receive at least some radio broadcasts of SIMA price data, 40% of the population did not receive it. This constraint to market price access cannot simply be explained by lack of radio ownership (54% own a radio in 2005), because 45% of households which own a radio (and live in a village which receives price information via radio) said that they did not receive MPI. In addition, 30% of households which reported receipt of MPI via radio do not own a radio – thus they must have heard it from the radio of a family member or neighbor.

While there is one national radio station which broadcasts SIMA price information without charging SIMA for the service, this is not the case at the provincial level, where dissemination costs are relatively high (although still low on a per user basis). We would expect the frequency of SIMA broadcasts to decrease as air-time fees increase from province to province – and for household receipt of market price information to decrease as the frequency of broadcasts falls. Further research might test this hypothesized link between frequency of broadcasts and household receipt of MPI by investigating whether receipt of MPI varies significantly by some measure of the number of SIMA broadcasts in a given province (such as expenditures on time-fees in that year). Nevertheless, given the evidence above, we would expect that funding which would increase the number of SIMA broadcasts in a given area of the country, using existing radio stations, would increase the number of households which receive MPI.

Of course, another means by which to increase receipt of MPI would be to increase radio coverage to areas which appeared to not receive price information in 2005.[42] In fact, Mozambique is already investing heavily in community radio and hence the costs of additional radio towers need not be borne solely by SIMA (it is presumably built into "air time" fees), though expanded coverage of SIMA price data via radio would require increased funding for the air time fees from the new stations. Nevertheless, it is clear that the number of households which live in villages which receive MPI, yet did not personally receive MPI in 2005 (32% of households) is actually larger than the total number of households living outside these areas (20% of the rural population).

Another potential constraint to increased household use of MPI may be related to the appropriateness of the content of the SIMA price information relative to the marketing needs of farmers in specific areas of rural Mozambique. For example, we might expect more demand for SIMA price content if the messages were delivered in the local language,

existing TIA survey questions regarding market information receipt, to better investigate how farmers use market information, and whether some farmers face impediments to accessing or using the information.

[42] Future research might investigate the marginal social return to increasing the coverage of price information by improving radio access to more areas of Mozambique.

reported on all the major crops in that province, not simply the range of products which SIMA tracks on a national basis. In addition, broadcasts could report not simply the current price that week, but also some analytical content such as price forecasts and trends, or potential markets and transport costs. Addressing these types of constraints would require additional investments to set up provincial SIMA units (SIMAPS) that collect, analyze and disseminate more province-specific market information on a broader range of products than the national SIMA – which are specifically targeted to the needs of the radio audience in that province.

4.6.2 Extension

We find no significant coefficients on our 'principal' extension variable, *number of cumulative extension visits (among non-tobacco/cotton growers).* The coefficients in the north and center are quite small (and insignificant), which suggests that an extension visit in those regions does not significantly improve crop income in the year in which the visit is made. However, the coefficient on *received extension visit 2002 (non-tobacco/cotton growers)*TIME* is positive in the center (though insignificant), and significant in the south, where an extension visit in 2002 resulted in a 78% improvement in income from 2002 to 2005. The results from these two extension variables suggest that extension messages do not improve a household's crop income in the year in which the visit is made, but that this advice led to an increase crop income over time in the south. One policy implication of these results is that caution may be warranted prior to substantial increases in extension funding without a better understanding of what kinds of extension are working well and which are not, and why impacts are only found over time (and only in the South).

There are several potential explanations for the lack of evidence of extension impacts on the crop income of non-cotton/tobacco growers. First, it is possible that the technologies or advice which is recommended is not technically (agronomically) appropriate or profitable for farmers, thus farmers simply do not follow the recommendations (or they follow the recommendations but enjoy no benefit). Such a scenario would suggest that the agricultural research system needs to more effectively understand and translate farmer needs and constraints into research program priorities and design. Second, even if extension advice is appropriate, these recommendations may not be implemented by farmers in the event that farmers cannot access the inputs required due to lack of supply or financial constraints. Third, there are various organizations which supply extension agents (government, NGOs, input dealers, etc), and these organizations may differ in terms of the quality of advice, timeliness of visits, etc. Thus, it is possible that some organizations have more success with farmers than others, yet their positive effects may not be discernible because the TIA02 extension data do not enable us to differentiate among different extension sources.

Looking at extension advice received by tobacco/cotton growers, we find that an increase in the *number of cumulative extension visits* improves crop income by 35% in the north (the effect in the center is small and insignificant). We find the reverse with the effect of an *extension visit in 2002* over time for tobacco/cotton growers, where this visit has no significant effect in the north, yet leads to a significant 73% increase in crop income over time in the center. Because the TIA panel extension information does not tell us the nature of the extension visit or the organization which sent the extension agent, it is unclear whether the positive and significant effect among tobacco/cotton growers is due to the quality of the agents who visited or their message (i.e. they are likely from the tobacco/cotton company), the relatively high returns to tobacco/cotton, or perhaps to the advantages of tobacco/cotton growers in access to credit and fertilizer (which could improve food crop productivity). Nevertheless, a policy implication from the cotton/tobacco extension results is that it is possible for extension advice to result in higher crop income in both the year of receipt and over time.

Further investigation might discover whether the tobacco/cotton extension result is driven by increases in tobacco/cotton income or the income from other crops. If the former is true, then the extension impact is related to the high-value of tobacco/cotton. If the latter, then this suggests that extension impacts are only realized quickly for farmers with good access to credit, fertilizer, etc. Why we would find time-lag effects in the center but not the north is difficult to explain, though perhaps this is a function of the timing of the visit -- if the extension visit occurred during or after the main growing season, then we would not see the benefits of the visit until the next observed season (2005). Unfortunately, the TIA instrument does not ask the farmer when the visit was received.

Further evaluation of extension impacts is clearly warranted, though there are limits to what the TIA panel extension data can tell us. For example, further research could investigate whether or not extension visits have a positive influence on the adoption of technologies which are also controlled in this regression, such as animal traction or fertilizer use. TIA05 collected more information on extension than did TIA02, yet evaluating the impact of extension without panel data would be methodologically challenging, for the reasons outlined earlier. To better evaluate the effect of extension, future TIA instruments (and other rural surveys focused on agriculture) should ask respondents for information regarding the extension visit, namely: the source (organization) of the extension agent, the timing of the visit, and the nature of the advice received – for each visit received.[43]

4.6.3 Farmer associations

With respect to *farm association membership*, we find that membership significantly increased crop income by 22% in the north, yet had no significant effects elsewhere.[44] As with the extension variable, it should be noted that the *farm association membership* variable combines all kinds of farm associations because TIA data cannot distinguish between different types of organizations. Therefore, it is possible that some associations successfully improve farm incomes, but because others do not, we do not observe a significant effect of association membership. Nevertheless, one would think that membership in a farmer association should improve crop incomes.

A policy implication of this result is that caution may be warranted prior to substantial increases in funding to assist farm associations, without a better understanding of why associations in the north have had a significant effect on crop incomes, while those in the center and south have not. Policymakers might also consider pilot testing in order to

[43] Linking the benefit of extension to improved crop income may require a more disaggregated approach in which we look for evidence of the effect of crop management inputs or techniques on a specific crop's production or value, then doing a separate analysis to investigate the influence of an extension visit on the farmer's use of that input or technique.

[44] One potential explanation for the lack of significance could be that extension agents sometimes deliver their messages through farmer associations, thus if there is a large correlation between receipt of extension and farmer association membership, the coefficient's standard errors might be inflated due to multi-collinearity. However, the correlation between these variables in the center and south is less than 0.15, which is far from problematic.

determine which types of farm associations are successful in helping farmers improve their farm incomes in the Mozambican context. Such caution is warranted given that the existing literature on farmer associations and cooperatives in Africa suggests that they have often not delivered the anticipated benefits (Dorward, Kydd, and Poulton, 1998; Bingen et al, 2003). Further research with TIA data could investigate whether or not farm association membership is playing an indirect role in improving crop incomes in the Center and South. For example, if farm association membership improves access to animal traction, cash crop cultivation, fertilizer, etc, then the inclusion of these inputs in the same regression would tend to dilute the influence of membership on crop income as measured by the association membership dummy variable.

4.6.4 Market Access

The final public good variables in our model relate to the effect of road infrastructure on crop income, which we use as a proxy for market access. Because we only have observations of road variables at one point in time (2002), these time-constant variables are differenced out of our FD model. Therefore, we run a pooled OLS regression using our road variables as well as all the household and village-level regressors from the FD model. As noted above, without road variables which vary over time, we may have difficulty claiming a causal relationship between road density and crop income if roads are not distributed randomly across the sample. For example, we see that road density with respect to total land area in the district (kilometers of roads per 1,000 square kilometers) is higher on average for TIA households who live in areas of lower agroecological potential (Table 8). We also find that the higher the agroecological potential of a village, the further the village is located from the nearest public transport, on average. In order to try to control for these obvious differences in road density across different agroecological zones, we run separate pooled OLS regressions for each of the four agroecological potential zones which we have defined based on the 10-zone classification of IIAM (Table 9). Nevertheless, we hesitate to claim that these road variables are exogenous from crop income.

Table 8 Road infrastructure and market access variables, rural Mozambique 2002

Agricultural Potential Zone[a]	Kilometers of roads per 1000 km^2, 2002 (district-level)[b]	Kilometers of roads per 1000 people, 2002 (district-level)[b]	Distance from village to district capital, 2002[c]	Distance from village to nearest public transport, 2002[c]	Distance from village to nearest primary road, 2002[d]
	---------------------- mean values ----------------------				
Low	0.54	2.35	28.8	40.1	45.6
Low-Medium	0.50	1.46	30.2	58.6	41.6
Medium	0.45	2.51	29.1	54.6	45.4
High	0.48	2.14	19.5	94.3	40.8
National	0.49	2.06	28.7	55.2	43.7

Sources: a) Using the 10-zone agroecology definition of the national agronomic research institute (IIAM), we define Low Potential = zones 1,2,3,6; Low-Medium=zones 5,8,9; Medium=zones 4,7; High=zone 10; b) Computed by author from road data from Administração Nacional de Estradas and rural population data from the CAP, 2000; c) TIA02 community survey; d) Nielson 2009

We find that 'area road density' has a significant positive association with crop income in the low-potential zone, but no significant effect in the medium zone (it drops out of the model in the other zones due to collinearity with the district dummies).[45] By contrast, 'population road density' has a significant positive association with crop income in the medium and high potential zones, but a significant negative association in the low and low-medium zones. While we would expect that, controlling for district road density, villages which are further from the district capital should have higher crop income (if they are indeed closer to the 'relevant market'), we find that this variable has the expected significant negative association between *distance between the village and the capital* for the low-medium zone, but is effectively zero in the other zones. The coefficient magnitude shows that a 5 kilometer increase in the distance between the village and the capital is associated with a 1.5% decrease in crop income.

We find a significant positive association between *distance from the village to the nearest public transport* and crop income in the low-medium and high potential zones, which is counter-intuitive. We also find a significant association between distance from the village and the nearest paved road, though this is positive in the low and low-medium zones, and negative in the high potential zone. It appears that we have contradictory results for the low-medium zone, in which crop income increases the closer the village is to the capital, yet decreases the closer the village is to a paved road. One explanation for this result might be related to endogeneity of household livelihood choice as a function of proximity to a paved road. In the low-medium potential zone, where non-farm income is relatively high, households closer to the paved road (which is likely to be closer to Maputo or Beira) may have better access to non-farm employment which they pursue at the expense of their cropping activities. However, without variation in our road variables, it would be difficult to confirm this or other explanations.

In sum, the available road infrastructure variables offer conflicting evidence with respect to the effect of market access on crop income. In part, this is likely due to the lack of road variables which vary over time, which would enable us to ensure that non-random road construction (with respect to agroecological potential) and household livelihood choices do not confound the correlation between road density and crop income. It may also indicate that our village road variables are not suitable proxies for 'market access', because they do not appropriately measure the distance from the village to the relevant market. Given the potential methodological shortcomings of these road variables as well as the conflicting results from them, we consider the results on these market access variables to be inconclusive.

[45] When we run a regression with only provincial*time dummies, the coefficients on the 'area road density' are significant and negative in the low-medium, medium, and high potential zones.

Table 9. Pooled OLS Regressions of crop income determinants, including market access proxy variables, 2002-2005

	Change in ln(Household total net crop income)				
Household and village covariates (variables without a year indication are changes in the variable from 2002-2005)	National	--– Agroecological Potential --– Low	Low-Medium	Medium	High
km of roads per 1000 km^2, 2002 (district-level)	0.378**	0.441**	na	-0.04	na
	(7.30)	(4.26)		(0.20)	
km of roads per 1000 people, 2002 (district-level)	-0.051**	-0.064**	-0.741**	0.057**	0.123*
	(10.37)	(5.82)	(3.43)	(4.11)	(2.60)
distance from village to district capital, 2002	0.000	0.000	-0.003*	0.001	-0.001
	(0.18)	(0.20)	(2.09)	(1.18)	(0.76)
distance from village to nearest public transport, 2002	0.000	-0.001	0.003**	0.000	0.004+
	(0.40)	(1.14)	(2.79)	(0.09)	(1.75)
distance from village to nearest primary road, 2002	0.002+	0.002+	0.009**	0.001	-0.005**
	(1.84)	(1.74)	(3.63)	(1.20)	(5.51)
All other household and village-level variables	Yes	Yes	Yes	Yes	Yes
District X time dummies	Yes	Yes	Yes	Yes	Yes
Number of observations	7,458	2,948	1,740	2,172	598
R-squared	0.36	0.34	0.36	0.42	0.47

Source: TIA 2002, TIA 2005

Notes: *** Significant at the 1% level; ** Significant at the 5% level; + Significant at the 10% level. Numbers in parentheses are absolute t-ratios computed with linearized standard errors which account for complex sampling using STATA. The regressions above included all household and village-level variables from the model in Table 7. na = variable dropped out of the regression due to multicollinearity with district dummies

5. Conclusions

This paper aims to better understand the determinants of household crop income in rural Mozambique, by using the TIA panel household survey of 2002-2005 to measure the impact of various private and public assets on crop income. Our principal focus is to measure the effect on total household net crop income of factors which are assumed to have a positive effect on crop productivity and profitability, including: private assets such as landholding; household use of improved inputs (fertilizer, animal traction) and diversification into tobacco or cotton; and access to public goods such as extension advice, market price information, and farm association membership. In this section, we briefly summarize our findings as well as policy implications.

While our analysis focuses on a few specific private and public assets, we control for many additional household and spatial factors which may affect household crop income, including drought, flood, and crop disease shocks. We find that an additional *day of drought* during the principal growing season results in an average 5.5% loss in crop income in the south, and a 2.0% loss in crop income in the north. These results highlight the extreme sensitivity of crop income to weather shocks, and thus the potential value of: a) promotion of smallholder access to low-cost methods of irrigation and/or conservation farming techniques to reduce the impact of drought -- in contrast to the recent emphasis of heavy investment in formal perimeter irrigation schemes; and b) investment in development and dissemination of drought-tolerant maize varieties as well as varietal improvement in traditionally drought-resistant crops such as cassava and sweet potato.

We find large significant effects of increased landholding on crop income, as a 5% increase in *total landholding* significantly increases crop income by 1.9% in the north, 2.1% in the center and 1.2% in the south. A potential constraint to increased landholding is the low use of animal traction in the center, and virtual non-existence of it in the north (attributed to trypanosomiasis spread by the tsetse fly). We investigate the determinants of landholding using regression analysis and find that adoption of animal traction use increases total landholding by 13.8% in the center and 18.5% in the south.

We also find that *animal traction use* significantly increases crop income by 29.7% in the Center. Given that the crop income regression controls for total landholding separately, the return to animal traction use is likely due to improved soil productivity. The evidence of significant, large positive effects of animal traction use on both productivity (in the Center) and total landholding (in the Center and South) suggest that promotion of animal traction use could lead to increased crop income both through increased landholding and improved productivity. Public investment could potentially increase adoption of animal traction in the North by alleviating disease constraints to animal traction via medicinal subsidies and/or eradication of the tsetse fly. Because oxen ownership represents a high investment cost, support for rural financial services might help to address household financial constraints to financing traction rental. Given the lack of tradition of maintaining oxen in these areas, livestock extension could also play a valuable role in promoting oxen ownership or rental. While cost-benefit studies may be required to evaluate the expected ex ante rate of return to some of these investments, the high farm-level benefits which we find from animal traction use suggest that such investments could have large aggregate returns, and could help foster the emergence of more commercial farmers.

Diversification into cotton or tobacco resulted in very large and significant increases in total net household crop income. Central households which grew tobacco had 55% higher crop income than that of non-growers, while cotton grower income was 194% higher than that of non-growers. Northern cotton growers had 43% higher crop income relative to non-growers; the effect of growing tobacco in the north was positive but not significant. While these crops have historically offered high returns, the option of growing such crops is only available for households which live within a reasonable distance from concession areas, and previous research has suggested that there appear to be landholding thresholds below which household participation is unlikely. Thus, tobacco and cotton are unfortunately not a panacea for widespread poverty reduction among smallholders due to these existing barriers to participation.

We also find evidence that some *non-farm income* sources may reinforce and multiply growth in the agricultural sector. Fishing/charcoal resource extraction activities have a significant positive association with crop income in the north and center (24% and 43%), while high-return medium-small enterprise activities such as trading and construction are associated with 22% higher crop income in the North. On the other hand, skilled nonfarm income in the center appears to compete for family labor, as it has a rather large and significant negative association (-40%) with crop income. What is surprising about these results is while non-farm income opportunities are most viable in southern Mozambique -- where crop potential is limited and demand for labor from South Africa is a reality -- there are no significant associations between non-farm income sources and crop income in that region. This suggests that non-farm income is not reinvested into agriculture in the South. Although we find a significant association between some non-farm income sources and crop income in the Center and North, policymakers should bear in mind that the types of non-farm activities available in the Center/North are largely dependent upon growth in agriculture.

We find that *household receipt of market price information* significantly increased crop income by 22% in the center and 31% in the south. There are several potential policy implications from these results. First, considering the size of these farm-level benefits of market information, and the widespread receipt of market price information (MPI) by rural households (40% of rural households in 2005), it is likely that the rate of return to SIMA investments to date is quite large, and would justify the restoration of SIMA funding to previous (higher) levels. Second, these results suggest that there would also be large returns to investments which increase household access to market price information. Given that radio is the predominant and lowest-cost (per household) method of dissemination price information (74% of households receiving price information received it via radio), there appear to be at least three ways to increase household-level access to MPI via radio broadcasts.

One means to do this would be to expand radio coverage to areas previously not served (19% of households live in villages which do not report receiving SIMA radio broadcasts). However, the number of households which live in villages which receive MPI, yet did not personally receive MPI in 2005 (32% of households) is actually larger than the total number of households living outside these areas (20% of the rural population). Thus, it would appear that the principal constraint to increased household access to MPI is not necessarily a lack of radio coverage in rural Mozambique. Low frequency of broadcasts may explain why we observe that 45% of households which own a radio (and live in a village which receives price information via radio) said that they did not receive MPI. Thus, within areas already receiving radio coverage, another option to increase the number of household which receive

MPI would be to increase the number of SIMA broadcasts in a given area of the country, using existing radio stations.

Another potential constraint to increased household use of MPI may be related to the appropriateness of the content of the SIMA price information relative to the marketing needs of farmers in specific areas of rural Mozambique. For example, SIMA could able to deliver price information in local languages, report on all the major crops on a provincial basis. In addition, SIMA could perhaps add some analytical content to their messages, such as price forecasts and trends, or potential markets and transport costs. Addressing these types of constraints would require additional investments to set up provincial SIMA units (SIMAPS) that collect, analyze and disseminate more province-specific market information on a broader range of products than the national SIMA – which are specifically targeted to the needs of the radio audience in that province.

With respect to non-tobacco/cotton growers, we find no significant effects of *the number of cumulative extension visits* on crop income in any region, but we find that households in the South which received an *extension visit in 2002* had 78% higher crop income in 2005 than other households. The results from these two extension variables suggest that extension messages do not improve a household's crop income in the year in which the visit is made, but that, in the South, this advice led to an increase crop income over time. One policy implication of these results is that caution may be warranted prior to substantial increases in extension funding without a better understanding of what kinds of extension are working well and which are not, why impacts are only found over time (and only in the South).

With respect to tobacco/cotton growers, we find that an increase in the *number of cumulative extension visits* improves crop income by 35% in the North, while the effect of an *extension visit in 2002* over time is significant leads to a 73% increase in crop income over time in the Center. A policy implication from these tobacco/cotton extension results is that it is possible for extension advice to result in higher crop income in both the year of receipt and over time. This extension effect for tobacco/cotton farmers might derive from higher returns to their cash crops, or it could be that these farmers are better able to implement extension recommendations due to better input access. Further investigation is therefore needed to discover whether the tobacco/cotton extension result is driven by increases in tobacco/cotton income or by increases in income from other crops.

We find that *farm association membership* is associated with a 22% increase in crop income in the North, yet had no significant effects elsewhere. A policy implication of this result is that caution may be warranted prior to substantial increases in funding to assist farm associations, without a better understanding of why associations in the north have had a significant effect on crop incomes, while those in the center and south have not.

In order to measure the effect of market access on crop income, we use road density and village remoteness as proxies of market access. Because these variables are only observed in 2002, they drop out of our panel regression model, thus we run a separate regression (pooled OLS) to measure the effect of these variables on crop income. Given the methodological shortcomings of these road variables as well as the conflicting results from them, we consider the results on these market access variables to be inconclusive.

Finally, this study suggests ways to improve the effectiveness of the TIA survey to serve as an instrument to monitor the contribution of the agricultural sector to poverty reduction.

These include collecting additional information on: agricultural technology use; the specific activities of farm associations in each village; the nature of extension advice received by households and the organizational affiliation of the extensionist; and market access, preferably based on the satellite coordinates of interviewed communities, overlaid with a grid of roads in a GIS format.

APPENDIX TABLES

Appendix Table 1 Annual means of variables in first-difference model of net household corp income, 2002 and 2005

Household and village covariates (variables without a year indication are changes in the variable from 2002-2005)	National		North		Center		South	
	2002	2005	2002	2005	2002	2005	2002	2005
Total net crop income	5509.7	6166.4	5501.6	5182.8	4991.0	6940.5	6203.0	8972.6
ln(Total net crop income)	8.161	7.993	8.236	7.959	7.895	7.959	8.210	8.164
district drought days	27.865	45.223	7.040	28.837	42.682	50.693	88.692	101.015
% HHs in village which experienced extensive flooding	0.128	0.041	0.102	0.051	0.203	0.039	0.134	0.007
% of HHs in village with extensive crop disease	0.388	0.596	0.395	0.591	0.232	0.478	0.561	0.767
1=cassava production imputed in 2002	0.280	0.280	0.393	0.393	0.086	0.086	0.093	0.093
1=HH headed by non-widow female in 2002	0.148	0.148	0.154	0.154	0.131	0.131	0.145	0.145
1=HH headed by widow in 2002	0.091	0.091	0.066	0.066	0.111	0.111	0.165	0.165
no. of chronically ill PA adults	0.051	0.051	0.052	0.052	0.040	0.040	0.063	0.063
Head's age, 2002 (years)	41.9	44.4	39.6	42.4	43.1	45.1	49.2	51.0
Head's age squared, 2002 (years)	1972.9	2183.8	1755.9	1985.6	2087.6	2265.4	2657.9	2838.8
Head's education, 2002 (years)	2.206	1.972	2.137	1.905	2.334	2.003	2.307	2.188
max education (years)	3.173	3.588	2.870	3.212	3.504	3.969	3.909	4.540
no. of PA adults (age 15-59) in agriculture	2.27	2.37	2.15	2.26	2.52	2.70	2.43	2.35
no. of PA adults in agriculture squared	6.70	7.55	5.53	6.43	8.51	10.09	8.89	8.62
no. of children age 0-4	0.84	0.80	0.81	0.76	0.98	0.92	0.77	0.81
no. of children age 5-14	1.48	1.70	1.41	1.64	1.71	1.95	1.47	1.61
no. of adults age 60+	0.23	0.26	0.15	0.19	0.28	0.30	0.45	0.50
ln(total area (ha))	0.342	0.449	0.203	0.394	0.625	0.685	0.512	0.358
ln(total area squared (ha))	0.744	0.729	0.611	0.611	0.922	0.971	1.028	0.872
ln(farm equipment value)	3.637	4.147	3.521	4.222	3.969	4.257	3.658	3.720
1=HH uses animal traction	0.111	0.084			0.187	0.109	0.441	0.371
ln(Value of fertilizer used) ('05 contos)	0.163	0.224	0.109	0.177	0.359	0.444	0.118	0.126
ln(Value of fertilizer used squared) ('05 contos)	0.325	0.449	0.217	0.353	0.717	0.889	0.236	0.252
no. of temporary laborers hired	0.901	1.012	1.047	1.070	0.765	1.121	0.512	0.649
no. of temporary laborers hired, squared	76.8	17.6	118.6	20.8	8.5	16.6	4.0	6.4
no. of permanent laborers hired	0.031	0.038	0.022	0.026	0.057	0.060	0.029	0.054
no. of permanent laborers hired, squared	0.145	0.200	0.179	0.143	0.109	0.358	0.058	0.217

Household and village covariates (variables without a year indication are changes in the variable from 2002-2005)	National		North		Center		South	
	2002	2005	2002	2005	2002	2005	2002	2005
1=HH grows tobacco	0.039	0.027	0.039	0.027	0.061	0.046		
1=HH grows cotton	0.076	0.058	0.103	0.073	0.051	0.061		
1=HH has skilled nonfarm wage income	0.054	0.078	0.040	0.061	0.053	0.082	0.111	0.135
1=HH has MSE activity, NRE high (fishing/charcoal)	0.092	0.094	0.095	0.100	0.095	0.093	0.077	0.072
1=HH has MSE activity, non-NRE low cost activity	0.195	0.252	0.202	0.268	0.204	0.243	0.158	0.204
1=HH has MSE activity, non-NRE high cost activity	0.143	0.185	0.123	0.185	0.172	0.183	0.185	0.189
1=HH received remittances	0.194	0.232	0.162	0.200	0.153	0.190	0.370	0.412
1=HH member of farm association	0.040	0.069	0.041	0.070	0.034	0.052	0.041	0.084
HH received extension visit, non-tob/cotton HH, 2002	0.112	0.131	0.106	0.130	0.154	0.126	0.080	0.138
HH received extension visit, tobacco/cotton HH, 2002	0.027	0.027	0.033	0.030	0.031	0.040		
1=HH received price information	0.354	0.409	0.407	0.438	0.374	0.397	0.126	0.312
Number of observations	3730		1678		1098		954	

Source: TIA 2002, TIA 2005

Appendix Table 2 First Difference regression of rural household crop income determinants, 2002-2005 (includes outliers)

Household and village covariates (variables without a year indication are changes in the variable from 2002-2005)	Change in ln(Household total net crop income) National (A)	North (B)	Center (C)	South (D)
Δ district drought days	-0.01	-0.021*	0.012	-0.073**
	(1.13)	(2.57)	(1.34)	(40.06)
Δ % HHs in village which experienced extensive flooding	-0.136	-0.018	0.024	-0.906+
	(0.88)	(0.12)	(0.06)	(1.81)
Δ % of HHs in village with extensive crop disease	0.087	-0.035	0.234+	0.299
	(0.96)	(0.40)	(1.79)	(0.92)
1=cassava production imputed in 2002	-0.029	-0.085	0.215	0.445
	(0.44)	(1.32)	(0.96)	(1.73)
1=HH headed by non-widow female in 2002 * TIME	-0.014	-0.12	0.326	0.008
	(0.16)	(1.16)	(1.58)	(0.04)
1=HH headed by widow in 2002 * TIME	0.211+	0.012	0.421*	0.348
	(1.92)	(0.07)	(2.27)	(1.58)
Δ no. of chronically ill PA adults	0.065	0.125	0.223	-0.252
	(0.76)	(1.05)	(1.12)	(1.52)
Head's age, 2002 (years) * TIME	-0.014	-0.003	-0.025	-0.014
	(1.16)	(0.18)	(0.76)	(0.38)
Head's age squared, 2002 (years) * TIME	0	0	0	0
	(0.91)	(0.15)	(0.69)	(0.41)
Head's education, 2002 (years) * TIME	0.011	-0.006	0.029	0.023
	(0.70)	(0.45)	(0.61)	(0.64)
Δ max education (years)	0.001	0.009	0.008	-0.052
	(0.08)	(0.60)	(0.22)	(0.89)
Δ no. of PA adults (age 15-59) in agriculture	0.126	0.097	-0.051	0.329*
	(1.57)	(0.63)	(0.49)	(2.41)
Δ no. of PA adults in agriculture squared	-0.004	0.003	0.01	-0.024
	(0.34)	(0.11)	(0.88)	(1.35)
Δ no. of children age 0-4	0.090**	0.053	0.139*	0.096
	(3.24)	(1.53)	(2.54)	(1.05)
Δ no. of children age 5-14	0.053+	0.067*	0.027	-0.024
	(1.97)	(2.60)	(0.43)	(0.34)
Δ no. of adults age 60+	-0.102	-0.064	-0.085	-0.07
	(1.28)	(0.61)	(0.41)	(0.41)
Δ ln(total area (ha))	0.427**	0.402**	0.592**	0.424**
	(9.82)	(8.98)	(5.00)	(4.28)
Δ ln(total area squared (ha))	-0.104**	-0.079+	-0.185*	-0.141**
	(3.38)	(1.71)	(2.49)	(4.13)
Δ ln(farm equipment value)	0.015	0.015	0.025	-0.01
	(1.44)	(1.35)	(1.21)	(0.30)
Δ 1=HH uses animal traction	0.066		0.257	-0.068
	(0.45)		(1.62)	(0.30)
Δ ln(Value of fertilizer used) ('05 contos)	-0.017	0.011	-0.019	-0.240**
	(0.34)	(0.33)	(0.16)	(3.11)
Δ ln(Value of fertilizer used squared) ('05 contos)	-0.02	0.023*	-0.07	-0.247**
	(0.96)	(2.59)	(1.48)	(5.40)

Δ no. of temporary laborers hired	0.017*	0.013+	0.052*	0.036
	(2.14)	(1.76)	(2.58)	(1.17)
Δ no. of temporary laborers hired, squared	-0.000+	0	-0.001	0
	(1.86)	(1.53)	(1.37)	(0.49)
Δ no. of permanent laborers hired	0.160*	0.002	0.208	0.365+
	(1.99)	(0.02)	(1.26)	(1.91)
Δ no. of permanent laborers hired, squared	-0.012**	0.001	-0.016**	-0.026
	(2.90)	(0.13)	(2.82)	(0.74)
Δ 1=HH grows tobacco	0.721**	0.187	1.394**	
	(3.67)	(1.09)	(2.86)	
Δ 1=HH grows cotton	0.451**	0.342*	1.103*	
	(2.66)	(2.29)	(2.31)	
Δ 1=HH has skilled nonfarm wage income	-0.188	-0.144	-0.348*	-0.136
	(1.56)	(0.92)	(2.18)	(0.47)
Δ 1=HH has MSE activity, NRE high (fishing/charcoal)	0.314**	0.264**	0.651*	-0.073
	(3.52)	(2.82)	(2.50)	(0.18)
Δ 1=HH has MSE activity, non-NRE low cost activity	0.139**	0.101*	0.260+	0.109
	(2.74)	(2.06)	(1.82)	(0.83)
Δ 1=HH has MSE activity, non-NRE high cost activity	0.156*	0.242**	0.166	-0.189
	(2.31)	(2.83)	(1.13)	(1.09)
Δ 1=HH received remittances	0.038	0.012	-0.038	0.181
	(0.79)	(0.23)	(0.34)	(1.21)
Δ 1=HH member of farm association	0.107	0.204*	-0.076	0.121
	(1.20)	(2.20)	(0.31)	(0.68)
Δ cumulative # of extension visits to non-tobacco/cotton HH	0.052	0.012	0.046	0.345
	(0.58)	(0.14)	(0.26)	(1.11)
HH received extension visit, non-tob/cotton HH, 2002 * TIME	0.003	-0.158	0.271	0.322
	(0.03)	(1.32)	(1.21)	(1.36)
Δ cumulative # of extension visits to tobacco/cotton HH	0.454**	0.327**	0.653*	
	(3.70)	(2.66)	(2.09)	
HH received extension visit, tobacco/cotton HH, 2002 * TIMI	0.245+	0.111	0.559	
	(1.66)	(0.74)	(1.53)	
Δ 1=HH received price information	0.112*	0.052	0.199+	0.298+
	(2.44)	(0.96)	(1.99)	(2.07)
Δ Constant	-0.201	0.683+	-1.248	-3.511**
	(0.42)	(1.79)	(0.94)	(4.47)
District X time dummies	Yes	Yes	Yes	Yes
Number of observations	3909	1685	1149	1075
R-squared	0.20	0.21	0.21	0.29

Source: TIA 2002, TIA 2005

Notes: *** Significant at the 1% level; ** Significant at the 5% level; + Significant at the 10% level. Numbers in parentheses are absolute t-ratios computed with linearized standard errors which account for complex sampling using STATA.

REFERENCES

Alderman, H., J. R. Behrman, H-P Kohler, J. A. Maluccio, and S. Cotts Watkins. 2001. "Attrition in Longitudinal Household Survey Data." *Demographic Research* Vol. 5 Article 4: 80-123.

Bingen, J., A. Serrano, J. Howard. 2003. "Linking Farmers to Markets: Different Approaches to Human Capital Development." Food Policy 28: 405-419.

Birkhaeuser, D., R.E. Evenson, and G. Feder. 1991. "The Economic Impact of Agricultural Extension: A Review." *Economic Development and Cultural Change*, 39 (3): pp. 507-21.

Boughton, D., D. Mather, C. Barrett, R. Benfica, and D. Abdula. 2007. "Market Participation by Rural Households in a Low-Income Country: An Asset-Based Approach Applied to Mozambique." *Faith and Economics* 50, pp. 64-101. Available at: http://aec.msu.edu/fs2/mozambique/market_participation_rural_households.pdf

Boughton, D., D. Mather, D. Tschirley, T. Walker, B. Cunguara, and E. Payongayong. 2006. "What's Driving Mozambique's Rural Income Growth? A Comparative Analysis of the 1996 and 2002 National Agricultural Sample Surveys." MINAG Directorate of Economics Research Paper 61E.
Available at: www.aec.msu.edu/fs2/mozambique/wps61E.pdf

Chapoto, Antony. 2006. The impact of AIDS-related prime-age mortality on rural households: panel survey evidence from Zambia. Unpublished Ph.D. dissertation, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan. Available at: www.aec.msu.edu/agecon/theses/index.htm

De Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained." *Economic Journal*, 101(November): 1400-17.

Dorward, A., J.Kydd and C. Poulton. 1998. *Smallholder Cash Crop Production Under Market Liberalization: A New Institutional Economics Perspective*. CAB International.

ECON Analysis. 2005. 'Impacts of Extension Services in Rural Mozambique'. Report prepared for the World Bank, Maputo, Mozambique.

Foster, A. and M. Rosenzweig. 1995. "Learning by Doing and Learning From Others: Human Capital and Technical Change in Agriculture." *Journal of Political Economy* 103 (December): 1176-1209.

Lipton, M. 2005. "Crop Science, Poverty, and the Family Farm in a Globalising World." 2020 Discussion Paper 40, International Food Policy Research Institute, Washington, D.C.

Marrule, Higino. 1998. *Land-Poor in a "Land-Abundant" Setting: Unraveling a Paradox in Mozambique.* Unpublished M.Sc. Thesis, Department of Agricultural Economics, Michigan State University.

Mather, D., B. Cunguara, and D. Boughton. 2008. "Household Income and Assets in Rural Mozambique, 2002-2005: Can Pro-Poor Growth Be Sustained?" MINAG Directorate of Economics Research Paper 66, Maputo, Mozambique.
Available at: http://aec.msu.edu/fs2/mozambique/wps66.pdf

Mather, D. and C. Donovan. 2007. "The Impacts of Prime-age Adult Mortality on Rural Household Income, Assets, and Poverty in Mozambique." Background paper for the Mozambique Poverty, Gender and Social Impact Assessment, Africa Region, The World Bank, Washington, D.C. and MINAG Directorate of Economics Research Paper 65E, Maputo, Mozambique. Available at: http://aec.msu.edu/fs2/mozambique/wps65e.pdf

Nielson, Hunter. 2009. *The Role of Cassava in Smallholder Maize Marketing in Zambia and Mozambique.* Unpublished M.Sc. thesis. Department of Agricultural, Food, and Resource Economics, Michigan State University, East Lansing, Michigan.

Reardon, T., E. Crawford and V. Kelly. 1994. "Links between Non-farm Income and Farm Investment in African Households: Adding the Capital Market Perspective." *American Journal of Agricultural Economics*, 76: December, pp. 1172-1176.

Owens, T., J. Hoddinott, and B. Kinsey. 2003. "The Impact of Agricultural Extension on Farm Production in Resettlement Areas of Zimbabwe." *Economic Development and Cultural Change*, 51 (January): 337-357.

Walker, T., D. Tschirley, J. Low, J., M. Tanque, D. Boughton, E. Payongayong, and M. Weber. 2004. "Determinants of Rural Income in Mozambique in 2001-2002." MINAG/DE/DAP Research Report No. 57E.
Available at: www.aec.msu.edu/fs2/mozambique/wps57e.pdf

World Bank. 2005. Impacts of extension services in rural Mozambique. AFTS1. Environment, Rural and Social Development Department, Africa Region. World Bank: Washington.

World Bank. 2007. "Beating The Odds: Sustaining Inclusion In A Growing Economy: A Mozambique Poverty, Gender and Social Assessment." World Bank: Africa Region, Poverty Reduction and Economic Management.

Wooldridge, J.M. 2002. *Econometric Analysis of Cross Section and Panel Data*. MIT Press.