Adoption Pathways project discussion paper 11

February 2015

Predicting the adoption of conservation agriculture under alternative agricultural policy environments in Eastern and Southern Africa

Paswel Marenya[a], *Menale Kassie*[b], *Moti Jaleta*[c], *Dil Rahut*[d], *Olaf Erenstein*[e]

[a] ***Corresponding author:*** International Maize and Wheat Improvement Center (CIMMYT), P.O. Box 5689, Addis Ababa, Ethiopia. Email: p.marenya@cgiar.org, Tel. +251-11-64-62-324

[b] International Maize and Wheat Improvement Center (CIMMYT), P.O. Box 5689, Addis Ababa, Ethiopia. Email: m.jaleta@cgiar.org

[c] International Maize and Wheat Improvement Center (CIMMYT), United Nations Avenue, Gigiri, PO Box 1041-00621, Nairobi, Kenya. Email: m.kassie@cgiar.org

[d] International Maize and Wheat Improvement Center (CIMMYT), Apdo. Postal 6-641 06600 Mexico, D.F., Mexico. Email: d.rahut@cgiar.org

[e] International Maize and Wheat Improvement Center (CIMMYT), Apdo. Postal 6-641 06600 Mexico, D.F., Mexico. Email. o.erenstein@cgiar.org

Abstract

Despite having been promoted in Africa for close to twenty years, adoption of conservation agriculture (CA) remains sparse. Extant literature has variously associated micro-level household and community factors with CA adoption. There is a notable gap in the literature concerning the need to analyze the adoption of CA beyond the micro-level. This paper focuses on the role of agricultural policies — input subsidy policies, investments in agricultural extension and access to markets — in predicting CA adoption. Using data from 2,736 households and 11,188 plots in Ethiopia, Kenya, Malawi and Tanzania, and controlling for household and farm level factors, we implement a series of policy simulations based on a binary probit model to compare the predicted probabilities of adoption under different policy scenarios. We find that high extension-personnel-to-farmer-ratios and input subsidies enhanced the adoption of CA, while there was an inverse relationship with the distance to input markets. The results imply that good market infrastructure, low input-output cost ratios and strong extension systems provide clear basis for increased CA adoption. We conclude that the same favorable policy conditions needed for other agricultural innovations are equally relevant for CA as well.

Key words: adoption, conservation agriculture, policy, subsidy, extension

JEL: Q01, Q18, Q12

1. Introduction

In recent years, the concept of sustainable intensification has gained much (justifiable) momentum (The Royal Society, 2009). Due to burgeoning populations, rising food demand and pressure on a finite resource base, the need to produce more food from the same or less amount of resources without undermining their underlying productive capacity in the future is critical (The Royal Society, 2009; Godfray et al., 2010). In this regard, conservation agriculture (CA) is one of the recent sets of farming practices that is being widely advocated and generated widespread policy interest and discussion. The main principles of conservation agriculture are: minimizing soil disturbance, maintaining soil cover, and practicing crop rotation and intercropping. Pretty *et al*. (2006) in a wide ranging study in developing countries, reported that if CA and CA-related practices were implemented, average water productivity would increase in irrigated agriculture (rice by 16%; cotton 29%) and particularly in rain fed agriculture (cereals by 70%, legumes 102%, and roots and tubers 108%). The benefits of CA, while emphasized from a broader view of sustainability, also contribute to the individual productivity of farms (Kassam et al., 2009).

2. The Problem

Despite having been promoted in Africa for close to twenty years (Ekboir et al., 2002; Pascal and Josef, 2007, Jaleta, Kassie and Shiferaw 2013), adoption of CA remains sparse (Corbeels et al. 2014). Why has this promising set of agricultural practices not found widespread application? For one, CA is not a panacea – and so may need adaptation and/or targeting to specific circumstances (Giller et al 2009; Erenstein et al, 2012; Tesfaye et al, in press). A successful technology will also not be equally adopted by a heterogeneous farmer population and many factors have been associated with CA adoption in the literature, often in the realm of micro-level household and community factors (Knowler and Bradshaw, 2007). This paper focuses specifically on the contribution of agricultural policies — particularly the role of input subsidies, levels of agricultural extension and access to markets —in shaping the adoption of CA after controlling for household and farm-level factors. There is a notable gap in the literature concerning the need to analyze the adoption of CA beyond the micro-level. Indeed most focus on the micro-level factors at the farm and household level, yet Knowler and Bradshaw (2007) reported that whereas most of the CA costs are incurred at the farm level, most of the (environmental) benefits transcend the farm boundary. Still, to the best of our knowledge, there is little information on how the broader agricultural policy environment can determine whether farmers adopt CA (or not) and by extension whether they will realize these benefits (or not). The main contribution of this paper therefore is to demonstrate how national level policy and market access indicators can be predictors of CA adoption[1] in maize growing areas of four Eastern and Southern Africa (ESA) countries (Ethiopia, Kenya, Tanzania and Malawi).

Generally the results showed that both subsidy and extension had powerful effects on probability of adoption depending on the base from which the effects were simulated. When the ratio of extension —personnel- to- farmer- ratios are compared to public expenditures on subsidies, the effect of the subsidy variable appears to have had the stronger effect on adoption of CA judging from the simulations involving reductions in subsidy and increasing extension. The impact of credit availability was less instrumental: compared to subsidy expenditures the results showed that when subsidy was reduced, a universal availability of credit did not prevent the probability of adoption reducing when subsidy was reduced, and when credit was reduced but subsidy increased, the probability of adoption still increased. Where fertilizer-price ratio was raised above base levels, the effect was to lower probability of adoption even when extension was increased. The strong effect of extension was also clear in simulations where the extension variable was compared to credit availability. By increasing extension, the probability of adoption increased even in the complete absence of credit.

The results suggest that although either policy of heavily subsidizing inputs or increasing the levels of extension reach can have clear positive impacts on CA adoption, it is possible to argue that investing in elements of cost reduction of inputs (e.g. through infrastructural improvements and agribusiness development) together with strengthening extension systems may be more sustainable in the long run especially if viewed from a fiscal as well as long run development impact perspectives.

[1] In this paper, adoption of conservation agriculture is defined as such if the farmer reported having implemented minimum or reduced tillage and residue retention on the plot during 2009 cropping season.

3. Emergence of CA in East and Southern Africa

The vast majority of successful CA adoption has been in the United States, Canada and Latin America (most notably Brazil and Argentina) (Trigo et al 2009; Ekboir 2001). As of 2009, more than 106 million of hectares were estimated to use under zero tillage were counted across the world (Kassam et al., 2009). In the large scale mechanized systems of Canada, the USA, Argentina and Brazil, farmers the benefits to CA adoption are readily apparent because the significant resource savings nature (especially fuel) is quickly realized at such large scales of operation. Presently the evidence base as to what exactly will make CA work is only beginning to emerge and remains thin (Giller et al., 2009). It is apparent that factors that have always conditioned the adoption of other agricultural technologies may still pose similar hurdles for CA. For example, Ojiem et al., (2006) and Knowler and Bradshaw (2007) stated that CA adoption by African smallholders may be influenced apparently by an array of socio-economic factors such as input prices, knowledge, labour scarcity, lack of capital, farm size or poor infrastructure.

The emergence of CA as a critical tool in sustainable agriculture emerges from the 1990's with evolving nomenclature and concepts including the 1996 World Food Summit where the Soil Fertility Initiative was launched followed by the Better Land Husbandry approach; and for Africa a 1998 conservation tillage workshop in Zimbabwe and the formation in 2000 of the African Conservation tillage network (Benites *et al*, 1998, Bishop-Sambrook et al. 2004). The core support for the promotion of CA in sub-Saharan Africa (SSA) has invariably come from donor funding. For example in 2003 in Zambia, FAO piloted draught animal power (DAP) ripping and input packs as part of an FAO's emergency agricultural intervention plan. The Monstanto seed company in collaboration with Sasakawa-Global (SG2000) also has promoted no-till practices that rely on herbicides and the retention of crop residues in countries such as Burkina Faso, Ghana, Guinea, Mali, Malawi, Nigeria, Senegal, Ethiopia, Kenya, Mozambique, Uganda and Tanzania (Bisop-Sambrook et al. 2004).

In Ethiopia one of the early efforts to introduce minimum tillage was done by the Sasakawa-Global (SG2000) in South Achefer district (Matsumoto, Plucknett and Mohammed, 2004). Using on-farm demonstrations of minimum tillage, improved maize varieties and herbicides, the program was implemented for some years involving field demonstrations. There is evidence that in these areas where SG2000 worked, minimum tillage practices are still being used by smallholder farmers.

Conservation agriculture has been formally promoted in Kenya since 1998 under the Kenya Conservation Tillage Initiative (KCTI) and by 2005; KCTI had projects in five districts in the country with plans at that time to scale up the pilot programs through farmer field schools. From these efforts CA is now emerging in several parts of Kenya among a diverse group of farmers in such areas as the semi-arid Machakos and Laikipia, the high potential Nakuru and in the smallholder sub-humid western Kenya. The 3rd World Congress on Conservation Agriculture was held in Kenya. During this Congress, the government (represented by the vice president of the Republic of Kenya at that time), expressed its commitment to CA in its strategy to revitalize agriculture (ACT, 2008 p. 9).

Experimental trials on CA in Malawi can be traced back to the 1980's at Bunda College (Mloza-Banda, 2002). In recent years, the authorities have shown that they are keen to promote processes and policies to redress land degradation and created a National Conservation Agriculture Task force (NCATF). This task force has the mandate of overseeing the proper application of sustainable use of natural resources/ land management practices and the advocacy of CA initiatives throughout Malawi by participating in land resource policy processes especially with regard to CA. The NCATF brings together researchers, developers and policy-makers to share information and advance conservation agriculture to new frontiers.

One of the earliest concerted efforts at promoting CA in Tanzania is reported in Marietha et al. (2011) in which they report that in 2004 a joint program between the German Ministry of Agriculture and FAO, supported CA practices in Northern Tanzania. The project used farmer field schools as entry points for extension and farmer education on CA. The project also encouraged the private sector to participate in the fabrication; retailing and developing custom hire services for CA equipment such as jab planters, ripper sub-soilers, DAPs, and rippers. These projects were pioneered in the North Eastern regions of Arusha and Kagera later expanding to Manyara region (also North East) and Kilimanjaro (in the North West). This project facilitated the formation of 130 farmer field schools and reaching 3,500 farmers during the 2007-2010 phases (Marietha et al. 2011). Overall, this brief review suggests that there have been notable CA promotion efforts in the study countries. The question then remains what factors are empirically associated with CA adoption?

4. Conceptual Framework: Household characteristics, policies, markets access and CA Adoption

This paper focuses on the role of extension and subsidy policies and market access at a macro level to identify how the extension–to-farmer-ratio (number of extension personnel to 10,000 farmers), market access (distance to market), and input subsidy policies can affect CA adoption. We begin with household level factors, outlining pathways through which these variables affect the adoption outcomes of CA and then link this to the broader policy and market access indicators.

4.1 Household level constraints

Even if CA generally is a labor saving technology, its implementation is not a costless venture for resource poor farmers who, *ex ante*, are not using any significant amounts of external inputs. For these farmers, even the modest financial resources needed for complementary external inputs such as herbicides (and fertilizers) to implement CA and perhaps the increased labor demand for weed management still represent *relatively* high resource expenditures if they are starting from base production practices involving little more than family labor. Many of such farmers can find it difficult to put the critical labor and management into their farms if these demands compete with the need to sell labor to meet subsistence requirements. Therefore, the adoption of even a labor saving practice such as CA can run into headwinds when farmers are very resource poor. Under these circumstances, if opportunities for the supply of financial products (credit) or the ability to earn cash income are limited, technologies that require up front commitment of finances and labor may not be readily adopted (Jack 2013).

Therefore, at the micro-level, access to and the ability to acquire information, the need to meet minimum subsistence food needs and lack of financial resources (savings or cash income) can prevent the adoption of otherwise profitable agricultural innovations. On the other hand even if resources are available, if farmers lack the information on how best to implement recommended practices, they may fail to do so, because they lack the technical knowhow to adopt them optimally and profitably (Jack 2013).

To conceptualize the pathway from these constraints to CA adoption, consider a subsistence farmer (of the type we have just described) who is faced with the choice of implementing CA. This choice can be seen as an intertemporal utility maximization problem, intertemporal because input use and other production costs decisions have to be made at planting time based on expected yield and market (price) outcomes several months at the end of the agricultural calendar.[2]

Therefore, given a certain amount of land for maize production and other complementary productive assets including labor, the household utilizes these fixed assets (mainly land), and other resources such as labor and cash to generate utility as a function of its consumption. The choice facing the household is that of *implementing* CA or *not implementing* CA in the production process. As already explained, the baseline practice (no CA) involves little or no external inputs as is common among poor rural farming households.

Consider that the initial decisions are made at planting time with the harvest time being four to six months later, so that (for simplicity) this constitutes a two period discreet time framework. Recall that most of the costs of production must be incurred up-front, from savings, credit or other non-crop income. Alternatively if farmers have adequate autonomous or market-purchased food supply, then instead of selling their labor to buy food or using savings for the same, they use it on their own farms to grow maize. This is especially a critical issue during peak labor demand periods when on-farm operations may demand labor at a time when food stocks from previous harvests have been drawn down and purchases are now necessary. This is the reason measure of liquidity (credit access); off farm employment among other covariates can be important predictors of who adopts a new agricultural innovation. In rural settings where own production is (often) the only source of food, a subsistence constraint that specifies what must be consumed during the year is an important consideration. Also, a budget constraint can set the upper limits for consumption and liquidity and a credit constraint, reflected in low savings or inability to access credit can limit the ability to purchase needed inputs at the critical production window. These constraints can be ameliorated by specific policies.

4.2 Macro level policy variables

4.2.1. Agricultural extension, information and human capital formation

In agricultural economies of SSA, extension services remain one of the most critical public investments and rural services. Recent interest in reforming agricultural extension services

[2] The time lapse between sowing and harvesting could be between six to eight months in the four countries.

has given new impetus to revamping these services, which suffered neglect subsequent to the 1980s (Rivera and Alex 2004, Pye-Smith, 2012). These declines were partly due to unsustainable expansion during the 1980s and the need for public sector contraction as part of the structural adjustment reforms. At the peak of investments in extension in the pre-adjustment years, the developing country average of extension-agent-to-farmer-ratio was 1 in 300 and that declined to 1 in 1500-3000 by 2012 (Pye-Smith, 2012).

An effective extension system can make available the information needed to make CA profitable or educate farmers on the long term benefits and the need to accept benefits that come with a lag and to implement recommended practices properly in order to attain full/maximum benefit. Yet in SSA and our study countries, extension institutions are largely publicly funded with extension personnel being part of the broader cadres of government employees. Yet in view of existing challenges to agricultural extension, the issue of investing in and improving extension a critical one. These challenges include few extension personnel serving many farmers spread over large areas, low willingness to pay for extension services by users and lack of technical skills among some extension personnel. This is because the major role of extension is the building human capital by imparting the knowledge, skills and managerial abilities needed for successful farming. This is one reason why a measure of extension, its effectiveness and message content can proxy for human capital formation in agriculture (Coen and Eisner, 1987 cited in Zapeda, 2001). For example, in a study on the impact of extension in Ethiopia, it was shown that contact with extension at least once during the production year led to a 7% production increase and 10% poverty reduction (Dercon et al. 2008).

Reflecting the new impetus for extension, the Ethiopia government has recently been investing considerably in agricultural extension specifically the number of frontline extension staff. An indicator of the levels of this investment is found in Davis et al (2010) which showed that given these efforts, Ethiopia was on track to have one of the most favorable ratios of extension personnel-to-farmer-ratios (at 16 per 10,000 farmers at the time of publishing Davis et al (2010). This ratio was projected to rise to 21 per 10,000 in short order (Davis et al. 2010). The extension-to-farmer-ratio in Ethiopia is certainly high, if compared to 4 in Tanzania, 3 in Nigeria, 6 in Indonesia and 2 in India and 16 in China (Davis et al. 2010). Compare this with the recommendation in Pye-Smith (2012) that a good ratio of extension agents would be about one extension agent for every 300 farmers or 33 extension agents per 10,000 farmers, suggesting that Ethiopia may be halfway towards this threshold.

In Kenya, smallholder farmers have traditionally benefited from two major types of extension systems; (i) the government extension system, and (ii) the commodity-based systems run by government parastatals, out grower companies, and cooperatives. However, reflecting the hard times that the extension system has gone through, the budget for extension services declined from 6% of the annual government budget in the 1980's to only 2% (in real terms) in the years since then (Muyanga and Jayne 2006). A new extension policy has just been published by the government (GoK, 2013), reflecting a re-focus on extension. The government extension services remain the major provider of extension services in Malawi (Masangano and Mthinda, 2012). The new extension policy, launched in 2000, under the heading *Agricultural Extension in the New Millennium: Towards Pluralistic and Demand-Driven Services in Malawi*, has a bottom-up and participatory strategy for planning interventions (Masangano and Mthinda, 2012). In Tanzania, like the rest of the study countries, agricultural extension services are provided by the public sector through the Ministry of Agriculture. Recently, there have been efforts reflected in the National Agriculture Policy of 2007 which states the government's intension to increase the number of extension workers by 15,082 in 2015 (Daniel 2013). The common thread in the four countries is that there is renewed policy focus on agricultural extension to expand the space for more providers and increase government spending in extension systems by increasing the number of staff.

4.2.2. Market access, input-output prices and incentives for technology adoption

The late 1980s through to the 1990s was an important era of change in the economies of many SSA countries. Hitherto, the agricultural sectors had been dominated by state controlled institutions and agricultural markets (especially grain markets) which were controlled by state monopolies with many restrictions on private commerce in these sectors (Jayne, Chapoto, and Shiferaw, 2011). The liberalization reforms (structural adjustment programs) of this period included the removal of restrictions on private commerce in agriculture and removal of pan-territorial and pan-seasonal pricing among other reforms. There has been noticeable progress in many countries since then as evidenced by the entry of large numbers of small traders and greater competition in grain markets. Nevertheless, outstanding issues remain which prevent these sectors from attaining the fullest efficiency. These revolve around inadequate infrastructure and weak agricultural supply chains. The effect being high input prices and low effective prices for produce. These impediments hamper technology adoption because they make otherwise beneficial technologies (e.g. hybrid –fertilizer combinations, herbicide-based conservation methods) inaccessible or expensive. Poor infrastructure leads to market isolation and lack of integration with national or regional markets implying that any increased production can undermine producer prices, erode profitability and undermine technology use. Due to poor infrastructure, fertilizer/grain price ratios in SSA have been found to be two times those found in Latin America or Asia a (Yamano and Arai, 2010).

4.2.3. The role of subsidies under unfavorable fertilizer and crop price regimes

The return of fertilizer subsidies in SSA in recent years comes after a period of their absence in the wake of the aforementioned structural adjustment programs of the 1980s and 1990s. At their peak in the 1960s and 1970s the main reasoning was that the lessons from the Asian green revolution showed that subsidies were crucial in supporting the widespread adoption of improved seeds and fertilizers. Consequently, public expenditures on subsidies have been considerable in countries that have chosen to implement them. For example, Malawi spent about 72% of its agricultural budget in 2008/09 on agricultural input subsidies (Dorward and Chirwa 2010). Such policy of increasing government investment on subsidies has inevitably led to a number of challenges including high fiscal costs and crowding out investment in other areas of agricultural development.

How do input (mainly fertilizer) subsidies relieve financial, liquidity, profitability or infrastructural constraints? Carefully targeted subsidies can enable liquidity constrained farmers to overcome short-term financing constraints. Keeping other things constant; by lowering the overall costs of inputs these farmers may find it easier to use fertilizer and other complementary practices such as CA. There is a consensus that whether a subsidy policy achieves its objectives will depend on a number of conditions being met. The conditions would include creating programs that are “market smart” to jumpstart agricultural input markets (since subsidies can be helpful in stimulating the demand side of agricultural input value chains), underwriting risks for adoption of technology to facilitate scaling up, and having credible exit options (Smale, Byerlee and Jayne 2011).

5. Empirical approach

5.1. Estimating the adoption equation

When presented with the decision to implement CA or not, farmers are essentially making a binary choice. There are several elements in this choice process including the environment in which farmers operate and the observed household and farm characteristics of the decision maker (e.g. gender, educational attainment, age, plot characteristics) and unobserved attributes (risk attitudes, motivation, etc.). We use a set of farm household and environment indicators in a binary Probit model to estimate the factors that affect plot level adoption of conservation agriculture in the study sites.

5.2. Policy Simulation framework

We implement a series of policy simulations on the base model results to compare the predicted probabilities of adoption under different policy scenarios. Specifically, we simulate the following policy scenarios based on the predicted probabilities obtained from the probit model:

(a) $\mathrm{E}[Pr(CA_i|\mathrm{p}_i)]$, is the base scenario, the expected probability of CA adoption in *country i when the policy variable takes on the country specific value in each country,* where *i*=Ethiopia, Kenya, Malawi and Tanzania.

(b) $\mathrm{E}[Pr(CA_i|p)]$, is the predicted probability of CA adoption in *country i when the policy variable takes on the average value across all countries, p.*

(c) $\mathrm{E}[Pr(CA_i|\mathrm{p}_j)]$, is the expected probability of CA adoption in *country i when the policy variable takes on a specific alternative policy* (i.e. $i \neq j$*)*. In this case *j* would be policy specifically based on another country within our sample which best typifies the policy in question.

Finally, in a fourth category (**d**) of comparisons we combine different policy variables to reflect the fact that policies do not work in isolation and to capture the different policy permutations possible in the real world and the implied interaction effects by simulating what the predicted probabilities would be if a particular policy value was combined with a different policy level e.g. high numbers of extension staff but low input subsidies or low fertilizer-maize price ratios with low input subsidies. Therefore:

(d) E$[Pr(CA_i|p_{i,}p_{j,})]$, is the expected probability of CA adoption in *country i when the policy variable takes on a combination of alternative policies*. In this case *j* would be a set of two policies specifically based on 1-2 countries within our sample which best typifies the policy in question.

6. Data and data sources

The empirical analysis uses household- and plot-level data gathered in 2010/11 in Kenya, Malawi, Ethiopia, and Tanzania. The survey was conducted by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with the respective countries' national agricultural research institutes (NARIs).

In Ethiopia, the survey was carried on selected maize-legume based farming systems in different regions of the country (SNNP, Benshangul- and Oromya regions). A multi-stage sampling was employed to select households to be included in the survey. In the first stage nine districts were selected purposively based on the importance of maize and the associated agroecology (Bako Tibe, Gubuesyo, Shalla, Dudga, Adami Tullu, Mesrak Badawacho, Meskan, Hawassa Zuriya and Pawe). In the second stage, 69 Peasant Associations (PAs) were randomly picked from a list of PAs in each district. At the final stage, 896 households were randomly selected from each PA; with the number of households selected from each PA proportional to the number of the households in the PA.

In Kenya, five districts were selected (two districts from western Kenya region (Bungoma and Siaya) and three districts from eastern Kenya region (Embu, Meru South and Imenti South). The two regions were assigned an equal number of sample households (300 each). The households in a region were distributed across the respective districts according to the total number of farm households per district (proportionate sampling). Multi-stage sampling was employed to select lower level sampling clusters: divisions, locations, sub-locations, and villages. In total, 30 divisions were selected – 17 from western Kenya and 13 from Eastern Kenya. Efforts were made to ensure representation of the sample depending on the population of the study areas. Proportionate random sampling was designed to select divisions from each district, sub-locations from each division, villages from each sub-location, and households from each village.

In Malawi as with the rest of the countries, purposive sampling was used in the first stage to select regions of the country where smallholder maize farming is important. Stratified sampling was used to select six districts; five in the Central region (Lilongwe, Kasungu, Mchinji, Salima and Ntcheu) and one (Balaka) in the South. Eventually, 64 Extension Planning Areas (EPA's), 89 Sections and 235 villages were selected using multi-stage random sampling combined with probability to proportional size. Similarly, using the same process, 891 households from the 235 villages were selected for this study.

In Tanzania the survey targeted two maize-legume based farming systems in the eastern and northern zones of Tanzania (Kilosa and Mvomero in the eastern zone and Mbulu and Karatu districts in the northern zone). These districts were purposively selected followed by multi-stage random sampling to arrive at a total sample of 60 villages and using probability to proportional size, a final tally of 701 households were interviewed. From the four countries, the total data set comprised of 2,736 farm households and 11,188 maize plots from 700 villages in 43 districts.

6.1. Household variables descriptive Statistics

We summarize the descriptive statistics in Table 1. These data show that CA was variously used in the study sites of Ethiopia (30%), Kenya (4%), Malawi (35%) and Tanzania (11%) respectively with a pooled sample average of 22%. The demographics of the farming population as per this sample show that on an average, the farmer in Kenya was older (50 years) compared to the Tanzania (45 years), Ethiopia (43 years) and Malawi (42 years). The Kenyan farmer had on average 7.5 years of formal schooling compared to 3.0, 5.7 and 5.4 in Ethiopia, Malawi and Kenya, respectively. Only a minority had any non-farm sources of income; 23% of the Kenyan households has non-farm source of income, followed by Malawi (13%), Tanzania (6%) and Ethiopia (5%). The average household size appears to be within a narrower range in all the three countries ranging from 5 members in Malawi to 7 members in Ethiopia. As expected households in Ethiopia had the highest livestock numbers (6.24 TLUs or tropical livestock units) and Malawi had the lowest at 0.72 TLUs. The farm size of cultivated during the major agricultural season was 2.8 ha in the pooled sample and was least in Kenya at 1.32 ha and highest Tanzania (4.7 ha) followed by Malawi (3.4 ha) and Ethiopia (2.6 ha). The value of non-livestock assets was highest in Ethiopia ($ 883) and least in Tanzania ($152). The data on credit constraint shows that typically about 50% of households reported needing credit and not finding it. In Ethiopia, Kenya and Malawi credit constrained households were 56%, 45% and 49%. In Tanzania relatively few (26%) of households reported needing credit and not finding it. Overall, 25 percent of the farmers belonged to any farmers' groups. Similar proportion was observed in Tanzania. Malawi had the highest proportion (39 percent) of farmers belonging to any farmer groups and Kenya and Ethiopia the proportion was approximately 20%.

Table 1 Variable Definitions

	Pooled (N=11,188)		Ethiopia (N=3,861)		Kenya (N=2851)		Malawi (N=2937)		Tanzania (N=1539)	
Variable Description	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Conservation agriculture practices on plot	0.22	0.41	0.30	0.46	0.05	0.21	0.35	0.48	0.11	0.31
If household head is male (yes =1)	0.87	0.33	0.94	0.24	0.82	0.39	0.83	0.37	0.88	0.32
Age of the household head (years)	45.0	14.2	42.5	12.7	50.7	14.3	42.4	14.4	45.9	13.8
Education of the household head (years completed)	5.21	3.96	3.03	3.33	7.54	3.82	5.73	3.74	5.40	3.16
Household has some non-farm income (yes=1)	0.35	0.48	0.05	0.22	0.23	0.42	0.13	0.34	0.06	0.24
Number of family members	5.98	2.56	6.81	2.60	5.85	2.70	5.21	2.17	5.65	2.29
Tropical Livestock Equivalent (TLU)	4.75	61.19	6.24	5.74	2.40	2.47	0.72	1.74	3.49	7.15
Total farm size in long rain season (ha)	2.75	3.12	2.58	1.85	1.32	3.14	3.38	2.60	4.66	4.78
Total non-livestock assets owned by the household in USD$	647	1163	883	1371	740	1134	506	1033	152	507
Household is credit constrained (yes=1)	0.47	0.50	0.56	0.50	0.45	0.50	0.49	0.50	0.26	0.44
Respondent confident in extension provider (yes=1)	0.28	0.45	0.29	0.45	0.26	0.44	0.25	0.43	0.39	0.49
Perceived plot soil fertility (1=Poor, 2=Medium, 3=Good)	2.29	0.65	2.40	0.61	2.18	0.65	2.34	0.70	2.11	0.52
Perceived plot slope (1=Gentle/flat, 2=medium slope, 3=Steep slope)	1.49	0.61	1.36	0.54	1.57	0.57	1.49	0.69	1.70	0.63
Perceived plot soil depth (1=shallow, 2= medium, 3= deep)	2.17	0.70	2.19	0.79	2.06	0.59	2.25	0.73	2.18	0.55
Number of grain traders from outside village known to respondent	4.26	6.20	4.21	5.35	3.52	3.59	6.14	6.04	2.19	10.10
Number of grain traders from within village known to respondent	2.52	4.84	1.81	2.68	3.14	3.87	2.96	4.99	2.31	8.64
Number of non-relatives outside village respondent can rely on for help	4.27	8.30	4.93	10.84	5.98	8.80	2.66	4.00	2.54	4.23
Number of non-relatives within village respondent can rely on for help	5.18	9.60	6.91	13.54	5.62	8.63	3.15	4.06	3.91	4.81
Number of relatives outside village respondent can rely on for help	5.02	8.02	6.12	9.52	5.98	8.80	3.17	3.47	4.00	7.87
Number of relatives outside village respondent can rely on for help	4.74	6.55	5.50	6.86	5.62	8.63	3.41	3.34	3.78	5.23
Household head belongs to a farmers' association (cooperatives etc.) 1= yes, 0 otherwise	0.25	0.44	0.20	0.40	0.19	0.40	0.39	0.49	0.25	0.43
Perception of main road out of village (1=poor or very poor, 2=Average, 3=Good or very good)	1.94	0.82	1.73	0.83	1.88	0.81	2.26	0.74	1.96	0.78
Cost in US$ of reaching main market by typical means	0.53	0.69	0.27	0.22	0.62	0.43	0.63	0.71	0.84	1.32
Distance to market at from household's residence	8.92	6.39	8.95	3.79	6.05	4.42	8.67	4.82	14.62	11.49

6.2. Policy and market access variables descriptive statistics

Table 2 shows the policy and market access variables used in the policy simulations as well as the sources for these data. We chose the policy and market access data for the year 2010 because the time the household data was collected. In cases where the data for 2010 were not available, we chose the data for the year nearest to 2010. In terms of extension–personnel-to-farmer-ratio (EFR) - measured as the number of frontline staff per 10,000 farmers- Ethiopia had the highest EFR at 16, followed by Kenya (10), Malawi (6) and Tanzania (4). Malawi spent the most (58.9%) on input subsidies as a percent of government's agricultural budgets (SER) between 2009 and 2011 compared to Ethiopia (10%), Kenya (19%) and Tanzania (46%). The fertilizer-maize-price-ratio (FMPR) was highest in Kenya (3.5) and lowest in Tanzania (1.8) and was 2.9 and 2.3 in Ethiopia and Malawi, respectively. Yet the distance to the nearest market was 15 km in Tanzania (the highest), 9 km in Malawi and 6.4 km and 6.0 km in Ethiopia and Kenya, respectively (Table 1). This perhaps raises an apparent contradiction between FMPR and distance to market. However the low FMPR in Tanzania and Malawi may be the result of the very high input subsidy (mainly fertilizer subsidies) in these countries. The Tanzanian subsidy model for example has emphasized subsidy on transportation thereby mitigating the effect of long distances to markets on FMPR. In both Malawi and Tanzania, the high subsidies may have led to a generalized decline in market prices for fertilizer.

Table 2: Policy simulation variables

	Ethiopia	Kenya	Malawi	Tanzania	Average
Extension personnel per 10,000 farmers (EFR)					
	16.0	10.0	6.2	4.0	9.0
Period	2010	2012	2008	2010	2008-2012
Source[a]	Davis et al. (2010)	GoK (2012)	Pablo et al. (2008)	Davis et al. (2010)	
Input subsidy expenditure as a percent of public agriculture spending (%) (SER)					
	10.4	19.0	58.9	46.0	33.6
Period	2009-2011	2009-2011	2009-2011	2009-2011	2009-2012
Source	Jayne and Rashid (2013)	Jayne and Rashid (2013)	Jayne and Rashid (2013)	Jayne and Rashid (2013)	
Farm gate maize prices (US$/kg)					
	0.158	0.230	0.170	0.189	0.187
Period	2010	2010	2010	2010	2010
Farm gate fertilizer prices (US$/kg)					
	0.455	0.807	0.392	0.344	0.500
Period	2010	2010	2010	2010	2010
Fertilizer-maize price ratios (FMPR)					
	2.9	3.5	2.3	1.8	2.7
Period	2010	2010	2010	2010	2010

[a]Source: Authors' computations unless otherwise indicated

7. Results and Discussions

7.1 Results from adoption model:

Table 3 presents the results from the adoption model. Since the objective of this paper is to simulate the effects of policy variables discussed above, we briefly discuss the adoption model results mainly focusing on the policy variables. Distance to the nearest market had a negative but not significant impact on adoption of CA. The higher the EFR and the higher the percentage of public agricultural expenditure spent on input subsidies (SER), the more likely was adoption of CA. The lack of credit was negatively and significantly associated with adoption of CA. Those households where the head belonged to a farmers' association and the higher the number of non-relatives the household could rely on for help, the more likely were such households to have implemented CA. This suggests the strong influence of social connectivity as predictor of agricultural technology adoption either through information or resource flows and other mutual support systems. All the signs of the other variables are intuitive and we do not observe any effects that may be considered counterintuitive from either a theoretical point of view or from the literature. In the following section we report the results from the policy simulations based on the estimated probit model (reported in Table 3).

Table 3: Probit Estimate of factors that affect plot level adoption of conservation agriculture in Ethiopia, Kenya, Malawi and Tanzania

Variable	Coefficient
Sex of the household head	0.098**
	(0.049)
Age of the household head (years)	-0.001
	(0.001)
Education of the household head (years completed)	-0.010**
	(0.005)
Household head had salaried income (yes=1)	-0.238***
	(0.064)
Number of household members	-0.000
	(0.007)
Tropical Livestock Equivalent (TLU)	0.000
	(0.000)
Total farm size in long rain season (ha)	-0.005
	(0.006)
Total non-livestock assets owned by the household in US$	0.000
	(0.000)
Number of grain traders from outside this known to household head	-0.010***
	(0.003)
Number if grain traders within village known to household head	0.008**
	(0.003)
Number of non-relatives living outside this village that the household can rely on for help	0.006**
	(0.003)
Number of non-relatives living in this village that the household can rely on for help	0.010***
	(0.002)
Number of relatives living outside this village that the household can rely on f	-0.007**
	(0.003)
Number of relatives living in this village that the household can rely on for help	-0.002
	(0.003)
Household head belongs to a farmers' association	0.106***
	(0.034)
If credit is needed but unable to find it	-0.152***
	(0.032)
Household head confident in skill of extension staff	0.033
	(0.033)
Plot is of medium soil fertility (base=poor quality)	0.024
	(0.053)
Plot is of good soil fertility (base=poor quality)	-0.111**
	(0.054)
Plot is of medium slope (base = flat gradient)	0.126***
	(0.033)
Plot is of steep slope (base = flat gradient)	-0.208***
	(0.065)
Plot is of medium soil depth (base=shallow depth)	-0.128***
	(0.042)
Plot is of deep soil (base=shallow depth)	-0.237***
	(0.042)
Distance to nearest main agricultural market	-0.004
	(0.003)
Average single trip transport cost to the main (US$)	-0.000***
	(0.000)
Extension personnel per 10,000 farmers	0.058***
	(0.013)
Percent spent on input subsidies as a percent of public agricultural spending	0.027***
	(0.004)
Constant	-2.495***
	(0.274)
Model Statistics	
Observations	11,188
Log likelihood	-4737.995
LR chi2	2295.32***
Pseudo R^2	0.195

7.2. Policy Simulations

7.2.1 Extension simulations

Changing individual country's extension to farmer ratios (EFR): The impact of extension to farmer ratio (EFR) on the predicted probability of CA adoption (hereafter probability of adoption) is high across all countries (Table 4). In the pooled sample, the probability of adoption is about 17.0 percent in the base case (corresponding to a whole-sample average mean EFR value of 9 12) and this increases to 21.4 percent when Ethiopian EFR value (16) is assumed (Table 4). In Kenya, the probability of adoption increases from 3.9 to 6.5 percent by increasing the EFR from 10 to 16. Similarly, in Malawi (Tanzania) the probability of adoption increases from about 3.4 percent to about 5 percent (10 percent to 21.4 percent) given the EFR increase from 6 to 16 (and 4 to 16) in Malawi (Tanzania) respectively. The effect of reducing the Ethiopian EFR from 16 to 9 (whole-sample average) lowers the probability of adoption among Ethiopian farmers from 26 percent to about 13% and with marginal effects in Kenya since the reduction in EFR was also small (from 10 to 9). Since setting the EFR at sample average involves an increase in EFR for the other two countries, the probability of adoption increased in either case, from 34 to 38 and 10 to 14 percent in Malawi and Tanzania respectively. When EFR was changed from each sub-sample mean to either Ethiopian subsample mean or pooled sample mean, the average[3] elasticity of the predicted probability of CA adoption (hereafter elasticity of adoption) was such that increases the EFR by 1 percent would lead to an average of 0.8 percent increase in the probability of adoption in the whole sample simulation (Table 5).The average elasticity was approximately 2.0 in Ethiopia and approximately 0.35 in Kenya, 1.0 in Malawi and 0.3 in Tanzania (Table 4).

Table 4: Extension Simulations

	Predicted probability of CA Adoption by sample)				
	Whole sample	**Ethiopia**	**Kenya**	**Malawi**	**Tanzania**
Base case (A)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
Panel I: *Effect of changing Extension-Staff-to-Farmer-Ratio (EFR): for each country set EFR at Ethiopian level*					
EFR at whole sample mean (**B**)	NA	0.126*** (0.040)	0.036*** (0.004)	0.384*** (0.022)	0.139*** (0.019)
EFR at Ethiopian mean (**C**)	0.214*** (0.019)	NA	0.065*** (0.013)	0.498*** (0.067)	0.214*** (0.057)
Chi-square tests					
A=B	NA	8.60**	7.09**	6.0**	4.61**
A=C	5.47***	NA	4.47**	5.91**	4.10**
Elasticities of adoption wrt EFR					
A to B	NA	1.997	0.975	0.138	0.205
A to C	0.795	NA	1.111	0.284	0.387
Panel II: *Effect of low EFR and high subsidy (SER): For each country set EFR Tanzania's level and SER at Malawi's level*					
At Tanzania's EFR *and* Malawi's SER (**D**)	0.213*** (0.023)	0.301*** (0.037)	0.092*** (0.029)	0.308*** (0.014)	0.142*** (0.019)
Chi-square tests **A=D**	3.85*	1.31	3.60*	6.50*	5.62*
Panel III: *Effect of high EFR with low SER*					
At Ethiopia's EFR *and* Ethiopia's SER (**E**)	0.129*** (0.015)	NA	0.048*** (0.006)	0.201*** (0.047)	0.080*** (0.015)
Chi-square tests **A=E**	7.22**	1.31	3.61*	7.89*	2.35
Panel IV: *Effect of high extension with complete absence of credit: for each country set credit constraint at 1 and EFR at Ethiopia's level*					
No credit available and EFR at Ethiopia's level (**F**)	0.192*** (0.019)	0.179*** (0.022)	0.056*** (0.011)	0.469*** (0.067)	0.184*** (0.051)
Chi-square tests **A=F**	1.75	12.16***	2.33	4.04*	2.73*
Observations	11,188	3,861	2,851	2,937	1,539

Reducing extension (EFR) but increasing subsidies (SER): In Table 4, we also report simulation results of what happens to probability of adoption when extension is reduced (by setting it at Tanzanian level) and at the same time increasing SER (hereinafter simply referred to as subsidy) by setting it at Malawi's level of 58.9 percent. The results suggest the powerful impact of subsidy expenditures on probability of adoption. Despite reducing EFR in Ethiopia by 75 per cent, the probability of adoption increases by about 4 percentage point (from 26 to 30 percent). The result for Malawi provides a "counterfactual" in this case. Since the SER stayed the same only the EFR reduced to Tanzanian level and the probability of adoption reduced in Malawi's case from about 34 to31 per cent. For all the other countries (including pooled sample), the increased SER appear to more than compensate the reductions in EFR, so that probability of adoption increases despite reductions in EFR (Table 4, panel II).

Increasing extension (EFR) and reducing subsidies (SER): In panel III of Table 4, the results show the effect of increasing EFR to compensate for reductions in SER as a policy alternative. This simulates for the other countries what would happen if the EFR and SER combinations were similar to Ethiopia's. This combination leads to a marginal increase in probability of adoption in Kenya. For the pooled, Malawi and Tanzanian sample the probability of adoption declines by between 2 percent (Tanzania) and 14 percent (Malawi). This is intuitive because in this setting, even though Tanzania had a 78 per cent reduction in SER, the EFR was increased by 300 per cent. This could be responsible for the (relatively) small (2 point drop) compared to 14 points for Malawi even though both had large reductions in SER.

Increasing extension (EFR) with no credit availability: In these simulations (Panel IV of Table 4), the compensatory effect of high extension with an assumed lack of credit is demonstrated. This was achieved by setting the EFR at the highest Ethiopian level, and making the credit constraint variable to be binding for all famers. The results show that in all cases (except Ethiopia) adoption increased: Kenya (16), Malawi (13) and Tanzania (8) and overall (2). The decrease in probability of adoption in Ethiopia provides a useful benchmark for demonstrating the effect of credit constraint on probability of adoption: the probability of adoption fell from 26 to 18 percent by making all households credit constrained (up from 56 percent, whereas EFR is unchanged).

7.2.2. Subsidy simulations

Changing individual country's input subsidies (SER): In panel I of Table 5, the results show that when SER is set at whole sample mean (33.6), the probability of adoption falls in Malawi (by 14 per cent) and in Tanzania (by 3 percent). The whole sample SER average of 33.6 percent entails an increase in SER and hence probability of adoption. Setting SER at the Malawian level increases probability of adoption by more than 100 percent in Ethiopia and Kenya and by about 40 percent in Tanzania. In terms of elasticity, a policy that increases the SER by 1 percent would lead to an average of 1.2 percent increase in the probability of adoption in the whole sample simulation (Table 5).This (average) elasticity was approximately 0.25 in Ethiopia and approximately 1.1 in Kenya, 1.0 in Malawi and 1.4 in Tanzania. Overall the elasticities reported in Table 4 and 5 suggest that the responsiveness to adoption arising from changes in EFR or SER are roughly of similar order of magnitude.

Reducing (increasing) subsidies (SER) and increasing (reducing) credit: In Panel II and III of Table 5, we compare the compensatory effects between subsidies (SER) and credit. In panel II, lowering SER and increasing credit (by treating every household as if they all had credit) leads to lower probability of adoption in all cases (including the pooled sample) except in Ethiopia. The Ethiopia outcome provides a benchmark because in this case the SER was unchanged but credit constrained removed hence probability of adoption increased – albeit by only 3% points from 26 to 29 percent. In panel III, the simulation involved assuming no credit was available with subsidy at the highest (Malawian) level. In this case the probability of adoption increased in all cases except in Malawi where the reduction in credit availability with EFR staying the same, led to a reduction in probability of adoption from 34 to 31 percent.

Table 5: Subsidy Simulations

SER level	**Whole sample**	**Ethiopia**	**Kenya**	**Malawi**	**Tanzania**
Base Level (A)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
Panel I: *Effect of changing input subsidy as a percent of public expenditure on agriculture (SER): for each country set SER at Malawi's level*					
			Predicted probability of CA Adoption by sample		
At whole sample mean (**B**)	NA	0.401*** (0.060)	0.065*** (0.013)	0.197*** (0.045)	0.067*** (0.013)
At Malawian mean (**C**)	0.319*** (0.67)	0.572*** (0.126)	0.140*** (0.057)	NA	0.143** (0.019)
Chi-square tests					
A=B	NA	5.90**	4.80**	9.27***	9.91***
A=C	5.12**	6.38**	3.11*	NA	5.62**
Elasticities of adoption wrt SER					
A to B	NA	0.248	0.868	0.971	1.199
A to C	1.194	0.261	1.233	NA	1.585
Panel II: *Effect of low subsidy with full credit availability: for each country set SER at Ethiopia's level and credit constraint at 0*					
At Ethiopia's SER *and* no credit constraint (**D**)	0.109*** (0.024)	0.285*** (0.010)	0.033*** (0.006)	0.119*** (0.062)	0.031*** (0.017)
Chi-square tests					
A=D	6.15**	19.3***	2.54	11.83***	17.93***
Panel III: *Effect of high subsidy with no credit available: for each country set credit constraint at 1 and SER =at Malawi's level*					
At Malawi's SER *and* no credit available (**E**)	0.292*** (0.064)	0.547*** (0.126)	0.124*** (0.052)	0.312*** (0.010)	0.120*** (0.017)
Chi-square tests					
A=E	3.80*	5.34*	2.61	20.96***	1.63
Observations	11,188	3,861	2,851	2,937	1,539

7.2.3. Fertilizer-maize price ratio simulations

Changing fertilizer-maize price ratios ***(****FMPR):* A high fertilizer-maize price ratio (FMPR) can mean either fertilizer prices are high relative to those of maize grain or maize prices are low relative to those of fertilizer. If FMPR is high because of relatively high fertilizer prices then the probability of adoption can be expected to decrease if fertilizer is seen as a critical component for CA to succeed. If FMPR is high because of relatively low maize prices, then this too can reduce the profitability of fertilizer and maize production generally, thereby discouraging CA adoption. In Table 6 we simulate the impact of FMPR on probability of adoption when the FMPR takes on the whole sample mean and the lowest value observed (1.8 in Tanzania). When the FMPR was set at the whole sample mean, hence *increasing* FMPR for Malawi and Tanzania, then the probability of adoption *reduced* somewhat in both cases. Reducing the FMPR to Tanzanian levels would increase probability of adoption in all cases.

Table 6: Fertilizer-maize price ratio (FMPR) simulations

	Predicted probability of CA Adoption by sample				
FMPR level	**Whole sample**	**Ethiopia**	**Kenya**	**Malawi**	**Tanzania**
Base Level (A)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
Panel I: *Effect of increasing fertilizer maize price ratio (FMPR): for each country set FMPR at Tanzania's level*					
At whole sample mean (**B**)	NA	0.268*** (0.010)	0.051*** (0.007)	0.315*** (0.015)	0.076*** (0.009)
At Tanzanian mean (**C**)	0.207** (0.021)	0.316*** (0.031)	0.067*** (0.016)	0.367*** (0.016)	NA
Chi square tests					
A=B	NA	4.04**	3.54*	4.28**	4.38*
A=C	3.65*	3.76**	2.89*	4.04**	NA
Elasticities of adoption wrt FMPR					
A to B	NA	-0.562	-1.346	-0.391	-0.465
A to C	-0.696	-0.593	-1.478	-0.395	NA
Panel II: *Effect of high FMPR with high EFR: for each country set FMPR at Kenya's level and EFR at Ethiopia's level*					
At Kenya's FMPR *and* Ethiopia's EFR (**D**)	0.181*** (0.029)	0.171*** (0.017)	0.065*** (0.013)	0.424*** (0.091)	0.145*** (0.063)
Chi-square tests					
A=D	0.21	22.94***	4.47*	0.93	0.51
Panel III: *Effect of low FMPR with low EFR: for each country set FMPR and EFR at Tanzania's level*					
Both FMPR and EFR at Tanzania level (**E**)	0.127*** (0.038)	0.119** (0.065)	0.040*** (0.018)	0.336*** (0.023)	NA
Chi-square tests					
A=E	1.22	4,32*	0.01	0.01	
Observations	11,188	3,861	2,851	2,937	1,539

Increasing (reducing) FMPR and increasing (reducing) extension[4]*:* An increased FMPR combined with high EFR only had significant effects in Ethiopia and Kenya. For Ethiopia the increase in FMPR significantly reduces probability of adoption (EFR stays unchanged) but for Kenya where EFR increases (from 10 to 16 and FMPR remains constant), the probability of adoption increases from 4 to 6 percent. Therefore, the co-increase in EFR and FMPR tend to mute and cancel each other out – albeit suggesting perhaps a stronger effect of extension. The result in panel III, appear to corroborate the results in panel II. The reduction in FMPR (effectively cheaper fertilizer or more remunerative maize prices), does not lead to higher increased probability of adoption apparently because of the reduced EFR (set at 4, the Tanzanian level). However the reductions are not statistically significant except in Ethiopia where the effect of 75% EFR reduction appear to have a significant effect.

7.2.4. Distance to market simulations

The distance to market (DTM) simulations show that there are marginal increases[5] in the probability of adoption when DTM is reduced (suggesting market access can be associated with higher adoption). The average DTM across all four countries was 8.9 km and reducing this to 6.1 km (the Kenyan average) increased the probability of adoption from 16.8% to 17.5% (a 0.7% point increase) (Table 7). In the Ethiopian, Malawi and Tanzania DTM simulations, reducing the DTM to the Kenyan levels (which translate to 32%, 30% and 58% reductions respectively) increase the probability of adoption by 0.9, 0.8 and 1.4 percent points respectively). All the elasticities of adoption with respect to DTM are less than -0.2. The exception was Tanzania which was 0.24, the largest). These small increases were nevertheless all statistically significant at the 1 percent level.

[4] Note that we do not compare FMPR with SER for the following reasons. FMPR is computed from the subsidized fertilizer price data reported by farmers. Thus, FMPR cannot remain the same when SER is set to zero. Subsidy (measured by SER) has a direct effect on FMPR. So it is counterintuitive to keep FMPR constant when varying input subsidies (which for all practical purposes are fertilizer subsidies in the study countries).

[5] Given the small increases in probability of adoption observed for DTM in Table 7, we refrained from simulating other DTM iterations.

Table 7: Distance to Market (DTM)

	Predicted probability of CA Adoption by sample				
Extension: farmer ratio level	**Whole sample**	**Ethiopia**	**Kenya**	**Malawi**	**Tanzania**
Base Level (A)	0.168*** (0.004)	0.258*** (0.008)	0.039*** (0.004)	0.338*** (0.009)	0.099*** (0.008)
Panel I: *Effect of reducing the distance to market (DTM): for each country set the DTM at Kenya's level*					
At whole sample mean (**B**)	NA	0.258*** (0.008)	0.037** (0.004)	0.337*** (0.009)	0.108*** (0.009)
At Kenyan mean (**C**)	0.175*** (0.005)	0.267*** (0.009)	NA	0.346** (0.010)	0.113*** (0.10)
Chi square tests					
A=B	NA	9.35***	9.29***	9.37***	8.75***
A=C	9.16***	9.20***	NA	9.27***	8.50***
Elasticities of adoption wrt DTM					
A to B	NA	0.0000	-0.1117	-0.1287	-0.2329
A to C	-0.132	-0.110	NA	-0.079	-0.246
Observations	11,188	3,861	2,851	2,937	1,539

8. Conclusions and policy implications

In this paper we set out to determine the impact of extension-personnel-to-farmer-ratio, government expenditures on input subsidies and market access variables in empirically predicting adoption of CA, controlling for household demographic, plot and market characteristics. From both the base probit and subsequent simulation results, we find that the likelihood of CA adoption was greatly enhanced by increasing input subsidies and (or) by increasing the extension-staff-to-farmer-ratio. Distance to markets was also influential: the higher the distance to markets the less likely was CA adopted.

Generally the results showed that both subsidy and extension had powerful effects on the probability of adoption depending on the base from which the effects were simulated. When the extension-personnel-to-farmer-ratios are compared to public expenditures on subsidies, the effect of the subsidy variable appears to have had the stronger effect on CA adoption judging from the simulations involving reductions in subsidy and increasing extension where the results showed that in most cases the probability of adoption dropped even when extension were increased to mitigate reductions in subsidy. Similarly when subsidy (SER) was reduced and extension (EFR) increased, probability of adoption fell nevertheless. The impact of credit availability compared to subsidy expenditures showed that when subsidy was reduced, a universal availability of credit did not prevent the probability of adoption reducing and when the simulation involved no credit but with high levels of subsidy, the probability of adoption still increased, an intuitive result because subsidy can alleviate liquidity constraints. Where fertilizer-price ratio was raised above base levels, the effect was to lower probability of adoption even when extension was increased. The strong effect of extension was clear in simulations where the extension variable was compared to credit availability. By increasing extension, the probability of adoption increased even in the complete absence of credit. The relative balance of investing extension and other public goods compared to subsidies have been made by Lohr and Salomonsson (2000) and Genius, Pantzios and Tzouvelekas (2006) because information availability is more effective in positively influencing adoption because it enables farmers to allocate resources effectively and to update their knowledge and perceptions about the profitability of new technologies.

The implications of these results are threefold. First, the power of input subsidies in predicting CA adoption suggests that lowering costs of inputs is central in encouraging CA adoption. Since subsidies are essentially ways to reduce prices of inputs, diverse options for structurally lowering input-output price ratios should be put on the policy table. These diverse options should naturally include efficient markets and supply chains to lower the costs of inputs for CA implementation. From a political economy point of view, providing input subsidies may be a tempting option to circumvent structural difficulties currently inherent in many rural agricultural markets. The merits of using this approach must however be carefully examined. Second, investing in agricultural extension systems and increasing the number of personnel (increasing the extension personnel to farmer ratio) and expanding the reach of publicly funded extension systems among other complimentary providers is a crucial element in the success of CA as was confirmed by the large positive and significant impacts of high extension to farmer ratios on probability of CA adoption in the probit model and in the simulations. Third, although CA consists of a set of practices that are resource conserving with demonstrable cost advantages and sustainable intensification dividends, the same factors known to facilitate or impede agricultural technologies generally will remain relevant for CA as well. Similar to other agricultural technologies and innovations, policy attention in support of CA should remain focused on better access to markets, solid information delivery through strong agricultural extension and creating policy and physical infrastructure to produce favorable input and output price ratios. The key policy principles in promoting CA appear to be a focus on long term strategies to reduce the costs of inputs and invest in agricultural extension.

Acknowledgement

This study was supported by the Australian Centre for International agricultural Research (ACIAR) and the Australian International Food Security Research Centre (AIFSRC) through the International Maize and Wheat Improvement Center (CIMMYT)-led Sustainable Intensification of Maize-Legume Cropping Systems in Eastern and Southern Africa (SIMLESA) program, and Adoption Pathways Project. The views expressed here are those of the authors and do not necessarily reflect the views of ACIAR, AIFSRC or CIMMYT. We are solely responsible for any errors in this paper.

References

ACT, 2008, *Linking Production, Livelihoods and Conservation;* Proceedings of the Third World Congress on Conservation Agriculture, 3 - 7 October, 2005, Nairobi. African Conservation Tillage Network, Nairobi.

Barrett, C. B. (2008). Smallholder market participation: concepts and evidence from eastern and southern Africa, *Food Policy*, 33, 299-317.

Benites, J., Chuma, E., Fowler, R., Kienzle, J., Mapolang, K., Manu, J., Nyagumbo, I., Steiner, K. and van Veenhuizen, R. (eds) (1998). *Conservation tillage for sustainable agriculture,* Proceedings from an International Workshop, Harare, 22–27 June, Part 1 (Workshop Report).

Bishop-Sambrook, C., Kienzle, C.J., Mariki, W., Owenya, M., Ribeiro, F. 2004 *Conservation Agriculture as a Labour Saving Practice for Vulnerable Households*. A Joint Study by IFAD and FAO, FAO Rome.

Coen, R.M. and Eisner, R. 1987. Investment, in J. Eatwell, M. Milgate and P. Newman, eds*., The new Palgrave Dictionary of Economics, vol 2*. Stockson Press, New York.

Corbeels M., Graaff, J., Hycenth N.T., Penot, E. , Baudron, F., Naudin, K., Andrieu, N., Chirat, G., Schuler, J., Nyagumbo, I., Rusinamhodzi, L., Traore, K., Mzoba, H.D., Adolwa, I.S. . (2014). Understanding the impact and adoption of conservation agriculture in Africa: A multi-scale analysis. *Agriculture, Ecosystems & Environment* 187, 155–170.

Daniel, E., 2013. *Assessment of Agricultural Extension Services in Tanzania. A case Study of Kyela, Songea Rural and Morogoro Rural Districts.* Internship Report. Wegeningen University, Wageningen, Netherlands.

Davis, K., Swanson, B., Amudavi, D., Mekonnen, D.A., Flohrs, A., Riese, J., Lamb, C., Zerfu, E. 2010. *In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendations for Improvement.* International Food Policy Research Institute (IFPRI) Discussion Paper No. 01041, IFPRI, Washington DC.

Dercon, S., D. O. Gilligan, J. Hoddinott, and T. Woldehanna. 2008. *The Impact of Roads and Agricultural Extension on Consumption Growth and Poverty in Fifteen Ethiopian villages*. IFPRI Discussion Paper 00840, IFPRI, Washington, D.C.

Dorward, A., Chirwa, E., 2010. *Evaluation of the 2008/9 Agricultural Input Subsidy Malawi: Notes on Regression Analysis of Maize Production*. School of Oriental African Studies (SOAS), London.

Ekboir, J. 2002. Developing no-till packages for small farmers, in J. Ekboir, ed., *CIMMYT 2000-2001 World Wheat Overview and Outlook: Developing No-Till Packages for Small-Scale Farmers.* CIMMYT, Mexico, DF.

Ekboir, J., Boa K., Dankyi, A.A., 2002. *Impact of No-Till Technologies in Ghana.* Economics Program Paper 02-01. CIMMYT, Mexico.

Erenstein, O., Sayre, K., Wall, P., Hellin, J., Dixon, J., 2012. Conservation agriculture in maize- and wheat-based systems in the (Sub)tropics: lessons from adaptation initiatives in South Asia, Mexico, and Southern Africa. *Journal of Sustainable Agriculture* 36, 180-206.

Genius, M. C.J. Pantzios and V. Tzouvelekas. 2006. Information acquisition and adoption of organic farming practices. *Journal of Agricultural and Resource Economics* 31, 93-113.

Giller, K.E., Witter, E., Corbeels, M., Tittonell, P., 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research* 114, 23-34.

Godfray, H. C. J., Beddington J. R., Crute, I. R.,Haddad, D. L., Muir, J. F. , Pretty, J., Robinson, S., Thomas , S. M., Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science* 327(5967), 812-818.

GoK (Government of Kenya), 2012. *National Agricultural Sector Extension Policy (NASEP)*. Agricultural Sector Coordination Unit (ASCU), Government of Kenya, Nairobi, Kenya

Jack, B. K., 2013. *Constraints on the Adoption of Agricultural Technologies in Developing Countries: Literature Review.* Agricultural Technology Adoption Initiative, J-PAL (Massachusets Institute of Technology) and CEGA (University of California, Berkeley).

Jaleta M., Kassie, M., Shiferaw, B. 2013. Tradeoffs in crop residue utilization in mixed crop–livestock systems and implications for conservation agriculture. *Agricultural Systems* 121, 96–105.

Jayne, T.S, Chapoto, A., and Shiferaw, B., 2011. *Improving the Performance of Staple Food Markets to Exploit the Productive Potential of Smallholder Agriculture*. Proceedings of an International Conference, 13-15 May 2009, Nairobi, Kenya

Jayne, T.S., Rashid, S., 2013. Input subsidy programs in sub-Saharan Africa: A synthesis of recent evidence. *Agricultural Economics.* 44*(*6*),* 547–562.

Lohr L., Salomonsson, L., 2000. Conversion subsidies for organic production: results from Sweden and lessons for the United States. *Agricultural Economics*, 22, 133-146.

Kassam A H, Friedrich,T., Shaxson, T. F., Pretty, J. N., 2009. The spread of Conservation Agriculture: Justification, sustainability and uptake. *International Journal of Agriculture Sustainability* 7: 292-320.

Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32(1), 25-48.

Masangano, C. and Mthinda, C. (2012). *Pluralistic Extension System in Malawi.* International Food Policy Research Institute (IFPRI) Discussion Paper No. 01171. Washington DC.

Marietha Z.O., Wilfred L. M., Josef K., Theodor F., and Amir K. (2011). Conservation agriculture (CA) in Tanzania: the case of the Mwangaza B CA farmer field school (FFS), Rhotia Village, Karatu District, Arusha. *International Journal of Agricultural Sustainability* 9(1), 145-152.

Matsumoto, T., Plucknett, D. L., Mohamed, K., 2004. *Evaluation of the Sasakawa Global 2000 Program in Ethiopia, 1992-2002*. Sasakawa Africa Association.

Mloza-Banda, H.R., 2002. Development and application of conservation agriculture in Malawi’s smallholder subsistence and commercial farming systems, in: H.R. Mloza-Banda, W.F. Kumwenda, M. Manda, and M. Bwalya, eds., *Proceedings of Workshop on Conservation Farming for Sustainable Agriculture.* Lilongwe, Malawi, 20-24 October 2002.

Muyanga, M. and T. S. Jayne. 2006. *Agricultural Extension in Kenya: Practice and Policy Lessons.* Tegemeo Working paper 26/2006. Tegemeo Institute of Agricultural Policy and Development, Egerton University, Nairobi.

Ojiem, J.O., de Ridder, N., Vanlauwe, B., Giller, K.E., 2006. Socio-ecological niche: A conceptual framework for integration of legumes in smallholder farming systems. *Int. J. Agric. Sust*. 4, 79-93.

Pablo, S., Precious, G., Kelvin, S., Alexander, L. 2008. *HIV/AIDS, Climate Change and Disaster Management: Challenges for Institutions in Malawi.* Policy Research Working Paper

4634. The World Bank Development Research Group, Sustainable Rural and Urban Development Team. World Bank, Washington D.C.

Pascal, K., Josef, K., 2007. *Conservation Agriculture as Practiced in Kenya: Two Case studies*. FAO, Rome.

Pretty, J. N., Noble, A.D., Bossio, D., Dixon, J., Hine, R.E., Penning de Vries, F.W.T., Morison, J.I.L. 2006. Resource-Conserving Agricultural Increases Yields in Developing Countries. *Environmental Science and Technology* 40, 1114-1119.

Pye-Smith, C., 2012. *Agricultural Extension, a Time for Change: Linking Knowledge to Policy and Action for Food and Livelihoods.* Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA). Wageningen, the Netherlands.

Rivera, W.M., Alex, G., 2004. *The Continuing role of the Public sector in Pluralistic Extension Systems.* Proceeding of the Association for International Agricultural and Extension Education. AIAEE 20th Annual Conference, Dublin:

Smale, M., D. Byerlee, and T. Jayne. (2011). *Maize Revolutions in Sub-Saharan Africa*. World Bank Development Group, Policy Research Working Paper, No. 5659. World Bank, Washington D.C.

Tesfaye, K., Jaleta, M., Jena, P., Mutenje, M., in press. Identifying Potential Recommendation Domains for Conservation Agriculture in Ethiopia, Kenya, and Malawi. *Environmental Management,* 1-17. DOI 10.1007/s00267-014-0386-8

The Royal Society. 2009. *Reaping the Benefits. Science and the Sustainable Intensification of Global Agriculture.* Royal Society Policy Document 11/09.

Trigo E, Cap, E., Malach, V., Villarreal, F., 2009. The case of zero-tillage technology in Argentina, in D.J. Spielman and R. Pandya-Lorch, eds., *Proven Successes in Agricultural Development. A Technical Compendium to Millions Fed*. International Food Policy Research Institute, Washington D.C.

Yamano, T, Arai, 2010. *Fertilizers Policies, Price and Application in East Africa.* GRIPS Discussion Paper 10-24. National Graduate Institute for Policy Studies. Tokyo, Japan.

Zepeda, L. 2001. Agricultural investment, production capacity and productivity, in L. Zepeda, ed., *Agricultural Investment and Productivity in Developing Countries*. FAO, Rome:, 2001.