IIIS Discussion Paper

No.352/February 2011

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February 3, 2011

Abstract

The paper investigates whether positive network effects may have existed between large-scale commercial farmers and small-scale communal farmers prior to the recent land redistribution in Zimbabwe. A difference-in-difference approach is used where measurement is carried out using several data sources including farm level, geographic and survey information for cotton farmers in Mashonaland Central. It tests whether the removal of large-scale farmers has resulted in a decline in productivity for those small-scale farmers close to redistributed land as compared to those located at greater distances from large-scale/commercial farms. A significant negative productivity effect is found in addition to a country-wide negative redistribution effect. The latter is most likely due to wider economic and political instability over the last 10 years.

Keywords: Land redistribution, network effects, cotton farming, agricultural productivity, Zimbabwe **JEL Codes:** Q12, Q15, O17, O33, N57

1 Introduction

Implementing land reform programmes has been an important element of post-independence government policy in many developing countries. Successful redistribution can address societal inequalities as well as economic inefficiencies inherent in pre-reform systems (Deininger et al. 2000). Redistribution can also

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Thanks to Marcel Fafchamps, Abigail Barr and Erland Berg for useful comments at a CSAE Seminar as well as Pedro Vicente, Alan Mattews and Carol Newman at TCD. Financial support from Trinity College and the Institute for International Integration Studies is gratefully acknowledged.

however, be disruptive to important processes in the agricultural sector and the wider economy (Horowitz 1993). The potential success of land redistribution policies may be especially vulnerable if the structure of the existing system is not well understood and particularly dichotomous, potentially leading to the dismantling of both positive and negative characteristics of the old system. By making use of a natural experiment in Zimbabwe, this paper analyses how network effects may be compromised to the detriment of agricultural productivity when land redistribution polices do not acknowledge the importance of informal and localised agricultural support structures and social learning processes.

The significance of agricultural support structures for productivity gains in developing countries is well understood (Deininger et al. 2009, Kinsey 2004). Similarly, there is a large emerging literature on the importance of social learning in encouraging technology diffusion and growth processes (Bandiera and Rasul 2006, Conley and Udry 2010). Land reform outcomes have also received much attention, across a range of countries and policy structures (Binswanger et al. 1995). This paper aims to contribute to these three areas of the literature by investigating network effects and land redistribution in Zimbabwe's recent Fast Track Land Reform (FTLR) programme, started in 2000. Important positive spillover effects are found to exist between farmer groups in Zimbabwe. These may facilitate social learning and contribute to other agricultural productivity drivers. The paper tests whether recent land redistribution policies in Zimbabwe have compromised these positive spillovers by removing from agricultural communities a large part of the farmer group generating the spillovers. Further, the paper shows that the breakdown in these spillover effects may explain part of the redistribution policy's poor performance to date.

The country's recent FTLR was designed to reallocate under-utilised agricultural land to small-holder farmers located on over-utilised, low-quality agricultural land. The Zimbabwean agricultural sector is comprised of two main farming groups. Large-scale commercial farmers, the target of the recent resettlement policy, have by and large exited the agricultural sector since 2000. On the other hand, small-scale communal farmers, the intended beneficiaries of the policy, have received little benefit from the programme, as relatively few households have been permanently resettled to date (Dore et al. 2008). Both preand post-redistribution, these groups of farmers operated in rural, often remote areas of the country with limited access to infrastructure including transport links, access to markets and agricultural extension services.

The paper's motivation comes partly from anecdotal evidence suggesting that commercial farmers offer informal and localised access to inputs and extension services to communal farmers. Second, a commercial farming sub-group was not directly targeted by the land reform which allows identification in this paper. And finally, the land redistribution policy has not achieved the success government anticipated at the implementation of the policy in 2000.[1]

Using a difference-in-difference approach the paper investigates, at farm level, the effect of distance from commercial farms on the agricultural productivity of communal cotton farmers. Identification of the distance effect is carried out using an artefact of the land redistribution policy as follows. I exploit the fact that the FTLR was largely driven by the desire to correct historical racial inequalities with regard to land holdings. Thus, 'indigenous' farmers with large commercial farming enterprises prior to the reform were not targeted by the FTLR policy. Utete (2003, p.46) notes explicitly: "Reasons for de-listing farms were that some of the farms were indigenous[ly] owned...". On the other hand, 'non-indigenous' commercial farmers were the primary targets of the policy (AFP 2010).[2] This *de facto* policy of non-targeted (indigenous) and targeted (non-indigenous) commercial farmers provides the natural experiment with which the distance effect of interest can be identified. As with any natural experiment perfect randomisation may not be achieved in practice but minor differences between commercial farmer groups are controlled for here.

The estimation strategy then compares communal farmers' productivity both as a function of distance from commercial farms and proximity to indigenous or non-indigenous commercial farmer groups. Here distance is the treatment whilst redistribution, through use of the natural experiment as described, provides the necessary identification. Implementation of this strategy is achieved by using high quality agricultural production data and farm/er-level

[1] For example, national agricultural output has, on average, declined. A government commissioned report (Utete 2003) explains this as (partly) due to low access to inputs and extension services in the agricultural sector coinciding with the onset of the resettlement programme.

[2] The differentiation of farmers into indigenous and non-indigenous groups is contentious. Here I use the government of Zimbabwe's categorisation of indigenous to mean black and non-indigenous to mean white (or non-black) large-scale farmers (Utete 2003, p.12;27).

controls.

The richness of the available data allows several robustness tests to be carried out which examine the validity of the paper's design. This is possible by utilising pre- and post-redistribution data (available for alternate outcome variables) explicitly. Further, several mechanisms are investigated through which the distance (or network) effects of interest within agrarian communities may operate and examine potential selection bias between indigenous and non-indigenous commercial farmers.

Measurement of the effect of distance is carried out using agricultural input and output data at farm level as well as farmer characteristics, survey and farmer training data for 22,766 cotton farmers in a fertile, northern province of the country which is located spatially. The identification strategy is facilitated by using data on the current and pre-resettlement ownership structure of agricultural land in the province.[3]

Spatial location of the data allows further enrichment of the dataset with geographic, climactic and location-specific, institutional cotton-market information. This enables several robustness tests to be carried out as follows.

Survey data, available from both pre- and post-redistribution, offers alternate outcome variables that can be matched to the farm level, using geographic location information. Results on survey-outcomes that confirm the presence of the distance effect of interest before redistribution will provide support for the paper's identification strategy.

Productivity effects of a Non-Governmental Organisation (NGO)-led training programme for small-scale communal cotton farmers is also examined. This exercise also makes use of both pre- and post-redistribution data. This exercise tests the validity of the primary estimation strategy as well as investigating a specific mechanism through which the network effects of interest may operate, namely social learning.

Nearest-neighbour matching techniques are used to examine the robustness of the primary estimation results by controlling for observables non-linearly.

Detailed records for a sub-group ('detailed sub-group') of the farm-level sam-

[3]While most non-indigenous commercial farmers were subject to the FTLR, a small number of these farmers remain on their land. These farms and the communal farmers close to this land have been excluded from the empirical analysis.

ple is investigated in order to examine the effects of observed links between cotton farmers. This tests whether access to timely transportation of inputs is important for farmer productivity.

Selection bias between land farmed by indigenous and non-indigenous commercial farmers is investigated and controlled for by testing the similarity of geographic conditions facing both farmer groups.

Finally, the indigenous farmer-group is augmented with high-quality, small-scale, communal farmers. This allows examination of the importance of land ownership structures over farmer-quality on the network effects of interest. Should the network effects of interest survive, it would mean that land ownership structures are not important for the network effects of interest implying that these effects are instead contingent on farmer-quality.

The results show significant negative effects for communal cotton farmer productivity on removal of proximate, non-indigenous commercial farmers. This is in addition to the country-wide negative productivity effect of land redistribution (due to wider economic and political instability in the country over the last 10 years). The results provide evidence first that network effects exist and are important to the structure of the agricultural sector and second that the negative productivity effect of interest is a result of the breakdown in localised positive externalities that operated between those commercial farmers whose farms have been redistributed under the policy and surrounding communal farmers.

Section 2 examines literature on network effects, agricultural productivity, land reform processes and cotton farming in Zimbabwe. Section 3 describes the recent land resettlement policy as well as characteristics of the cotton sector in Zimbabwe. The difference-in-difference design, data, analytic specification and several robustness tests are described in Section 4 while Section 5 reports the paper's results. Section 6 concludes.

2 Literature

This paper adds to the emerging literature on the importance of social learning in encouraging technology diffusion and growth processes. This is exemplified by Bandiera and Rasul (2006), who examine the adoption of a new crop in

Mozambique and test the theory of economies of scale in commercialisation and Conley and Udry (2010), who systematically investigate social learning in relation to networks and communication channels in the context of new technology adoption in Ghana. In the case of cotton farming in northern Zimbabwe, the current paper shows that social learning contributes to sustainable technology diffusion within the wider cotton-growing community. My paper also adds to the empirical work on treatment effects. Seminal work by Miguel and Kremer (2004) measures health intervention impacts, the current paper investigates the impact of land reform on agricultural network effects.

Cotton market systems in Africa have recently attracted attention in the form of a comprehensive review by the World Bank (Poulton et al. 2004), which examines the liberalisation experiences of Ghana, Mozambique, Tanzania, Uganda, Zambia and Zimbabwe. Zimbabwe compares favourably to other countries.[4] For example, Cottco's[5] credit-input scheme is described as 'unrivalled within liberalised cash crop systems in Africa in terms of coverage and repayment record' (Poulton et al. 2004, p.526).[6] This credit-input scheme provides some of the data used in this paper.

Technical papers highlight the requirement for adequate training of farmers in order to ensure yield potentials are achieved, for example Matthews (1999) on the importance of pest control in cotton. Robustness checks in Section 5 confirm the existence of positive spillovers within communities containing trained-farmers in the context of cotton farming. While Govereh and Jayne (1999) look at the effects of cash crop production on food crop productivity in Zimbabwe and find significant synergies. This informs the 'insurance crop' role that cotton plays in the country, reducing the crop's price elasticity of supply, which is important to the empirical work here. For example, farmers grow the crop each year as access to chemical and other inputs for cash-crops facilitate simultaneous productivity gains in cash and food crops where state support for the latter has diminished. This is important for identification in the current

[4] Larsen (2002) describes the successful privatisation of the cotton marketing sector in Zimbabwe, whilst Imani-Development (2003) examines the role of cotton in the broader economy.

[5] Originally the state owned monopoly cotton marketing board, Cottco was successfully privatised in the early 1990s. Although there are now over 20 cotton marketing companies in the country, Cottco retains over 50% of the national market and operates a vital credit-input scheme for its growers.

[6] See Appendix A for further detail.

paper, for example, cotton's insurance role insulates it from large movements in real prices during the country's hyperinflation.

Land reform polices have received considerable attention in the literature, for example the importance of appropriate support structures widely (Deininger et al. 2009) and in Zimbabwe (Kinsey 2004), as well as land reform outcomes in general (Binswanger et al. 1995). Of particular importance to the current paper is the work by Conning and Robinson (2007) who utilise Indian data and a theoretical framework to illustrate the joint determination of economic and political institutions affecting agricultural organisation and property rights. They conclude that land reform, property rights and the political organisation of agriculture are key to the wider effects of land reform programmes. Further, they underscore the importance of understanding the economic organisation of agriculture pre-reform and subsequently shaping land reform to be consistent with these institutional conditions, even at the detriment of economic efficiency.

Zimbabwean land reforms carried out in the 1980s have received significant attention in the literature. There is less work on the recent reforms, in part due to the difficulty in accessing reliable data within the agricultural sector, though Scoons et al. (2010) is an important contribution here, representing one of the few available studies on the recent redistribution. This work carries out in-depth field-based analysis of Zimbabwe's recent land redistribution process in one area of the country. The findings show wide heterogeneity in the effects of the land redistribution, as experienced by resettled farmers and the wider agricultural community. Especially striking are the positive productivity, asset accumulation, land investment and livelihood adaptation experiences documented by the authors. Although not statistically representative, this study's conclusions provide significant motivation for wider spread, focussed studies on land redistribution and its effects throughout Zimbabwe. The book's conclusions highlight the potential present within the agricultural sector in Zimbabwe that may allow positive and wide-spread recovery of the sector in time.[7]

Work on the earlier reforms include Deininger et al. (2000) on the contribution of land reform to positive growth, Deininger et al. (2004) on the costs and benefits of early reforms, Robilliard et al. (2002) on their effectiveness as re-

[7]Further detail relating to official publications describing the country's land reform process can be found in Appendix B.

gards poverty reduction and Owens et al. (2003) on the importance of extension services for successful agricultural outcomes. Finally, Kinsey (2004) finds that although resettled villages in earlier reforms have achieved positive outcomes, successful agricultural development is predicated on access to appropriate inputs.[8]

Further, several papers investigate the impacts of the earlier reforms on civil society (Barr 2004, Barr et al. 2010b,a) including civil society engagement, trust and social enforcement and community-level organisational membership. Whilst more generally Bird and Shepherd (2003) examines the persistence of rural poverty in semi-arid Zimbabwe, finding important roles for remoteness, geographical conditions, and social and political exclusion. This informs the empirical work carried out here, especially taking geographic and climactic farm characteristics into account.

This paper aims to make a further contribution here, both in its focus on the recent reform and on non-beneficiaries within a large redistributive process. Although disruption to agricultural production is expected in the first years of reform, long-run estimates suggest sustainable livelihoods for beneficiaries. I examine agricultural outcomes some years after the onset of the redistribution of interest, and focus exclusively on non-beneficiaries. This is of interest as the recent redistribution was expected to both boost the outcomes of direct beneficiaries, but also to have wider effects in non-beneficiary communities as land pressure was relieved.

3 Context

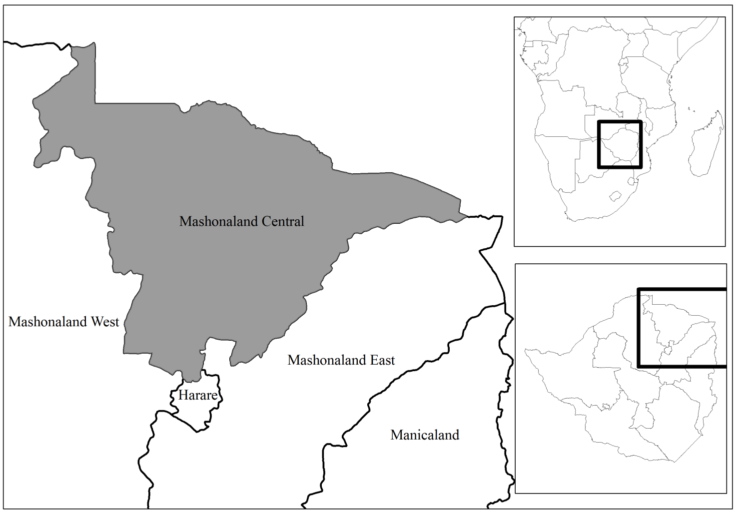
Zimbabwe is a medium-sized,[9] low-income country in sub-Saharan Africa (see Figure 1). The World Bank estimates purchasing power parity (PPP) adjusted income at US$170 per capita. The country's debt to GDP ratio is currently over 300% and although growth has been positive in 2010 the previous decade was characterised by contraction. Official development assistance accounts for

[8]These were provided generously by government agencies to resettlement programmes initiated in the 1980s.

[9]The population stands at between eight and nine million inhabitants.

11% of gross national income (GNI).[10]

Figure 1: *Mashonaland Central, Zimbabwe*



Sources: Diva, 2010 and ArcGIS.

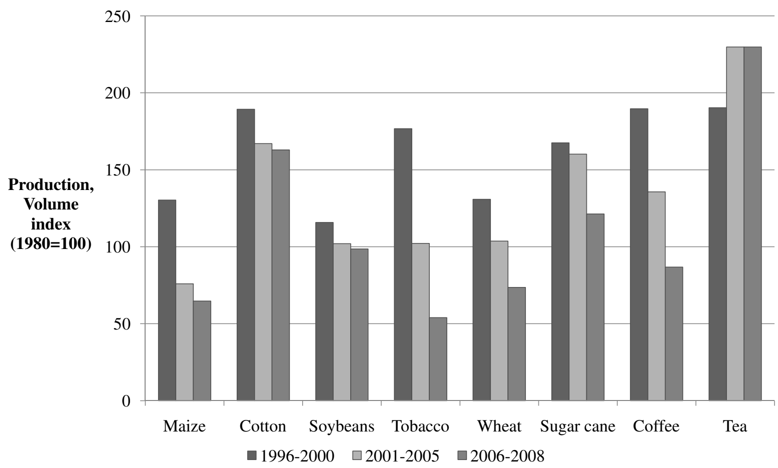
Land redistribution has been an ongoing policy instrument for authorities in the country since colonisation over 100 years ago. Post-independence policies have been designed to address the inequalities resulting from pre-independence redistributions. In contrast to the 1980s reforms, which although limited were largely successful (Deininger et al. 2002), Zimbabwe's FTLR policy, implemented in 2000 on the back of wider economic and political concerns, remains ongoing and has been marred by violence as well as extra-judicial, chaotic and patchy implementation.[11] In the empirical work I proxy for violence using, proximity to roads. Many of the intended beneficiaries have not yet been allocated secure areas of land to farm (Utete 2003), whilst national agricultural output

[10]Source: World Development Indicators (WDI), figures are for 2005, the last year that reliable figures were available. Further background information available in Appendix A1.

[11]For example, Dore et al. (2008) note that the FTLF policy, as described by the government in 'People First', resulted in a process that was at best complex and at worst extra-judicial, where actions were taken by district officials who proceeded to allocated land despite lacking official authority to do so. These opportunistic and chaotic allocations, often accompanied by violence, may in part have been correlated with access (at least initially) to farms close to urban centres and/or major roads. For example, Utete (2003, p.31) notes: "...problems were compounded by the activities of certain persons who, though lacking any official status or authority, nonetheless proceeded to allocate land, mainly in districts adjacent to the main towns and cities: the rural districts close to Harare, Bulawayo, Masvingo and Gwanda being perhaps the most affected."

has declined for most major crops (bar tea) since the onset of the redistribution policy (see Figure 2). State commissioned reports, such as Utete (2003), outline some of the primary challenges facing the FTLR, for example, reduced access to inputs, lack of appropriate infrastructure provision and tenure insecurity.

Figure 2: *Agricultural Output in Zimbabwe, 1996-2008*



Sources: FAO (2010), and Quton (2009).

Agriculture in Zimbabwe is characterised by two groups of farmers. Large-scale commercial farmers (indigenous and non-indigenous) hold title to large areas of land and are, in general, highly skilled and productive. Prior to the FTLR, commercial agriculture was the largest formal private sector employer in the country as well as being a significant contributor to national output and export earnings (Dore et al. 2008). A large proportion of these farms were redistributed as part of the FTLR policy, of the redistributed land the vast majority had previously been owned by non-indigenous farmers.

Indigenous commercial farmers are a small but important component of this group. They were not targeted as part of the FTLR policy due to the policy's underlying aims i.e. to address historic, namely racial, imbalances in land ownership across the country.[12] There is little documentation regarding this group of farmers. However, in so far as indigenous commercial farmers purchased[13] their land on the open market and were subject to country-specific market and environmental risks and rewards, there is no reason to believe these farmers can be differentiated from their non-indigenous counterparts other than along racial lines.

Small-scale communal farmers comprise the second group of farmers. This group farms smaller plots of land, on average 16 hectares per family (including communal grazing land) in 1980 (Chavunduka 1982). Neither resettled nor non-resettled farmers in this group hold the title to their land. Communal land is state-owned with user rights conferred, according to traditional tenure structures, to members of a local community by traditional leaders (Rukuni 1994).[14] This reduces their ability to access credit essential to the development of their farms. For example, Rukuni (1994, p. 16) notes that "...communal land is not accepted by private credit institutions as a form of collateral security...". Communally farmed areas have thus seen low levels of investment in immovable compared to movable assets. This has been singled out as one of the main drivers of low productivity gains in this sector of agriculture. Furthermore, communal farmers are relatively unskilled, having had more limited access to higher level education and agricultural training than their commercial counterparts.

'Treated' cotton farmers, by definition close to large-scale commercial land, are expected to reap some benefits from this proximity in the form of the land itself being located in the areas most conducive to agricultural output in the country. Anecdotal evidence[15] suggests that commercial farmers, as part of their local rural communities, provided proximate communal farmers with access to services, inputs and machinery that may otherwise have been unavailable in a

[12]Utete (2003, p.14) specifically mentions commercial land owned by 'white' farmers as that to be redistributed under the policy: "No black Government could be expected to uphold this racially skewed land structure."

[13]The majority of these farmers are expected to have purchased their land since independence, which implied the end of racial segregation laws in 1980. Significant amounts of non-indigenously owned land was similarly exchanged on the open market since 1980, notwithstanding the large numbers of white-owned farms that had been held within the same family's ownership for several generations.

[14]Although residents may return after an absence and reclaim land, in general there must be some birth right to take up user rights on communal land in Zimbabwe.

[15]For example, Auret (2009, p.103) notes "that many commercial farmers whose land bordered the Communal Areas assisted their neighbours with inputs and equipment to improve the cropping ability of the communal farmer, with some great success."

timely manner to communal farmers.

Since 1980, cotton farming in the country has become increasingly dominated by communal farmers due to the following. First, it is a labour-intensive crop, being hand-picked in Zimbabwe, communal farmers have a comparative advantage here. Second, at least in the 1980s, producer prices for cotton were kept artificially low in order to support the large textile industry in the country. This resulted in commercial farmers largely substituting away from cotton production. Finally, the drought-resistant cotton strains used in the country mean that income from cotton goes some way to ensuring against total maize crop failures.

Although there are now over 25 cotton marketing companies in the country, Cottco, the previously state-owned marketing board, provides a wide-spread credit-input scheme for cotton farmers. According to Cottco, its credit-input scheme achieves repayment rate of over 90%. This is in part facilitated by detailed records on each of its farmer-client. Access to this information for 2008 and 2009 forms the primary data for this paper. Further relevant details of the credit-input scheme include that cotton farmers are organised into groups where credit is accessed by individual farmers and continuity of the facility is dependent on the entire group repaying the total utilised credit at the end of each season (Dore et al. 2008, p. 71). Cottco grants its most credit worthy farmers "goldclass" status, conferring higher credit access and public recognition of their productivity and timely credit repayment histories.[16] Cottco also records who collects each farmer's inputs. In most cases this is the farmer himself however in some cases a secondary farmer or farmers may collect inputs on behalf of the primary farmer. This detail is available for 200 farmers in the sample and traces direct assistance-linkages between farmers.

Cottco is a majority shareholder in Quton, the country's sole seed supplier. Communal farmers achieving high cotton yields per hectare are identified by the companies and recruited as seed-cotton growers.

The Cotton Training Centre (CTC) provides technical training to cotton farmers in Zimbabwe and to the region as well as agricultural extension workers employed by the department of agriculture. Farmers are selected for training

[16]Cottco gathers this data annually as part of the administration and risk management of its credit-input scheme.

depending on their ability to read and identify pests. Participants are drawn from several areas of the country each year. Both area and farmer selection (conditional on ability to read) is carried out randomly. The centre's effectiveness is designed to reach beyond the farmers that can be trained each year in the following way. Pest reduction is important to cotton yields. Thus, trained farmers have a strong incentive to reduce the local pest burden by passing on their training to non-trained farmers in their communities, pest reduction at the community level is more effective than at the farm level. The effectiveness of the CTC's objectives is tested in the empirical results that follow.

4 Design and Identification

This section describes a difference-in-difference approach to test for network effects and their importance for communal farmers' agricultural productivity in Mashonaland Central, Zimbabwe. Network effects here are described as operating at a localised level between commercial and communal farmers. They represent links between these communities whereby communal farmers access, otherwise unavailable, productivity-enhancing capital (physical and human) from commercial farmers.

The difference-in-difference design employed utilises location-specific information available for commercial and communal farmers. The treatment (or first difference) is measured as the geographic distance between commercial and communal farmers. In this way distance (the treatment) measures the intensity of available network effects. Those communal farmers located close to commercial farmers are expected to be able to access these networks and their effects in a way that those further away from commercial farmers are not. The identifying restriction (or second difference) is achieved by utilising an artefact of Zimbabwe's recent FTLR. Specifically, not all commercial farmers were targeted under the policy. I argue that this selection into non-targeted (indigenous) and targeted (non-indigenous) commercial farmers was *de facto* randomised, at least on the characteristics of interest among commercial farmers, namely land ownership structure which facilitates access to adequate capital.[17] However,

[17] As discussed FTLR selection was however, non-randomly contingent on ethnicity.

as with any natural experiment, perfect randomisation may not be achieved. Here minor observed differences between indigenous and non-indigenous commercial farmers are controlled for. This natural experiment allows comparisons between communal farmers associated[18] with indigenous and non-indigenous farmers, facilitating the paper's identification restriction.

The validity of the primary identification strategy can be tested by recourse to the paper's rich dataset. Specifically, two robustness tests make use of pre-reform data explicitly. First, alternate (non-agricultural) outcome variables are compared before and after the redistribution. Second information on the location of NGO-trained cotton farmers is also available before and after redistribution. This latter test allows the analysis to be augmented in order to investigate the effect of distance from a trained farmer, on production, before and after redistribution. Subsequent robustness tests examine the specific mechanisms through which these distance effects may operate.

4.1 Measurement

The measurement is carried out using several data sources for Mashonaland Central, a fertile, cotton growing area in northern Zimbabwe. The richness of the combined data allows the primary relationship of interest to be identified, yields testable hypotheses regarding the validity of the identification strategy and facilitates an investigation into the potential mechanisms through which commercial-communal pro-productivity network effects may operate.

The dataset is built around 22,766 unique farm-level observations over the agricultural seasons in 2008 and 2009 from Cottco.[19] This data is not constructed as a random sample, however the number of farmers that comprise the dataset as a proportion of all cotton farmers in Mashonaland Central[20] is expected to limit potential selection-bias at the sample selection stage. Furthermore, it is not expected that such a bias would be important for the relationships of interest.

This farm-level data includes information on the farms themselves: number

[18]'Associated' here relates farmers close to *and far away from* commercial farmer groups. Thus designating communal farmers to either indigenous or non-indigenous commercial farms.

[19]Details surrounding the sample selection are given in Appendix D.

[20]Approximately 59% in 2008 and 69% in 2009 of total provincial cotton-hectarage is contracted to Cottco in these years.

of hectares under cotton ('hectarage') and farm location; farming techniques: inputs, yield and yield quality; and the farmers themselves: identification of 'seed-cotton growers', which 'group' each farmer belongs to for credit repayment purposes and whether the farmer has been classified as a 'goldclass' farmer, all measures of the quality of cotton farmers in the sample. For example, farmers classified as goldclass farmers have been identified by Cottco as high quality farmers over one or several parameters and are dealt with at an individual level rather than at the group level. Similarly, seed-cotton growers are identified by Cottco and Quton as high quality farmers and approached to grow seed-cotton as described previously.

The farm location identifier (usually available at the polling station level) for each observation is attached to longitude and latitude coordinates using ordinance survey maps of Mashonaland (Government of Zimbabwe 1985), as well as online ward data from civic action group (Sokwanele, 2010). The coordinates are used to augment the primary data with geographic and other location-specific information.[21]

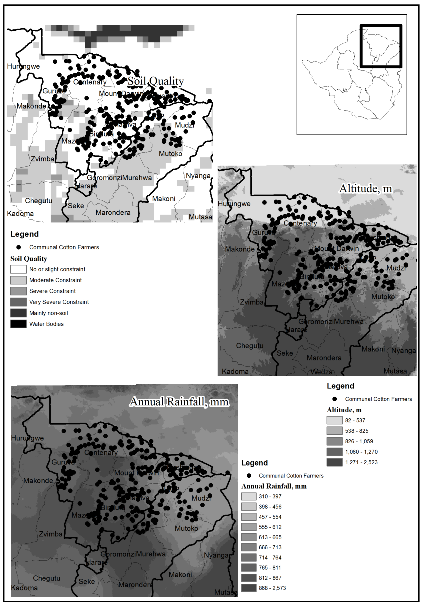
Several variables relating to the environmental characteristics of the region of interest are employed in order to add depth to the farm-level data. Soil quality data (Fischer et al. 2008) is utilised, where a soil quality composite variable measuring the nutrient retention capacity of the soil is used. This composite is relevant for crops requiring an intermediate level of inputs for example, cotton. Rainfall data (Matsuura and Willmott 2009) measure total rainfall in the area of interest for the years 2007 and 2008. There are between 1 and 3 rainfall stations per district (one administrative level above ward level) over the area of interest. Alternate sources (Hijmans et al. 2005) provide a long-run average annual precipitation variable, which are used for some specifications. This long-run average rainfall variable has a higher resolution than the Fischer et al. (2008) data, resulting in more spatial variation. Data on altitude and road networks comes from DIVA-GIS.[22] A visual display of farm level data superimposed on rainfall, altitude and soil quality data can be seen in Figure

[21]Geographic data are analysed using ArcGIS. All data are projected using the Universal Transverse Mercator system before performing distance calculations and/or extraction of data at the farm level.

[22]DIVA-GIS is a portal for free country-level geographic information, www.diva-gis.org/gdata.

3, which shows that altitude and long-run rainfall display significant variation whilst the composite soil quality variable takes one of just three values over the highly fertile Mashonaland Central province (the area of interest). This will affect the ability of the soil quality measure to explain variation in productivity amongst cotton farmers in the empirical analysis.

Figure 3: *Environmental Conditions, Mashonaland Central*

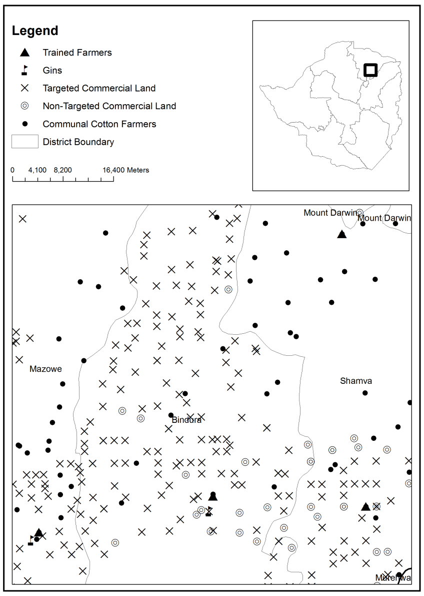


Source: Fischer et al. (2008), Matsuura and Willmott (2009), Hijmans et al. (2005), Cottco (2009) & Government of Zimbabwe (1985).

The farm location identifiers are also used to measure the distance of farms from locations of interest (see Figure 5). For example, distance to the closest road may be a proxy for relative exposure to political violence, as described in Section 3. Distance to the closest cotton-processing plants (gins) may also be important as this is where cotton inputs including seeds and fertilizer are accessed as well as being the final destination for picked, raw cotton.

Data on the number and location of farmers trained by an NGO, the CTC, is available at the district level each year from 1990-2008 (Cotton Training Centre 2007). This is mapped, using district level location data providing information on the relative proximity of each farm to nearby areas containing NGO-trained farmers. This data is used to examine the robustness of the main results. These

Figure 4: *Cotton Farmer Proximity to Commercial Farm Land*



Source: Farm Valuation Data, Cottco (2009) Cotton Training Centre (2009) & Government of Zimbabwe (1985).

relationships can be seen for a subset of the sample, also in Figure 5.

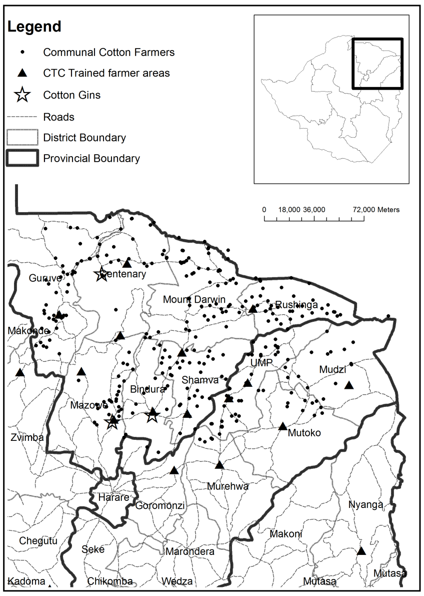
Further, relative proximity of commercial farms by ownership structure is calculated (see Figure 4). This is important for the design of the difference-in-difference estimation where proximity to commercial land represents the network effects (or treatment) that (treated) communal farmers are exposed to. The current and past ownership profile of commercial land, important for the identifying restriction (second difference), is available from a member of the farming community in the country working with commercial farmer compensation issues.[23]

The paper makes use of Central Statistics Office (CSO) 'Income, Household and Expenditure' (ICES) survey data at the Enumeration Area (EA) level for Mashonaland Central, collected in 1995 and 2001.[24] Each EA has a location identifier at the district level and comprises between 15 and 20 households. This

[23]This information is currently only available for Mashonaland Central. Thus, the main results of the paper are confined to the 22,766 cotton farmers represented in Cottco's records. Use of the full sample during robustness testing confirms the main results based on the smaller sample.

[24]Central Statistics Office (1997, 2005).

Figure 5: *Cotton Farmer Proximity to Gins, Roads, Trained Farmers*



Source: Cottco (2009), Cotton Training Centre (2009) & Government of Zimbabwe (1985).

data is mapped to the farm level data and survey outcome variables are substituted for output per hectare for a secondary difference-in-difference estimation. This allows identification of the effects of the redistribution on household survey outcome variables from before and after the redistribution explicitly. Each variable measures the proportion of people with the relevant income, consumption and expenditure outcomes for each EA.[25]

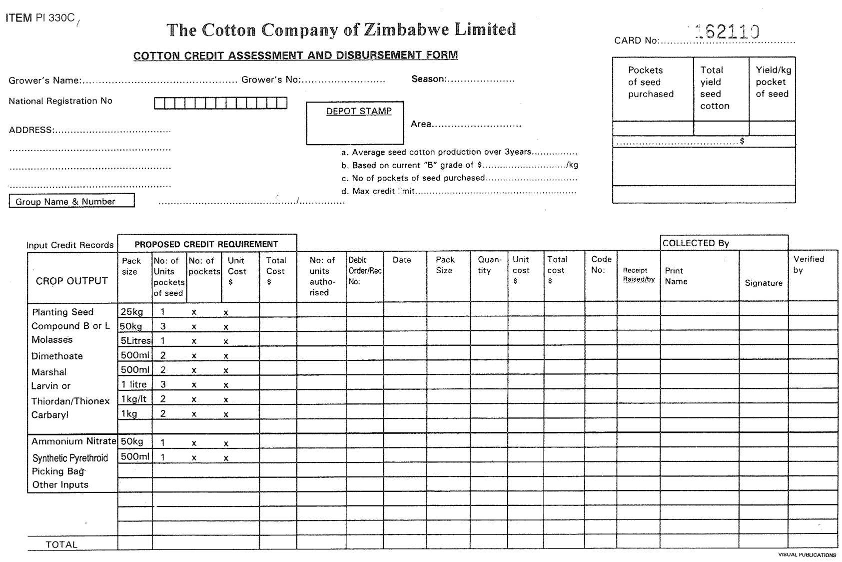
Finally, detailed data on cotton inputs are available for 200 farmers in the larger sample ('detailed sub-group'). This data was made available from three Cottco ginneries in Mashonaland Central, Bindura, Glendale and Muzarabani. As well as documenting the quantity and price of the inputs used by each farmer over a growing season and farm-level characteristics (hectares under cotton, location of the farm), these records also detail how the cotton inputs were transported to each farm. Specifically, whether a farmer relied on other farmers to assist him in delivering his inputs can be traced for this subgroup.[26] Figure 6

[25] The surveys are representative at the EA level.

[26] Whether farmers receive assistance is traced for all farmers, however all the assistance-providing farmers are not present in the sub-group. Thus, the sub-group cannot not provide a complete characterisation of all the linkages between farmers present within the group.

shows an empty input sheet. One is allocated to each farmer in order to record all the inputs the farmer will access from Cottco throughout the season. For example, Figure 7 indicates the inputs received by farmer Chikwira, this farmer signed for all of his own inputs at the ginnery. Figures 8 records the inputs received by farmer Mazoe. Here, the farmer signs for none of his cotton inputs, rather Chikwira signs for all these. In the dataset it is recorded that Chikwira assists Mazoe with transportation of his inputs.

Figure 6: *Cottco Credit Scheme: Inputs Sheet*


ITEM PI 330C

The Cotton Company of Zimbabwe Limited

CARD No:........ 162110

COTTON CREDIT ASSESSMENT AND DISBURSEMENT FORM

Grower's Name:........ Grower's No:........ Season:........

National Registration No

DEPOT STAMP

Area........

ADDRESS:........

Group Name & Number ..../........

a. Average seed cotton production over 3years........
b. Based on current "B" grade of $......../kg
c. No of pockets of seed purchased........
d. Max credit limit........

Pockets of seed purchased	Total yield seed cotton	Yield/kg pocket of seed
........$		

Input Credit Records — PROPOSED CREDIT REQUIREMENT — COLLECTED By

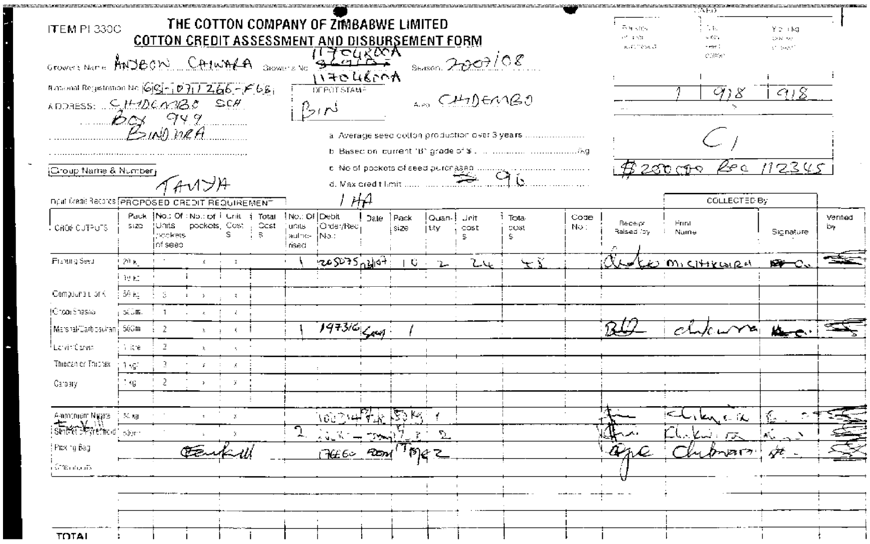
CROP OUTPUT	Pack size	No: of Units pockets of seed	No: of pockets	Unit Cost $	Total Cost $	No: of units autho-rised	Debit Order/Rec No:	Date	Pack Size	Quan-tity	Unit cost $	Total cost $	Code No:	Receipt Raised/by	Print Name	Signature	Verified by
Planting Seed	25kg	1	x	x													
Compound B or L	50kg	3	x	x													
Molasses	5Litres	1	x	x													
Dimethoate	500ml	2	x	x													
Marshal	500ml	2	x	x													
Larvin or	1 litre	3	x	x													
Thiordan/Thionex	1kg/lt	2	x	x													
Carbaryl	1kg	2	x	x													
Ammonium Nitrate	50kg	1	x	x													
Synthetic Pyrethroid	500ml	1	x	x													
Picking Bag																	
Other Inputs																	
TOTAL																	

VISUAL PUBLICATIONS

Source: Cottco (2009).

The rich dataset available allows the paper's primary design to be estimated, extensively tested and allows several mechanisms through which the network effects may operate to be uncovered in the following way. First, data on the large sample of cotton farmers is used alongside their relative proximity to commercial farms, differentiated into indigenous and non-indigenous commercial farmer groups to estimate the effects on productivity of treatment (distance to commercial land) controlling for farmer and farm-level characteristics. Possible selection bias between land farmed by indigenous and non-indigenous commercial farmers is then tested and controlled for: observable selection bias on the environmental conditions faced by each farming group is controlled for statistically.

Figure 7: *Cottco Credit Scheme: Inputs Sheet, Chikwira*



ITEM PI 330C

THE COTTON COMPANY OF ZIMBABWE LIMITED

COTTON CREDIT ASSESSMENT AND DISBURSEMENT FORM

Grower's Name ANDEON CHIWARA Grower's No ... Season 2007/08

National Registration No 63-071266-F68

ADDRESS: CHIDEMBO SCH BOX 949 BINDURA

DEPOT STAMP BIN Area CHIDEMBO

a. Average seed cotton production over 3 years

b. Based on current "B" grade of $ ... kg

c. No of pockets of seed purchased

d. Max credit limit 96

Group Name & Number TAMYA

1 HA

C1

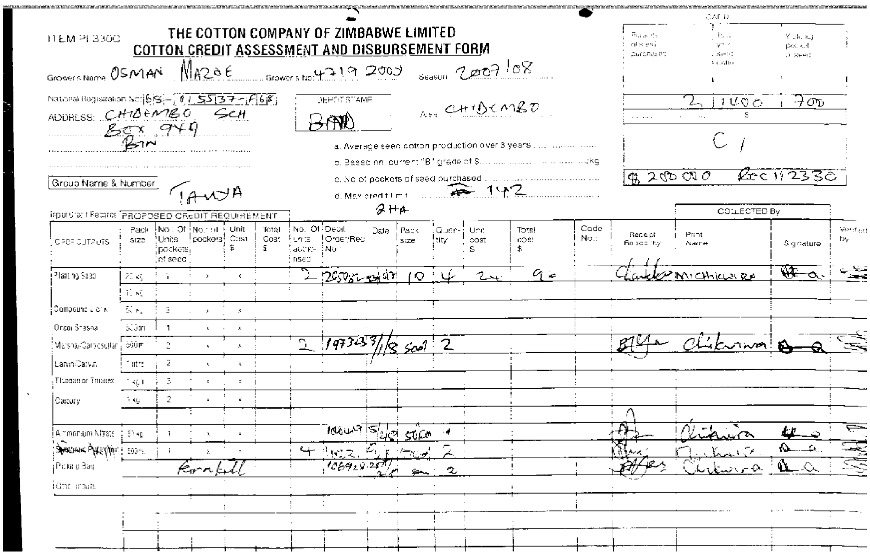
$200 000 Rec 112345

PROPOSED CREDIT REQUIREMENT

COLLECTED By

Source: Cottco (2009).

Figure 8: *Cottco Credit Scheme: Inputs Sheet, Mazoe*



ITEM PI 330C

THE COTTON COMPANY OF ZIMBABWE LIMITED

COTTON CREDIT ASSESSMENT AND DISBURSEMENT FORM

Grower's Name OSMAN MAZOE Grower's No 4219 2009 Season 2007/08

National Registration No 63-071537-F68

ADDRESS: CHIDEMBO SCH BOX 949 BIN

DEPOT STAMP BAND Area CHIDEMBO

a. Average seed cotton production over 3 years

b. Based on current "B" grade of $ ... kg

c. No of pockets of seed purchased

d. Max credit limit 142

Group Name & Number TAMYA

2 HA

C1

$200 000 Rec 112330

PROPOSED CREDIT REQUIREMENT

COLLECTED By

Source: Cottco (2009).

Pre-2000 data, available for non-agricultural outcome variables, allows the paper to make use of the time-dimension of the reform explicitly. This data allows a comparison of survey outcomes for communal farmers before and after the reform, as a function of their distance to commercial farms. Thus utilising an alternate difference-in-difference design and testing directly for unobservable selection bias between communal farmers associated with indigenous and non-indigenous commercial farmers.

Examination of the NGO-led training programme data, available to communal farmers, provides further credibility to the primary identification strategy and indicates a mechanism by which these positive network effects may operate. By utilising pre- and post- redistribution data on the location of trained farmers the effect of distance to a trained farmer can be estimated. This is carried out by comparing farmers close to trained farmers before and after redistribution. Further, this data indicates the importance of localised learning relating to improved pest-reduction techniques. This provides further evidence that unobservable variables specific to ethnic groups are not confounding the results.

Empirical matching techniques are used to examine the validity of comparing treated and control farmers by controlling for observables non-linearly. Matching utilises the distribution of the covariates among the treated, in order to weight covariant-specific estimates and thereby estimate the effect of the treatment on the treated (Angrist and Pischke 2008).

Uncovering the mechanisms through which the network effects of interest may operate is examined subsequently. Detailed information for a sub-group of communal farmers allows direct farmer-to-farmer linkages to be investigated explicitly. This shows that, within communal farming communities, receiving transport assistance in input provision positively affects beneficiary farmers.

The information identifying communal farmer quality (seed-cotton growers, goldclass and large communal farmers) indicates that ownership structure rather than 'quality' of farmer characteristics are important. This provides additional evidence that proximity to large-scale commercial farmers is of primary importance for the network effects of interest. This in contrast to the effects of interest being contingent on farmer-quality, which in turn may be correlated with cultural racial or other unobservables, confounding the paper's identification strategy. Both Rukuni (1994) and Utete (2003) highlight appropriate farm ownership structures as important for the development of small-holder farming, particularly with reference to accessibility of credit in the agricultural sector.

4.2 Estimation Strategy

To identify the effect of distance from from commercial farms and the impact of land redistribution on network effects in the cotton sector, the following is estimated. Let Y_{ir} denote farmer yield per hectare, or alternate relevant outcomes for farmer i associated with indigenous or non-indigenous commercial farms, $r = \{0, 1\}$ where r represents communal farmers associated with 0 indigenous and 1 non-indigenous commercial land. Let d_{ir}, defined here as the treatment, measure farm distance of communal farmers t from commercial land. This represents the quasi-natural experiment and allows identification in this model. The average treatment effect is coefficient β_3 in the following regression:

$$Y_{ir} = \alpha + \beta_1 d_{ir} + \beta_2 r_i + \beta_3 d_{ir} r_i + \epsilon_{ir} \tag{4.1}$$

As the sample is large, but not necessarily randomly selected, it may be preferable to include individual observable effects x_{ir} as a matrix of farm/er characteristics (for example cotton inputs, land quality, rainfall, proximity to gins, roads):[27]

$$Y_{ir} = \alpha + \beta_1 d_{ir} + \beta_2 r_i + \beta_3 d_{ir} r_i + \gamma x_{ir} + \epsilon_{i4} \tag{4.2}$$

Estimating equation 4.2 by ordinary least squares yields the standard difference-in-difference estimator whilst controlling for observables. The sensitivity of the results to potential selection on unobservables is also tested. Lastly, matching estimators are used to allow for the effects of non-linear controls on the variables of interest. Here treated and control groups are matched on observable characteristics, where potential outcomes are assumed to be independent of treatment status, conditional on these observables. Available matching estimators do not

[27] Dalton et al. (1997) note that productivity in Zimbabwe's small-holder agriculture sector rises as all of labour, purchased inputs and draft capital implements increase with available technology. Further, distance from roads significantly increases production costs.

allow for explicit interaction effects so matching is carried out for communal farmers associated with indigenous and non-indigenous farmers separately.

Within this framework, describing network effects and land redistribution, the following are expected, *a priori*, on the estimated coefficients in equation (4.2):

$$\beta_1 < 0 \tag{4.3}$$

$$\beta_2 < 0 \tag{4.4}$$

For communal farmers associated with indigenous commercial farmers, distance affects productivity negatively, (equation (4.3)), the marginal treatment effect of interest. Likewise, proximity of communal farmers to non-indigenous commercial farms (that has been redistributed) results in a reduced productivity in comparisons to remote farmers. If redistribution occurs in the absence of support structures for agricultural communities it has a negative productivity effect on those close to redistributed land (equation (4.4)).

For testable combinations of these coefficients:

$$\beta_1 + \beta_3 = 0 \tag{4.5}$$

$$\beta_2 + \beta_3 < 0 \tag{4.6}$$

Redistribution does not explain productivity or household outcome variables for communal farmers distant from non-indigenous commercial land (equation (4.5)), the average treatment effect on the control group. Thus, *a priori*, it is expected that once commercial farmers and associated network effects have been dismantled (post-redistribution), distance to commercial farmers no longer predicts productivity differentials between communal farmers. This suggests that communal farmers located some distance from commercially farmed land did not compensate for the lack of network effects available to those communal farmers closer to commercial farmers. Redistribution also has a negative effect on productivity for distant farms (due to wider economic and political instability in the country over the last 10 years) (equation (4.6)), the average treatment effect on the treated group. Finally:

$$\beta_3 > 0 \tag{4.7}$$

The average treatment effect is positive in this formulation, this to counteract β_2 but not surpass β_1. This indicates that the control group fares relatively better than the treatment group, due to the treatment group suffering both the disappearance of productivity enhancing network effects, as well as the economy-wide negative shock. The latter being the only one of the two shocks affecting the control group.

5 Empirical Results

5.1 Descriptive Statistics

Figure 9 indicates treated (within 10km of commercial land) and control (at least 10km away from commercial land) farmers for the purposes of the descriptive statistics.[28]

Observable differences between treated and control cotton farmers are investigated in Tables 1 and 3. As described in Section 3, it is expected that control farmers have access to relatively lower quality land than their treated counter parts. Table 1 confirms this, treated farmers have higher, wetter farms with better quality soil. Treated farmers are also closer to roads, gins and areas containing NGO-trained farmers, when compared to the control group, although the latter are closer to goldclass farmers. Treated farmers achieve higher yields per hectare.[29]

These observable differences are controlled for in the regression and matching analysis that follows, and are primarily a function of the historic process by which land was acquired for commercial use.

Differences across land farmed by indigenous and non-indigenous commercial farmers are described in Table 2, to examine potential observable selection bias across these groups. High levels of selection bias on observables may indicate

[28] Treatment is allowed to differ in intensity by distance in the regression analysis results.

[29] Table E1, in the Appendix, examines the mean difference between communal cotton farmers remaining on their land and those farmers who have benefited directly from the land redistribution - now located on commercial land.

Table 1: *Farm/er Characteristics: Treated and Control Farmers (Mean Difference)*

	Control[1]	Treated[2]	Mean Difference
Yield per ha, kg	250.68	280.48	-29.80***
			(3.51)
	Environmental Characteristics		
Altitude, m	599.34	1040.59	-441.24***
			(2.88)
Rainfall (annual average), mm	749.18	833.06	-83.88***
			(0.69)
Rainfall (2007), mm	817.18	877.80	-60.62***
			(0.56)
Rainfall (2008), mm	739.09	820.27	-81.18***
			(0.70)
Soil quality (1-7)	1.06	1.20	-0.14***
			(0.00)
	Proximity		
Road proximity, km	3.84	3.31	0.53***
			(0.06)
Gin proximity, km	56.22	30.46	25.76***
			(0.42)
Trained farmer proximity, km	21.34	16.18	5.16***
			(0.18)
Seed farmer, %	1.7	6.87	-5.17***
			(0.22)
Goldclass proximity, km	1.05	9.36	-8.31***
			(0.06)
Large farmer proximity, km	4.83	11.25	-6.42***
			(0.10)
	Commercial farms		
Indigenous farmer, km	38.97	8.29	30.68***
			(0.23)
Non-indigenous farmer, km	31.82	5.75	26.07***
			(0.17)
Observations	22623	7908	

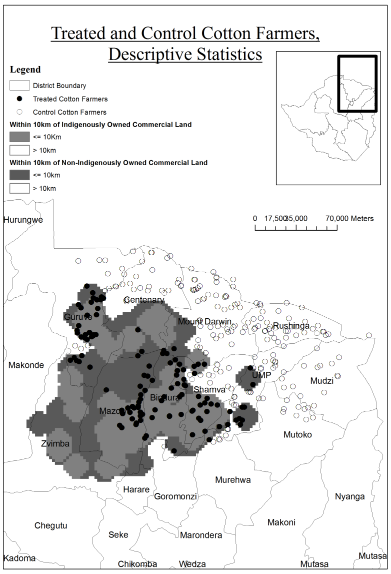
Source: Cottco (2009), Cotton Training Centre (2009), Quton (2009), Fischer et al. (2008), Matsuura and Willmott (2009) & Hijmans et al. (2005).

[1] Communal cotton farmers located less that 10km from commercially farmed land.

[2] Communal cotton farmers located greater than 10km from commercially farmed land.

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 9: *Treated and Control Farmers, Descriptive Statistics*



Sources: Farm Valuation Data, Cottco (2009) & Government of Zimbabwe (1985).

large differences in unobservables. Non-indigenous farmers have access to higher land, closer to roads. This is consistent with the hypothesis that proximity to roads may proxy for violence in this identification, as non-indigenous farms have been redistributed and thus are more likely to have experienced localised violence that may have affected surrounding communal farmers negatively. These observed differences are controlled for in the regressions that follow. However, all commercial farms experience similar rainfall and soil quality.

Table 3 reports observable differences for alternate (survey) outcome variables for the sample both before and after the redistribution. This will facilitate the empirical estimation using the conventional identification strategy. Here, before the redistribution, treated farmers record better employment, education, access to infrastructure (access to piped water, cooking fuels) and non-agricultural assets (grain mills). The control group reports higher agricultural asset ownership: ploughs, cattle, goats, scotch-carts and wheelbarrows. Although this picture remains broadly similar after the redistribution some interesting changes have occurred. For example, post-redistribution control farmers report higher relative access to cooking fuel (paraffin) although this figure has

Table 2: *Geographic Land Characteristics: Indigenous and Non-Indigenous Commercial Farms (Mean Differences)*

	Indigenous	Non-Indigenous	Mean Difference
Altitude, m	1154.20	1255.13	-100.93***
			(18.64)
Rainfall (annual average), mm	861.93	861.23	0.70
			(3.72)
Soil Quality (1-7)	1.52	1.63	-0.11
			0.09
Roads, km	3.69	3.06	0.63**
			(0.35)
Observations	75	816	

Source: Cottco (2009), Farm Valuation Data (2010) Fischer et al. (2008), Matsuura and Willmott (2009), & Hijmans et al. (2005).
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

reduced for both groups. The reversal in relative access to paraffin will be of importance in the robustness tests following the primary results. Here paraffin provision for example, may be linked to distribution channels vulnerable to the post-redistribution disruption for treated farmers.

Table 4 shows that treated communal farmers have less hectarage under cotton than control farmers, providing evidence that proximate communal farmers were not affected directly by the recent land reform. Increased cotton-hectarage for control groups likely reflects the high population densities in more fertile areas of the country, those typically farmed by commercial farmers in Mashonaland. This is acquires more weight given that the difference is not affected by redistribution.[30]

Hectarage may be inversely related to productivity (Carter 1984). In order to control for this in the main results I proxy seed use for hectarage under cotton.[31] Table 5 shows the correlation between seed use and hectarage, at least up to 10 hectares, which accounts for over 99% of the sample.

Within the ‘detailed sub-group’ (200 farmers), comparisons can be made between those farmers who receive assistance (in the form of transportation of inputs) from other farmers and those who do not access this additional sup-

[30]Table E2, in the Appendix, shows that treated farmers are relatively closer to non-indigenously redistributed commercial land than farms that continue to be farmed by indigenous commercial farmers. This is expected to bias the estimation results downwards as farmer access to network effects is a function of distance to commercial land.

[31]As hectarage forms part of the dependent productivity measure a proxy is required here.

Table 3: *Survey Outcomes (%): Treated and Control Farmers, 1995 and 2001 (Mean Differences)*

	1995			2001		
	Control[1]	Treated[2]	Mean Diff.	Control[1]	Treated[2]	Mean Diff.
Employment	28.43	38.51	-10.08*** (0.10)	5.20	28.51	-23.30*** (0.13)
Cook with Parafin	0.62	1.81	-1.18*** (0.03)	0.39	0.30	0.08*** (0.01)
Water, piped	0.21	2.14	-1.93*** (0.03)	0.28	2.58	-2.30*** (0.04)
Waged income	6.29	28.18	-21.89*** (0.13)	13.28	6.93	6.35*** (0.10)
Proximity to grainmill	18.15	20.86	-2.71*** (0.04)	0.00	0.00	-0.00 (0.00)
Schooling	77.75	84.96	-7.21*** (0.08)	83.74	86.98	-3.24*** (0.05)
Cook with Electricity	0.02	2.28	-2.25*** (0.03)	0.02	3.73	-3.71*** (0.04)
Radio	6.08	9.79	-3.71*** (0.03)	9.56	13.35	-3.79*** (0.03)
Bicycle	3.13	5.31	-2.19*** (0.02)	6.18	7.59	-1.41*** (0.03)
Plough	7.50	2.88	4.61*** (0.05)	10.55	2.80	7.75*** (0.03)
Cattle	8.64	2.67	5.97*** (0.04)	10.93	3.08	7.85*** (0.04)
Goat	8.23	1.53	6.69*** (0.04)	11.36	2.67	8.69*** (0.05)
Scotchcart	2.06	1.62	2.56*** (0.04)	4.95	1.65	3.30*** (0.03)
Wheelbarrow	4.12	1.56	2.56*** (0.04)	8.50	2.47	6.02*** (0.05)
Observations	22623	7908		22623	7908	

Source: Cottco (2009) & Central Statistics Office (1997, 2005)
[1] Communal cotton farmers located less that 10km from commercially farmed land.
[2] Communal cotton farmers located greater than 10km from commercially farmed land.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: *Communal Farm Cotton Hectarage: by Proximity to Indigenous, Non-Indigenous Commercial Farms (Mean Difference, ha)*

	Control[1]		Treated[2]		
	Mean	No. of Obs.	Mean	No. of Obs.	Mean Diff.
Communal farms, ha	2.89	22623	2.33	7908	0.55*** (0.11)
Indigenous, ha	2.87	24359	2.25[3]	6172	0.61*** (0.12)
Non-Indigenous, ha	2.88	22750	2.32[3]	7781	0.55*** (0.11)

Source: Cottco (2009) & Farm Valuation Data (2010)
[1] Communal cotton farmers located less that 10km from commercially farmed land.
[2] Communal cotton farmers located greater than 10km from commercially farmed land.
[3] Seen in Table E2 the mean difference between these figures is not significant.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: *Communal Farmer Seed Use, by Hectarage (Mean Difference, kg)*

	Proportion	Number	Mean Seed Use	Mean Difference
1ha	16.35	4,993	15.39	
>1ha & <=2ha	47.25	14,426	21.11	-5.72***
				(0.21)
>2ha & <=5ha	31.38	9,581	24.79	-3.68***
				(0.19)
>5ha & <=10ha	4.65	1,420	27.21	-2.43***
				(0.46)
>10ha	0.37	111	29.36	-2.05
				(1.80)
Total	100	30,531	21.64	

Source: Cottco (2009)
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

port. Table 6 shows that assisted farmers are, on average, worse off on available parameters than those farmers who do not receive assistance from secondary communal farmers in their communities. Here, assisted farmers achieve lower yields and lower employment, on average. Similarly these assisted farmers utilise less seed, fertilizer, herbicide and other inputs (indicating they have access to less Cottco credit than the comparison group) and their land is lower, drier and further from roads, gins, trained farmers, goldclass/large/commercial farmers than unassisted farmers. They do however have better soil quality and access to paraffin as a cooking fuel than their unassisted counterparts. Recalling Table 3 it can be noted that paraffin access may be a good proxy for access to network effects as paraffin is vulnerable to disruption of localised distribution channels.[32] These descriptive statistics indicate that identification may be difficult for the robustness test utilising the detailed sub-group data, especially if more vulnerable and/or lower quality farmers are more likely to avail of local assistance with input transportation than more productive farmers as may be expected given the descriptive statistics.

Finally, Tables 7, 8 and 9 report summary statistics and expected regression coefficient signs for the primary sample, survey outcome data and detailed subsample, respectively.

[32] Table E3, in the Appendix, compares characteristics of the detailed sub-group with the full sample.

Table 6: *Farm/er Characteristics: Assisted and Unassisted Farmers - Detailed Sub-Sample (Mean Difference)*

	Unassisted Farmers	Assisted Farmers	Mean Diff.
	Outcome Variables		
Yield per ha, kg	537.29	365.81	171.47***
			(55.58)
Paraffin, %	0.56	0.79	0.22**
			(0.12)
Employment, %	15.22	11.81	3.41**
			(1.95)
	Farm Input Characteristics		
Seed, kg	12.64	4.21	8.42***
			(1.25)
Fertilizer, %	78.57	52.94	25.63***
			(6.51)
Herbicide, %	16.33	0.00	16.33***
			(3.68)
Other inputs, %	36.73	4.90	31.83***
			(5.27)
	Environmental Characteristics		
Altitude, m	922.26	797.76	124.50***
			(47.34)
Rainfall (annual average), mm	841.67	829.38	12.29**
			(6.85)
Soil quality (1-7)	1.04	1.00	0.04**
			(0.02)
	Proximity		
Road proximity, km	1.69	3.45	-1.76***
			(0.35)
Gin proximity, km	24.21	24.54	0.32
			(3.51)
Trained farmer proximity, km	14.12	18.62	-4.50***
			(1.82)
Seed farmer, %	47.31	12.94	34.37***
			(6.47)
Goldclass farmer, km	1.43	3.21	-1.77***
			(0.51)
Large farmer , km	10.64	14.55	-3.91***
			(1.58)
Indigenous, km	14.00	18.28	-4.28**
			(1.95)
Non-Indigenous, km	9.37	12.63	-3.26**
			(1.69)
Observations	92	86	

Source: Cottco (2009), Cotton Training Centre (2009), Quton (2009), Fischer et al. (2008), Matsuura and Willmott (2009), Hijmans et al. (2005) & Farm Valuation Data (2010). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7: *Summary Statistics: Farm/er Characteristics (Communal Farmers)*

Variable	Obs	Mean	Std. Dev.	Min	Max	Expected Sign
Hectares, ha	30531	2.74	8.66	1.00	800.00	
Total yield, kg	30531	647.96	823.60	10.00	20190.00	
Yield per ha, kg	30531	258.40	269.25	0.08	7490.00	
Fertilizer, kg	30531	36.63	50.21	0.00	750.00	(+)
Seed, kg	30531	21.64	14.42	0.00	130.00	(+/−)
Soil quality (1-7)	30531	1.49	0.60	1.00	3.00	(−)
Rainfall (annual average), mm	30531	770.90	64.11	627.00	970.00	(+)
Rainfall (2007), mm	30531	832.88	50.75	644.90	927.40	(+)
Rainfall (2008), mm	30531	760.12	64.25	541.10	863.00	(+)
Altitude, m	30531	713.63	293.37	342.00	1505.00	(+)
Road proximity, km	30531	3.70	4.49	0.00	34.20	(+)
Gin proximity, km	30531	49.55	34.14	0.00	153.05	(−)
Trained farmer proximity, km	30531	20.00	13.95	0.00	62.54	(−)
Seed farmer, %	30531	3.04	17.16	0.00	100.00	(+)
Goldclass farmer proximity, km	30531	3.20	5.84	0.00	26.48	(−)
Large farmer proximity, km	30531	6.49	8.48	0.00	46.50	(−)
Indigenous farmer, km	30531	31.02	21.91	2.41	114.17	(−)
Non-indigenous farmer, km	30531	25.07	17.03	2.41	78.86	(−)

Source: Cottco (2009), Cotton Training Centre (2009), Quton (2009), Fischer et al. (2008), Matsuura and Willmott (2009), Hijmans et al. (2005) & Farm Valuation Data (2010).

Table 8: *Summary Statistics: Survey Data (%)*

Variable	Obs	Mean	Std. Dev.	Min	Max
Employment, 1995	30531	31.04	8.64	9.82	54.64
Employment, 2001	30531	11.24	14.50	0.00	53.82
Piped water, 1995	30531	0.71	2.67	0.00	18.67
Piped water, 2001	30531	0.88	3.05	0.00	20.77
Waged income, 1995	30531	10.59	15.68	0.00	48.63
Waged income, 2001	30531	11.96	13.96	0.00	50.00
Schooling, 1995	30531	79.62	6.83	67.90	94.93
Schooling, 2001	30531	84.58	4.17	70.85	97.76
Cattle 1995	30531	7.09	4.08	0.00	15.31
Cattle 2001	30531	8.90	4.66	0.00	17.02

Source: Cottco (2009) & Central Statistics Office (1997, 2005).

Table 9: *Summary Statistics: Detailed Sub-Sample*

Variable	Obs	Mean	Std. Dev.	Min	Max	Expected Sign
Hectares, ha	166	4.59	4.73	1.00	35.00	
Yield per ha, kg	157	455.38	357.25	5.00	1505.00	
Receives assistance, %	200	65.00	47.82	0.00	100.00	(+)
Collects own inputs, %	192	47.40	50.06	0.00	100.00	(+)
Number of assisting farmers	132	1.23	0.44	1.00	3.00	(+)
Average distance to Seedholder, km	132	25.75	40.34	0.00	143.16	(−)
Asset ownership, %	200	33.50	47.32	0.00	100.00	(+)
Seed, kg	189	8.27	9.57	1.00	80.00	(+)
Fertilizer, %	200	65.50	47.66	0.00	100.00	(+)
Compound (fertilizer), kg	78	11.62	12.93	1.00	60.00	(+)
Ammonium nitrate(fertilizer), kg	126	5.55	8.85	1.00	56.00	(+)
Other inputs,[1] %	200	20.50	40.47	0.00	100.00	(+)
Insecticide, %	200	94.00	23.81	0.00	100.00	(+)
Marshal(insecticide), kg	89	5.65	8.12	1.00	62.00	(+)
Larvin(insecticide), kg	76	6.82	9.18	1.00	70.00	(+)
Herbicide, %	200	8.00	27.20	0.00	100.00	(+)
Magnum(herbicide), kg	15	2.87	2.33	1.00	8.00	(+)

Source: Cottco (2009).

[1] Dummy variable taking the value 1 when a farmer uses insecticide and/or herbicide.

5.2 Main results

Table 10 provides empirical motivation for the regression results that follow. Column (1) indicates that having controlled for observed differences between them, proximity to commercially farmed land is a significant explanatory variable for productivity (defined here as yield per hectare). When the sample is divided into communal farmers associated with indigenous and non-indigenous commercial farms, proximity to non-indigenous farms is unable to explain productivity differences between communal farmers, whilst proximity to indigenously-farmed land is positively related to agricultural productivity gains. This motivates the paper's identification strategy: the type of commercial land cotton farmers are proximate to is of importance to productivity outcomes once redistribution has been carried out. This is attributed to network effects, suggesting that removal of commercial farmers has occurred to the detriment of communal cotton productivity. Other control variables have the expected signs and significance.[33]

[33] Rainfall has been excluded as it seldom enters the regression results significantly.

Table 10: *Empirical Motivation*

Yield per ha	(1)	(2)	(3)
Treated[1], (D)	29.72***	58.06***	8.02
	(6.56)	(20.69)	(7.84)
Fert, kg	0.70***	0.95***	0.59***
	(0.04)	(0.11)	(0.05)
Seed, kg	0.22**	-0.06	0.39***
	(0.11)	(0.27)	(0.13)
Altitude, m	-0.01	-0.36***	0.02*
	(0.01)	(0.09)	(0.01)
Soil quality (1-7)	-13.05**	-57.26***	-5.35
	(5.38)	(17.35)	(5.94)
Roads, km	1.17***	2.35*	1.70***
	(0.33)	(1.38)	(0.35)
Gins, km	-0.16**	-0.67	-0.21***
	(0.07)	(0.52)	(0.08)
Trained farmer, km	-0.30**	-3.53***	0.14
	(0.13)	(0.95)	(0.14)
Seed farmer, (D)	117.40***	30.65	148.76***
	(13.98)	(24.07)	(20.27)
Goldclass, (D)	104.30***	257.56***	92.91***
	(7.94)	(45.5)	(8.28)
Large farmer, (D)	-179.97***	-449.85***	-169.61***
	(17.49)	(42.40)	(17.87)
Year, (D)	-50.35***	-55.54***	-51.13***
	(3.06)	(7.99)	(3.38)
Region, (D)	42.38***	55.81***	57.33***
	(4.65)	(13.98)	(5.39)
Constant	245.45***	672.02***	202.02***
	(11.09)	(98.55)	(12.07)
Observations	30,531	5,172	24,237
R^2	0.062	0.076	0.058
Specification	All Observations	Communal Farmers Assoc. with Indig. Farmers	Communal Farmers Assoc. with Non-Indig. Farmers

[1]Where 'Treated'=Communal farmers within 10km of commercial farms,
'Untreated'=Communal farmers further than 10km from commercial farms.
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 11 contains the paper's primary results. The initial specification (Column (1)) shows that without controlling for environmental or farm characteristics distance to commercial land, land reform and their interaction are all important for determining cotton-farming productivity. The signs on these coefficients conform to *a priori* expectations: distance negatively affects productivity for communal farmers associated with indigenous commercial farmers, redistribution is negative for all treated farmers and the interaction effect is positive. These primary results survive the introduction of environmental, farm-level, year and region controls (Column (2)). Relative proximity of communal land to other locations of interest (trained farmers) is controlled for in Column (3), as well as observed quality characteristics (seed growers, goldclass and large farmers) of communal farmers.

This baseline specification (Column (3)), shows the expected signs on the distance, redistribution and interaction variables. Thus, distance from commercial land has a negative effect on productivity for communal farmers associated with indigenous commercial farms whilst redistribution has a negative productivity effect on those close to redistributed land (on disruption of the network effects of interest). The redistribution effect is larger than the distance effect: it is worse for cotton productivity to be close to a redistributed (non-indigenous) commercial farm than to be far away from non-redistributed land (indigenously farmed land). The interaction effect (average treatment effect) is positive: those communal farmers isolated from commercially farmed land have fared better than those relatively closer as a result of the redistribution. The redistribution effect is large relative to average yield per hectare (258kg/ha, seen in Table 7).

T-tests in Table 12 indicate that the overall effect of redistribution for proximate farmers (average treatment effect on the treated) is negative (due mainly to the wider economic collapse) and confirm that distance does not matter for productivity post-redistribution (average treatment on the controls).

The farm-level control variables have the predicted signs and are significant. Fertilizer and seed inputs[34] are positively associated with productivity, as is rainfall and soil quality[35] (with a large coefficient relative to the other

[34]Increased seed usage is correlated with increased land holdings (Table 5), at least up to 10 hectares. Thus, seed here proxies for relative land holdings among communal farmers.

[35]By construction, soil quality deteriorates as the size of this (categorical) variable increases.

Table 11: *Main Results*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance, km	-2.22***	-1.87***	-2.18***	-2.18***	-3.22***	-1.25**	-1.03**
	(0.42)	(0.50)	(0.50)	(0.81)	(0.81)	(0.62)	(0.51)
Redistribution, (D)	-21.88***	-31.72***	-35.79***	-35.79***	-39.87***	-35.84***	-23.28***
	(6.59)	(7.03)	(7.05)	(12.15)	(10.14)	(9.80)	(7.82)
D*R	1.22***	1.93***	2.35***	2.35***	3.17***	1.90***	1.47***
	(0.43)	(0.44)	(0.44)	(0.69)	(0.73)	(0.53)	(0.46)
Fert, kg		0.93***	0.70***	0.70***	0.77***	0.62***	0.64***
		(0.04)	(0.04)	(0.07)	(0.06)	(0.06)	(0.04)
Seed, kg		0.00	0.11	0.11	-0.31*	0.60***	0.28**
		(0.11)	(0.11)	(0.16)	(0.17)	(0.15)	(0.11)
Altitude, m		0.00	0.01	0.01	-0.00	0.03*	0.04***
		(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Soil quality (1-7)		-20.74***	-12.44**	-12.44	-18.17***	-5.72	-6.70
		(5.40)	(5.36)	(9.42)	(6.53)	(9.60)	(5.63)
Roads, km		1.45***	1.25***	1.25**	3.66***	-0.13	1.30***
		(0.33)	(0.33)	(0.63)	(0.67)	(0.36)	(0.34)
Gins, km		-0.57***	-0.42***	-0.42**	-0.25*	-0.66***	-0.41***
		(0.11)	(0.11)	(0.20)	(0.15)	(0.17)	(0.12)
Trained farmer, km			-0.37***	-0.37	-0.69***	-0.02	-0.02
			(0.13)	(0.27)	(0.20)	(0.17)	(0.13)
Seed grower, (D)			114.39***	114.39***	111.75***	120.92***	120.79***
			(12.50)	(19.93)	(17.44)	(17.93)	(15.16)
Goldclass, (D)			106.46***	106.46***	108.12***	103.81***	99.04***
			(7.63)	(25.66)	(12.98)	(8.95)	(7.92)
Large farmer, (D)			-175.93***	-175.93***	-193.96***	-157.00***	-168.68***
			(17.31)	(21.58)	(26.60)	(21.93)	(17.98)
Year, (D)		-48.00***	-50.42***	-50.42***			-50.21***
		(3.04)	(3.02)	(6.10)			(3.07)
Region, (D)		21.65***	32.16***	32.16***	25.51***	40.48***	52.80***
		(4.46)	(4.48)	(10.50)	(6.49)	(6.44)	(4.70)
Constant	304.17***	309.31***	287.75***	287.75***	313.49***	202.54***	223.32***
	(5.68)	(13.18)	(13.39)	(27.76)	(19.06)	(18.51)	(13.96)
Observations	31,653	31,653	31,653	31,653	16,519	15,134	29,807
R-squared	0.01	0.05	0.07	0.07	0.06	0.06	0.06
Specification	Treatment	Controls	Baseline	Group	2008	2009	Marginals

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 12: *T-tests on Coefficients of Interest: Main Regression Results*

	T-test		Accept/Reject	
D = D*R	F(1, 31637)	0.57	Prob > F	0.45
R = D*R	F(1, 31637)	26.72	Prob > F	0.00

environmental and agricultural control variables).

The roads proximity variable is consistently positive. Insofar as violence or the threat thereof often accompanies redistribution of commercial land and may spill over into adjoining communal land, this may reflect the effect of political violence on cotton productivity rather than the effect of access to roads themselves (which would enter with an expected negative sign here). Further, non-indigenous land (the focus of the political violence) is significantly closer to roads than indigenous land,[36] indicating that redistribution may have been largely opportunistic and thus facilitated by road proximity. The region dummy (taking the value 0 in northern Muzarabani and 1 in the Bindura and Glendale areas) may reflect reduced political violence in the north of the country where there are few urban areas and indeed few commercial farms, another control for unrest in the province.

Relative proximity to gins as well as NGO-trained farmers is positively related to productivity. Identifying as a goldclass and/or a seed-cotton grower are large, positive and significant for productivity. This informs one of the robustness specifications to follow. Further having 10 or more hectares under cotton negatively affects productivity. This is most likely to occur as larger communal farmers face binding credit and other resource constraints with increased land access. Last, the year dummy (taking the value 0 in 2008 and 1 in 2009) may pick up the deteriorating economic and political conditions in the country, especially hyperinflation which accelerated dramatically between the 2008 and 2009 seasons (Hanke and Kwok 2009).

Column (4) in Table 11 clusters the standard errors by 'group', a function of how farmers are organised within the Cottco credit-input structure. Farmers wishing to avail of Cottco's credit-input scheme are required to form groups with other cotton farmers in order to access credit. Although credit is disbursed at the individual farmer level, the group structure allows an extra level of credit repayment control by Cottco. If one person in the group is unable to repay the company satisfactorily, credit will be withheld from the entire group in the following year. The groups are primarily then a function of location. The results survive, with some increase in the size of the standard errors.

[36]As seen in Table 2.

The data on cotton inputs and outputs comprises information for the 2008 and 2009 agricultural seasons. Separating these two sub-samples, columns (5) and (6) respectively, sees a change in the size of the coefficients on distance, redistribution and the interaction term. This indicates a slight weakening of the negative effect of redistribution over time.

Last, column (7) shows results for the reduced sample: here those farmers equidistant from commercial land (within a 25km radius) are excluded from the regression to test for robustness on the construction of the difference-in-difference specification. Coefficient signs are maintained but there is some loss of significance for the soil quality and trained farmer controls. That the main results survive indicates these 'marginal' farmers are not driving the identification of the network effects of interest. The coefficients on soil quality and trained farmers loose their significance in columns (4) ,(6) and (7). This may be due to lack of variation in these variables, as discussed previously regarding soil quality in particular (see Figure 3).

5.3 Robustness Tests

The primary identification and sample are then augmented with additional data. Alternate outcome variables and details of a training scheme provide pre- and post-redistribution data and are used to test the validity of the identification strategy. Nearest-neighbour matching examines the robustness of the primary results to non-linear controls. Alternate specifications allow several possible mechanisms to be illuminated through which the network effects of interest may operate. Details on linkages between farmers tests the importance of access to transportation and therefore timely delivery of inputs to farmers. Data on communal farmer proximity to identified high-quality communal farmers facilitates testing of the relative importance of land ownership structures and farmer-quality to agricultural outcomes via network effects.

First, the validity of the primary identification strategy is examined using alternate outcome variables from the Zimbabwean CSO, the specification in Table 13 substitutes Income Consumption and Expenditure Survey (ICES) outcome variables for yield per hectare and allows for explicit examination of pre- and post-redistribution effects.[37] As effects on agricultural productivity are the primary concern of the paper, controls related to this productivity are maintained here. The results, based on alternate outcome variables, broadly confirm the paper's main conclusions.

For example, outcome variables measuring employment (column (1)), access to piped water (column (2)) and proportion of people receiving waged income (column (3)), reflect the baseline results on the difference-in-difference variables of interest, although there is some loss of sign and significance for the control variables. The latter is to be expected as the explanatory variables are constructed primarily to control for agricultural productivity drivers, rather than survey outcome covariates, in most cases. T-tests comparing coefficient sizes, shown in Table 14, do not reject the *a priori* signs and relative sizes of the coefficients of interest between the main results and this alternate specification.

Where the regression results are inconsistent with the primary hypothesis the following can be noted. The positive redistribution effect on schooling may reflect the large increase (seen in Table 3) in the proportion of people with at least basic schooling that occurred between the 1995 and 2001 rounds of the household survey.[38] This is similar to the results using cattle ownership as the dependent variable (column (5)) for the positive effect of redistribution. On the other hand, the positive effect of distance in (5) may reflect an artefact of communal farming practice in Zimbabwe, that is over-accumulation of cattle relative to sustainable grazing resources. This as cattle represent one of the few assets in communal farming communities that can be used as collateral to raise private credit. Cattle ownership is thus one of the few ways communal farmers have in order to achieve investment in their farms.[39]

Table 15 substitutes 'distance from areas containing NGO-trained farmers' for 'distance from commercial land' as the treatment. The redistribution indi-

[37]The number of observations increases to 66,174 from the baseline specification of 31,653 as survey outcome variables are available for all farmers (at the enumeration area level) whereas nearly 30,000 farmers do not record cotton output in the Cottco data and are therefore excluded from the baseline estimation.

[38]For example, Dore et al. (2008) notes the deterioration in social outcomes that has occurred since 2001 is concurrent with wider economic, social and political decline, especially in rural areas with regards to educational outcomes. Thus, '...poverty took on an increasingly rural...face' (Dore et al. 2008, p.17).

[39]Rukuni (1994, p.41) notes that '(l)evels of private investment into immovable assets in the (c)ommunal (a)reas is minimal, while that into movable assets like livestock has been large.'

Table 13: *Robustness: Alternate Outcome Variables (Survey Data)*

Dependent Variable	(1) Employment	(2) Piped Water	(3) Waged Income	(4) Schooling	(5) Cattle
Distance, km	-0.60***	-0.15***	-1.26***	-0.16***	0.28***
	(0.01)	(0.00)	(0.02)	(0.01)	(0.00)
Redistribution, (D)	-26.02***	-1.45***	-21.45***	3.77***	6.02***
	(0.18)	(0.05)	(0.20)	(0.07)	(0.05)
D*R	0.60***	0.16***	1.32***	-0.02***	-0.31***
	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Fert, kg	-0.00***	0.00***	-0.01***	0.01***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Seed, kg	0.05***	-0.00**	0.07***	0.00	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Altitude, m	0.02***	0.00***	0.02***	0.00***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Soil quality (1-7)	-3.15***	-1.32***	-2.14***	2.29***	1.99***
	(0.13)	(0.04)	(0.14)	(0.05)	(0.04)
Roads, km	0.02**	-0.01***	0.12***	-0.04***	-0.05***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)
Gins, km	-0.14***	-0.04***	-0.18***	0.04***	0.07***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Trained farmer, km	0.16***	-0.00***	0.18***	0.09***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Seed grower, (D)	0.13	2.51***	-1.55***	3.24***	-0.95***
	(0.24)	(0.07)	(0.26)	(0.10)	(0.07)
Goldclass, (D)	3.91***	1.28***	3.28***	0.04	-0.70***
	(0.17)	(0.05)	(0.19)	(0.07)	(0.05)
Large farmer, (D)	0.40	-0.21	0.41	-0.96***	0.03
	(0.70)	(0.21)	(0.77)	(0.29)	(0.22)
Year, (D)	1.29***	0.21***	1.12***	0.12***	-0.36***
	(0.07)	(0.02)	(0.08)	(0.03)	(0.02)
Region, (D)	0.55***	-2.11***	3.30***	-0.91***	-0.52***
	(0.11)	(0.03)	(0.12)	(0.05)	(0.03)
Constant	25.09***	4.68***	17.01***	79.80***	5.11***
	(0.32)	(0.10)	(0.35)	(0.13)	(0.10)
Observations	66,174	66,174	66,174	66,174	66,174
R^2	0.59	0.21	0.45	0.32	0.58

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 14: *T-tests on Coefficients of Interest: Survey Outcome Results*

	T-test		Accept/Reject	
		D = D*R		
Employment	F(1, 66158)	0.03	Prob > F	0.86
Piped Water	F(1, 66158)	119.86	Prob > F	0.00
Waged Income	F(1, 66158)	131.76	Prob > F	0.00
		R = D*R		
Employment	F(1, 66158)	20133.08	Prob > F	0.00
Piped Water	F(1, 66158)	790.08	Prob > F	0.00
Waged Income	F(1, 66158)	12253.54	Prob > F	0.00

cator takes the value 1 for those cotton farmers relatively close to NGO-trained farmers from 2000 onwards, and 0 otherwise, thereby utilising pre- and post-redistribution data explicitly. Column (2) is the specification of interest here. When the full sample[40] of cotton farmers is used, the difference-in-difference identification design reflects the positive effects that proximity to trained communal farmers has on farm level productivity. The coefficient on this alternate distance measure is significant, if smaller in size, to the effect of distance (to commercial farms) in the main results. Redistribution remains negative and large for productivity, suggesting that redistribution and the attendant economic decline disrupted post-training support structures for those communities proximate to trained communal farmers. This further validates the paper's preferred identification strategy as well as providing evidence that in the absence of commercial farms remaining communal farming communities may be able to replicate the network effects of interest in time. Discussion of the CTC in Section 3 supports this interpretation. Specifically, this mechanism indicates the importance of pest reduction on cotton productivity, as evidenced by the emphasis placed on pest reduction during the CTC training and the positive local spillover effects that are generated on wider dissemination of this knowledge. Whilst commercial farmers in Mashonaland Central grow a variety of crops tobacco has particular importance as an export crop. As tobacco requires high pesticide inputs the associated localised pest reduction may inform one of the commercial farmer network effects that characterises the relationship of

[40]The full sample comprises 47,000 observations, across both Mashonaland Central and East.

primary interest here.[41]

Table 15: *Robustness: Proximity to NGO-Trained Farmers*

Yield per ha	(1)	(2)	(3)	(4)
Distance, km	-0.02	-0.29***	-0.20**	-0.15
	(0.13)	(0.09)	(0.10)	(0.10)
Redistribution, (D)		-39.75**	-122.61	
		(19.02)	(167.54)	
D*R		1.28**	6.52	-1.65
		(0.62)	(9.14)	(2.78)
Fert, kg	0.66***	0.71***	0.72***	0.72***
	(0.03)	(0.03)	(0.03)	(0.03)
Seed, kg	0.25**	0.20**	0.18*	0.20**
	(0.11)	(0.10)	(0.10)	(0.10)
Altitude, m	0.03**	0.03***	0.04***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
Soil quality (1-7)	-22.57***	1.31	-0.44	-3.49
	(5.50)	(4.08)	(4.02)	(4.20)
Roads, km	1.49***	1.44***	1.44***	1.46***
	(0.38)	(0.28)	(0.32)	(0.32)
Gins, km	-0.36***	-0.37***	-0.36***	-0.38***
	(0.08)	(0.06)	(0.07)	(0.07)
Seed grower, (D)	117.03***	85.36***	96.32***	118.57***
	(9.41)	(8.41)	(7.09)	(8.25)
Goldclass, (D)	104.55***	103.13***	100.49***	95.31***
	(5.96)	(6.96)	(5.46)	(5.53)
Large farmers, (D)	-179.61***	-173.11***	-179.87***	-186.97***
	(25.07)	(14.43)	(21.56)	(22.28)
Year, (D)	-51.61***	-55.10***	-54.82***	-54.56***
	(3.09)	(2.56)	(2.71)	(2.76)
Region, (D)	48.06***	38.13***	39.45***	40.29***
	(4.72)	(3.56)	(3.92)	(4.00)
Constant	281.13***	216.96***	243.21***	243.27***
	(18.55)	(18.48)	(20.80)	(21.36)
Observations	30,531	47,000	40,143	38,285
R^2	0.06	0.06	0.06	0.06
Specification	Baseline Sample	Full Sample	Mash Central	Non-Resettled Only

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

T-tests comparing coefficient sizes, shown in Table 16, do not reject the *a priori* signs and relative sizes of the coefficients of interest between the main results and this alternate specification.

Table 17 shows the primary linear estimation strategy altered to allow for

[41] See Appendix F for further information.

Table 16: *T-tests on Coefficients of Interest: Trained Farmer Results*

	T-test		Accept/Reject	
D = D*R	F(1, 46973)	0.03	Prob > F	0.86
R = D*R	F(1, 46973)	8.98	Prob > F	0.00

non-linear relationships between covariates and the dependent variable. This allows for heterogeneity of the treatment effects. The nearest-neighbour matching estimator, proposed by Abadie and Imbens (2006), is used. This non-parametric approach bypasses the difficulties associated with propensity-score matching, especially balancedness on an *a priori* set of observables and the validity of bootstrapped standard errors.[42] Thus, columns (1) and (2) investigate the effect of distance on communal farmers. Column (1) confirms the main results that distance ($d = 1$) is negative for productivity, this broadly conforms to the expectations on β_1 previously. Column (2) indicates that, when utilising matching techniques, distance from commercial land may still be negative for productivity although the size of the coefficient has more than halved in size. This confirms conclusions from the primary analysis, namely of a reduced distance effect due to the reduced networks effects now available to near-by communal farmers, this significant effect is driven by the economy wide contraction evident post-redistribution in the country. Columns (3) and (4) show results for the effect of redistribution explicitly. Column (3) shows a negative effect for communal farmers close to commercial land when comparing those associated with indigenous and non-indigenous commercial farms. Redistribution is negative for productivity as pro-productivity network effects are removed, broadly conforming to the expectations on β_2 previously. Column (4) shows that distant communal farmers benefit, at the margin, on redistribution. This is in contrast to distant communal farmers associated with indigenous commercial farms. The combined effects illustrated by columns (2) and (4) go some way to replicating the expected sign on β_3 described previously. Although, the empirical limitations of the matching technique employed here does not allow this effect to be examined definitively here.

[42] The matching is carried out using four specifications allowing investigation of the relationships of interest. This is necessary as available estimators do not allow for interaction terms explicitly.

Table 17: *Robustness: Matching Estimator*

Yield per ha	(1)	(2)	(3)	(4)
Treated[1] communal farmers	-71.27	-29.89	-47.72	126.54
	(9.11)***	(10.52)***	(10.53)***	(20.84)***
Observations	8795	7902	12874	1357
Matches	2	2	2	2
Specification	$r = 0;$	$r = 1;$	$r = 0, 1;$	$r = 0, 1;$
Specification	$d = 0, 1$	$d = 0, 1$	$d = 0$	$d = 1$

[1]'Treatment' here refers to distance (as is standard in the paper) for columns (1) & (2); whereas in columns (3) & (4) treatment refers to redistribution. This is in order to examine the effects of both where interaction effects cannot be included with the nearest-neighbour estimator available. Note similar controls to those employed in the primary specifications are used here. Common support is established prior to each matching exercise by refining the sample after running logit regressions on treated/untreated sub-samples.
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 18: *Robustness: Detailed Sub-Sample (Identification Issue)*

Dependent Variable	(1) Yield per ha	(2) Paraffin	(3) Cattle	(4) Yield per ha	(5) Paraffin	(6) Cattle
Average distance to named Seedholder, km	-2.05***	-0.01***	-0.02*			
	(0.52)	(0.00)	(0.01)			
Average distance to Seedholder, km				-2.23***	-0.01***	-0.01
				(0.55)	(0.00)	(0.01)
Constant	407.84***	0.94***	8.68***	501.55***	0.89***	7.07***
	(36.15)	(0.10)	(0.35)	(31.83)	(0.07)	(0.38)
Observations	95	112	112	157	178	178
R^2	0.08	0.22	0.03	0.04	0.17	0.00

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Examination of detailed information available for 200 farmers within the larger sample of communal cotton farmers shows that when controlling for identified linkages between farmers receiving and providing assistance, timely delivery of agricultural inputs is important for cotton productivity, especially for 'weaker' farmers. This is a revealed mechanism through which the paper's main network effects operate. Table 18 confirms that distance from 'seed-holder' farmers (identified as providing transportation of inputs to other farmers) is negatively associated with cotton productivity, access to cooking fuel and asset levels. Distance from named seed-holders is augmented with distance from the closest seed-holder in the area for columns (4), (5) and (6). Some significance is lost, though the results hold overall.

Table 19 controls for agricultural inputs as well as environmental conditions, which prove weaker (lack of significance although correct signs are maintained) explanatory variables than in the main analysis despite more detailed information being available. This is due in part to the low sample size. Table 19 does however indicate consistency with earlier results regarding signs on the variables of interest, distance from seed-holders - negative - and a dummy variable indicating when farmers receive assistance from others - positive - although this is not significant for specification (6).

Table 19: *Robustness: Detailed Sub-Sample*

Yield per ha	(1)	(2)	(3)	(4)	(5)	(6)
Average distance to named Seedholder, km				-1.80***		
				(0.59)		
Average distance to Seedholder, km					-1.38**	-1.36**
					(0.60)	(0.60)
Received assistance, (D)						9.47
						(58.62)
Fert, (D)	144.98***		82.83	21.83	53.65	55.31
	(55.47)		(56.66)	(63.44)	(56.08)	(56.55)
Seed, kg	5.87*		3.66	0.74	3.80	3.89
	(3.05)		(2.99)	(11.42)	(3.04)	(3.05)
Other inputs, (D)	176.05*					
	(93.06)					
Soil quality (1-7)		-278.14**	-267.07*		-218.24	-218.13
		(139.00)	(142.20)		(136.02)	(136.72)
Goldclass, (D)		374.08***	284.96***	342.82***	279.84***	284.21***
		(64.18)	(86.80)	(77.15)	(88.82)	(93.27)
Constant	261.71***	620.78***	548.14***	365.74***	548.76***	540.46***
	(43.00)	(141.87)	(149.75)	(73.35)	(137.50)	(147.77)
Observations	151	154	148	89	148	148
R^2	0.18	0.22	0.23	0.12	0.24	0.24

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 20 reproduces column (6) in Table 19 for two alternate dependent variables, access to paraffin as cooking fuel and cattle ownership. Although some of the control variables are compromised here with regards to sign,[43] the significant controls consistently display the expected signs and, importantly, the dummy variable indicating farms that rely solely on input transportation from proximate seed-holders is significant and positive for both access to paraffin and cattle ownership.

Finally, as seen in the main results, belonging to the groups of goldclass, large

[43] As the explanatory variables are constructed primarily to control for agricultural productivity drivers, rather than ICES outcome covariates, it may be expected that some confounding of coefficients is possible.

Table 20: *Robustness: Detailed Sub-Sample (Alternate Outcome Variables)*

Dependent Variable	(1) Yield per ha	(2) Paraffin	(3) Cattle
Average distance to Seedholder, km	-1.36**	-0.01***	-0.02**
	(0.60)	(0.00)	(0.01)
Received assistance, (D)	9.47	0.39***	1.49*
	(58.62)	(0.12)	(0.78)
Fert, (D)	55.31	0.95***	-2.80***
	(56.55)	(0.11)	(0.73)
Seed, kg	3.89	0.00	-0.02
	(3.05)	(0.00)	(0.04)
Soil quality (1-7)	-218.13	-0.08	0.61
	(136.72)	(0.18)	(1.95)
Goldclass, (D)	284.21***	-0.16	-1.40
	(93.27)	(0.17)	(1.25)
Constant	540.46***	0.10	8.49***
	(147.77)	(0.22)	(2.05)
Observations	148	171	171
R^2	0.24	0.42	0.22

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

and seed-cotton growing farmers strongly predicts cotton productivity with coefficients some 2.5 times the size of the redistribution effect. These high quality farmers may thus also be providing some localized spillover effects, mirroring the spillovers produced by commercial farmers. In order to test this, the baseline specification is augmented in Table 21 by adding goldclass, larger-scale[44] and seed-growing communal cotton farmers to indigenous commercial farmers (column (1)), as well as each group separately (columns (2), (3) and (4) respectively), in setting up the difference-in-difference analysis. This augmentation tests whether unobserved characteristics shared by large and/or highly productive *communal* farmers explains localised productivity spillovers to communal farmers. If this is confirmed, high quality and/or larger farmers located relatively far away from commercial land, may provide social-learning effects in the absence of commercial farmers.

Table 21 indicates that this mechanism is not contributing to the results seen in the primary analysis in Table 11. Proximity to high quality farmers (column (2)) is not consistent with the network spillovers identified in the primary speci-

[44] I.e. farmers with over 10 hectares under cotton. This is where communal land holdings, including access to grazing, average 16 hectares across the country (Chavunduka 1982, p.64).

fication. These results imply that characteristics, specific to commercial farmers are important for the effects found in Table 11. For example, access to significant credit, facilitating investment in human and physical capital, may be important here. This access is predicated on the ownership structure of agricultural land.

Table 21: *Robustness: Goldclass, Large Farmers and Seed-Cotton Growing Farmers*

Yield per ha	(1)	(2)	(3)	(4)
Distance, km	0.10	0.91*	0.48*	4.20
	(0.28)	(0.48)	(0.25)	(4.02)
Redistribution, (D)	-2.39	-0.27	-1.52	35.04
	(3.96)	(4.21)	(4.11)	(27.71)
D*R	0.02	-0.82	-0.37	-4.03
	(0.28)	(0.51)	(0.26)	(4.05)
Fert, kg	0.59***	0.58***	0.65***	0.66***
	(0.03)	(0.03)	(0.03)	(0.04)
Seed, kg	0.32***	0.33***	0.27***	0.26**
	(0.08)	(0.08)	(0.08)	(0.12)
Altitude, m	0.03***	0.03***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)
Soil quality (1-7)	-9.69**	-9.32**	-9.69**	-11.77**
	(3.80)	(4.08)	(3.96)	(5.33)
Road, km	1.60***	1.41***	1.28***	1.79***
	(0.24)	(0.24)	(0.24)	(0.34)
Gins, km	-0.25***	-0.28***	-0.34***	-0.36***
	(0.05)	(0.05)	(0.05)	(0.11)
Trained farmer, km	-0.02	-0.06	-0.08	-0.07
	(0.09)	(0.09)	(0.09)	(0.13)
Seed grower, (D)		115.42***	134.53***	
		(10.78)	(11.38)	
Goldclass, (D)			102.26***	92.14***
			(5.72)	(7.90)
Large farmer, (D)		-162.85***		-149.52***
		(21.12)		(19.22)
Year, (D)	-51.08***	-49.88***	-49.10***	-49.15***
	(2.22)	(2.26)	(2.26)	(3.08)
Region, (D)	50.45***	46.93***	47.89***	51.30***
	(3.55)	(3.66)	(3.45)	(4.78)
Constant	215.70***	220.38***	219.95***	178.46***
	(7.98)	(8.25)	(7.94)	(29.03)
Observations	51,720	51,831	56,654	28,207
R^2	0.03	0.04	0.06	0.05
Specification	Goldclass, Large & Seed Growers	Goldclass	Large Farmers	Seed Growers

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

It can be noted that the R^2 statistics are low (less than 0.1) for the following specifications: Tables 10, 11 and two of the robustness checks (Tables 15 and 21). This indicates that important explanatory variables have not been controlled for in these specifications. If these are correlated with the independent variables this may be of concern. However, for the specifications utilising data from the detailed sub-group and alternate (survey) dependent variables, the value of R^2 increases to 0.24 and 0.59 respectively. These specifications are altered only slightly from the primary specification and the sign and significance on the coefficients of interest are preserved with the larger value of R^2. This indicates the the omitted variables may well be artefacts that are not strongly correlated with the independent variables included in the regressions here. Further information on the farmer's characteristics and more detailed information regarding the ecology of the farmland itself may be useful here (Neba et al. 2010).

Overall the estimated results described here provide clear identification of the network effects of interest between commercial and communal farmers and validity for the primary identification strategy. Furthermore the richness of the available secondary data describing alternate outcome variables as well as a detailed description of the overall structure of cotton production in the country strengthen the primary results and allow identification of some of the mechanisms through which these network effects may be operating. The estimation results, both linear and non-linear, show that communal farmers proximate to redistributed land have suffered significantly as a result of the dismantling of positive agricultural network effects that operate primarily between very large commercial farmers and small-scale communal farmers. On the other hand, assistance in timely transportation of agricultural inputs, as well as cotton training schemes may replace some of these positive spillovers for the communal cotton growing community in Zimbabwe.

A concern is that the identification of potential network effects may be confounded by omitted variables bias. Where network effects have been substituted for alternate coping strategies in control areas, the observed effects would likewise be confounded. This may result in a reduced 'distance effect'. This would bias the paper's overall results downwards from the true effect under experimental conditions.

Selection bias on types of commercial farmers may also be of concern. First, differences between indigenous and non-indigenous commercial farmers may confound the identification power of the paper's results. Relatively little research has been formally carried out between or indeed within these groups. To the extent that both are located in similar geographic areas with similar access to private sector credit there is little to suggest that indigenous farmers differ significantly from their non-indigenous counterparts. Differences across observable characteristics are tested across these groups, and controlled for where found (see Table 2).

Further, those communal farmers located close to non-indigenous, redistributed land may have been affected differentially by the land reform process itself. If these farmers received more land,[45] their per-hectare productivity may decline as finite resources are spread over increased plot sizes. Similarly, where household labour is reduced as a result of redistribution, cotton productivity, which is particularly reliant on household labour may be negatively affected. Testing for relative hectarage shows no difference between farmers close to redistributed land and those further away (see Table 4). A proxy for farm size (seed usage) controls for the potential negative effect of increased farm size on productivity (see Table 5).

6 Conclusion

This paper combines farm-level, geographic and survey data with information on land ownership structures both before and after recent land redistribution policies implemented in the country. The paper is specifically concerned with communal farmers who have not (as yet) benefited from recent land redistribution policies in Zimbabwe. The data is analysed to assess whether and to what extent communal farmer location, with respect to large scale commercial farms, affects cotton productivity, income, consumption or expenditure outcomes, as a result of social learning externalities and/or network effects between these two

[45]Either as a direct result of the redistribution, where the household's land holdings increase, or as an indirect result, where beneficiaries in the associated village receive land thus resulting in more land available for the remaining village households.

groups of farmers.

I find a negative effect on cotton productivity and some survey outcome variables for cotton farmers located close to recently redistributed commercial farms, when controlling for farm-level environmental characteristics as well as input use. This applies both when compared to those farmers near commercial land that has not been redistributed as well as those farmers located away from any commercial land. This supports the paper's main hypothesis, namely that communal farmers benefit from localised network effects, based on proximity to large-scale commercially farmed land. Removal of these network effects has resulted in negative agricultural outcomes for proximate cotton farmers that could be identified over and above the wider-spread negative effects of the redistribution policy coinciding with generalised economic, political and social decline.

The paper carries out several robustness tests both to control for selection bias and to attempt to uncover mechanisms by which the network effects of interest may operate. Examination of an NGO-led cotton training programme provides evidence for the existence of social learning amongst cotton growers. The difference-in-difference results for income, consumption and expenditure outcomes indicate the importance of these network effects for a wider set of social and economic outcomes as well as explicitly accounting for the difference in outcome before and after the redistribution. This secondary difference-in-difference identification strategy goes some way to ruling out the possibility that selection bias on commercial farm types is driving the results. Subsequent specifications indicate that network effects are correlated with land ownership structures and farm size rather than simply with relative productivity of larger-scale farmers. Where land ownership structures predicate ability to leverage land in order to access private credit markets, this may be driving the results, rather than unobservables on commercial farmers potentially correlated with ethnicity. Lastly, examination of a detailed sub-sample of cotton farmers indicates that transportation of inputs for under-resourced farmers may be one channel through which the network effects identified may operate.

These revealed network effects mechanisms suggest that the network effects of interest may be replaced, over time, by existing communal farmer networks in the country.

The results have policy implications for land redistribution policies both within Zimbabwe and more broadly. The rich empirical analysis as well as anecdotal evidence suggest that access to machinery, skills and pesticide spillovers provided by commercial farmers (directly or indirectly) and otherwise unavailable to communal farming communities, is important. This adds to existing work on land reform in Zimbabwe, for example, Kinsey (2004) where the effects of land redistribution on the outcomes of resettled farmers are investigated. Further, this paper addresses an area that has received little attention in the literature, namely the effect of land redistribution on those farmers who do not benefit directly through land allocation. Here I focus on those communal farmers yet to benefit from the recent land redistribution in the country.

Whilst it is acknowledged that addressing historic land ownership imbalances is of importance for sustained and equitable post-colonial development, the paper's results argue that an extensive knowledge of both formal and informal agricultural support structures is essential before engaging in wide-spread land reform. This is in order to avoid costly removal of support structures essential to the sustainability of the sector post reform. This is especially important where agriculture accounts for a large proportion of national output, as well as income and food security for large segments of society.

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A Cotton in Zimbabwe

Zimbabwe is widely regarded as the "star performer amongst liberalized cotton sectors" (Poulton et al. 2004, p.527) with high small holder yields and cotton quality. Cottco is recognised as giving good producer prices which may stimulate the higher yields and returns it realises when compared to other African countries. Quton, the country's seed-cotton supplier, is also applauded for its high quality research and development strategy. Poulton et al. (2004) also highlights some of the recent issues affecting the country's cotton including productivity, service delivery, relationships with producers and quality control as the market adjusts to a large number of new entrants since 2000.

B Background: Important Official Documents

Four official documents, three from the Government of Zimbabwe and one from the United Nations Development Programme (UNDP), inform much of the published background material documenting the progress of the reforms carried out in the country since independence in 1980. Chavunduka (1982) recognises the unsustainability of the land-ownership system the country inherited from previous regimes, specifically the falling productivity and rising population densities in communal farming areas. This report highlights the lack of capital formation under the communal ownership system and the difficulties that communal farmers have in accessing credit facilities. The report also indicates that commercial farmers recognised the need for orderly redistribution and that they were engaged in discussing the financing and execution of such a system[46] Rukuni (1994) focuses on appropriate land tenure systems noting early on that efficient land use depends on access to capital, education, agricultural services, infrastructure as well as land tenure. This report also describes the historic allocation of land between black and white farmers in the country prior to independence. Finally Utete (2003) examines the initial years of the FTLR programme. Several ongoing issues affecting the FTLR are noted, including relatively low take up of allocated land, lack of agricultural inputs hampering those farmers who have taken up allocated land but are unable to realize its full potential, the need for increased infrastructure as well as the chaotic and opaque nature of the allocation process itself. Last Dore, Hawkins, Kanyenze, Makina, Ndlela and Simpson (2008) examines some of policies required to begin sustainable recovery in the country, given the catastrophic economic and social decline since the late 1990s.

C Zimbabwe

Zimbabwe achieved majority rule in 1980 after declaring independence from Britain in 1965. The 1980s saw a continuation of many of the control economy arrangements initiated before 1980 as well as implementation of significant redistributive objectives, including land reform programmes. These saw improvements in social indicators, for example education attainment and primary health care outcomes, albeit at the cost of large budget deficits. Initial redistributive policies likewise contributed to increased domestic demand. However, low export growth as well as weak capital formation, scarcity of foreign exchange and on-going fiscal imbalances ultimately led to a wide-spread acceptance of economic restructuring, (Dore et al. 2008).

Resulting reforms, led by the World Bank and IMF, in the first half of the 1990s included trade liberalisation, which saw many inefficient, local manufacturing concerns whither, with few attaining international export status, including many involved in cotton processing (for example textile manufacturing).

[46]The report also discusses the constitutional limits placed on the government's policies to effect significant land reform, as laid out in the Lancaster House agreement.

Thus agriculture remained important for export earnings, employment and rural poverty reduction. This despite a failure to address fundamental weaknesses in the structure of the agricultural sector resulting from historic racial imbalances which contributed to low productivity gains for the communal sector.

Further, failure to accept the fiscal logic required by a sustained opening of the economy in the early 1990s reversed many of the gains from the previous decade, as inflation accelerated and growth stalled. This along side a failure to create jobs for the growing, and increasingly educated, work force led to heightened political and economic pressure towards the end of the decade. Finally, "government policy became increasingly interventionist as the authorities sought to reverse [the] economic decline" (Dore et al. 2008, p.10).

D Sample Selection

The sample of communal cotton farmers comprises all cotton farmers on Cottco's files for three (Bindura, Glendale and Muzarabani) of the company's nine business units. Cottco provides credit services to over 50% of the cotton farmers in the country, although not specifically representative the available sample relates to a large porportion of existing cotton farmers. Selection bias between Cottco and non-Cottco cotton farmers cannot be ruled out but are not thought to significantly affect the sample characteristics.

The sample is reduced to account for the availability of data on commercial farm ownership structures. Thus farmers in western and north-western Mashonaland Central have been excluded as well as several farmers in the south east of the province. Additionally, those farmers close to (within 10km of) land currently farmed by remaining non-indigenous commercial farmers have been excluded from the sample as selection-bias on commercial farm ownership is expected to be significant. Significantly farmers located on commercial land of any sort are excluded - these redistributed farmers are expected to introduce significant selection bias as they are outside of the targeted identification strategy of the paper. Last, the Cottco data contains many farmers for whom no yield information is available, these farmers are excluded from the baseline analysis but are included in the robustness check carried out by substituting yield information for household survey outcomes. The baseline analysis then comprises 30,531 observations from a possible 79,682 where 25,846 are excluded on geographic criteria (proximity to uncategorised commercial farm land etc) while 23,305 are excluded initially due to lack of yield data, although these farmers are subsequently re-introduced into the analysis.

E Additional Descriptive Statistics

Comparisons between communal cotton farmers remaining on their land and those farmers who have benefited directly from the land redistribution can be seen in Table E1. This is carried out across environmental, outcome, farm characteristics and relative location of these groups of farmers from economic entities of interest. Redistributed farmers achieve higher yields on similar hectarages than the combined group of control and treated communal farmers.

Differences between the 'detailed sub-group' (200 farmers) and the full sample can be seen in Table E3. Here the sub-sample records higher output per hectare and more conducive environmental conditions (altitude, rainfall and soil quality) than the large sample. The sub-sample is also closer, on average, to roads, gins and goldclass, and commercial land than the overall sample. Last the sub-sample are more likely to be seed-cotton growers than the baseline sample, a predictor of farmer quality. This indicates that the sub-group is may benefit from easier access to gins, trained communal farmers and environmental conditions but also that the group is more prone to experience violence as a result of the redistribution implementation (proximity to roads).

Table E1: *Farm/er Characteristics: Non-Redistributed and Redistributed Communal Farmers (Mean Difference)*

	Non-Redistributed	Redistributed	Mean Diff.
	Outcome		
Yield per ha, kg	258.40	321.26	-62.85***
			(7.83)
	Farm Characteristics		
Ha	2.74	2.63	0.11
			(0.24)
Seed, kg	21.64	15.49	6.15***
			(0.41)
Fertilizer, kg	36.63	68.77	-32.14***
			(1.46)
	Environmental Characteristics		
Altitude, m	713.63	1089.65	-376.13***
			(8.39)
Rainfall (annual average), mm	770.90	853.70	-82.79***
			(1.82)
Soil quality (1-7)	1.10	1.16	0.66
			(0.96)
	Proximity		
Roads, km	3.70	2.78	0.92***
			(0.12)
Gins, km	49.55	24.44	25.10***
			(0.97)
Trained farmer, km	20.00	15.79	4.21***
			(0.39)
Seed grower, %	3.04	34.11	-31.76***
			(0.55)
Goldclass farmer, %	7.91	7.02	0.89
			(0.78)
Large farmer, %	0.36	0.73	0.36**
			(0.17)
Indigenous, km	31.02	5.21	25.80***
			(0.62)
Non-Indigenous, km	25.07	0.23	24.83***
			(0.48)
Observations	30,531	1,240	

Source: Cottco (2009), Cotton Training Centre (2009), Quton (2009), Fischer et al. (2008), Matsuura and Willmott (2009), Hijmans et al. (2005) & Farm Valuation Data (2010). Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table E2: *Proximity and Hectarage: Treated Farmers (Mean Differences)*

	Indigenous		Non-Indigenous		
	Mean	No. of Obs.	Mean	No. of Obs.	Mean Diff.
			Hectarage		
Treated[1]	2.25	6172	2.32	7781	-0.08
					(0.12)
			Distance		
Treated	5.62	6172	5.55	7781	-0.07**
					(0.04)

Source: Cottco (2009) & Farm Valuation Data (2010).
[1] All cotton located less that 10km from any commercially farmed land.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E3: *Farm/er Characteristics: Detailed Sub-Group and Baseline Sample (Mean Differences)*

	Sub-sample	Baseline sample	Mean Diff.
		Outcome	
Yield per ha, kg	455.38	258.40	196.97***
			(21.58)
		Environmental Characteristics	
Altitude, m	862.11	713.63	148.47***
			(22.65)
Rainfall (annual average), mm	835.74	770.90	64.83***
			(4.81)
Soil quality (1-7)	1.02	1.10	0.75***
			(0.24)
		Proximity	
Roads, km	2.54	3.70	-1.16***
			(0.33)
Gins, km	24.37	49.55	-25.18***
			(2.56)
Trained farmer, km	16.29	20.00	-3.71***
			(1.48)
Seed grower, %	30.9	3.04	27.867***
			(1.31)
Goldclass farmer, km	2.29	2.50	0.21
			(0.38)
Large farmer, km	16.07	6.49	9.57***
			(0.64)
Indigenous farmer, km	16.07	31.02	-14.95***
			(1.64)
Non-Indigenous farmer, km	10.94	25.07	-14.12***
			(1.27)
Observations	178	30531	

Source: Cottco (2009), Cotton Training Centre (2009), Quton (2009), Fischer et al. (2008), Matsuura and Willmott (2009), Hijmans et al. (2005) & Farm Valuation Data (2010).
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

F Commercial Agriculture in Zimbabwe

In 1983 commercial farmers in Mashonaland had over 40,000 hectares under tobacco yielding 92,000 tons of tobacco, 204,000 hectares under maize (467,000t), 14,000 hectares under wheat (84,000t) and 40,000 hectares under soya beans (71,000t), the four most important cash crops in the area by land usage (Central Statistics Office 1983). By the late 1990s the total tobacco and wheat outputs in this area had doubled, whilst that of soya bean and maize had stayed roughly constant over time (Commercial Famers' Union 2004). Commercially grown tobacco has a high pesticide requirements (Taylor 1984), this is likely to reduce the local pest burden to the benefit of other farmers in the area. This provides one possible cause of the positive spillover effects found here.

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