Agricultural Productivity and Deforestation: Evidence from Input Subsidies and Ethnic Favoritism in Malawi[1]

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Abstract

This paper studies the underlying relationship between agricultural productivity and deforestation by analyzing the impacts of a large fertilizer and seed subsidy program in Malawi. In the absence of well-defined subsidy eligibility criteria, we demonstrate that areas with a high proportion of individuals of the same ethnicity as the president received more fertilizer subsidies, increased their hybrid maize yields, and deforested less compared to areas with other predominant ethnicities. We provide evidence that this effect is not due to increases in public sector employment or other public assistance programs. The results suggest that policies aimed at increasing small-scale agricultural productivity may have positive environmental spillovers.

1 Introduction

Low agricultural productivity presents a significant barrier to development for much of the world (Barbier and Hochard, 2014). At the same time, tropical deforestation, which has accounted for nearly 10 gigatons of carbon dioxide released into the atmosphere between 2000 and 2010 (Baccini et al., 2012), has been largely driven by clearing land for agriculture. It is therefore important to understand the underlying relationship between agricultural productivity and deforestation in the developing world. If improvements in agricultural productivity increase the demand for cleared land, development policies aimed at improving small-holder productivity may have negative environmental consequences. However, if increases in productivity allow small holders to delay the need to shift cultivation to new land, these development policies may have positive environmental spillovers.

In this paper, we study the largest public assistance program in Malawi. The program provides fertilizer and seed subsidies to small farmers throughout the country. Malawi is plagued with low land productivity and many small farmers have been unable to afford fertilizer and bio-enhanced seeds at market prices, prompting the government to distribute these items at significantly subsidized prices. The public provision of these subsidies offers spatial and temporal variation in agricultural productivity within country which we use to examine deforestation. The allocation of subsidized seeds and fertilizer did not reach all farmers and there were no strict eligibility criteria for the receipt of the subsidies that can be used for causal estimates.

We leverage ethnic favoritism in subsidy allocation to identify the impacts of improvements in agricultural productivity on deforestation. Particularly, we exploit a change in the ethnicity of the Malawi president following the 2004 election, and demonstrate that ethnically aligned households are 10 - 12 percentage points more likely to have access to fertilizer subsidies than households of a different ethnicity. Local jurisdictions that are predominately of the same ethnicity as the president experience much less deforestation (5 to 13 percent) than others. Additionally, we use district-level data on the quantity of fertilizer subsidies to estimate the elasticity of deforestation with respect to fertilizer subsidies and find it to be consistently negative and both economically and statistically significant. Finally, we check our identifying assumptions by showing that ethnic alignment with the president is not significantly correlated with a number of potential confounding factors such as public sector employment and other public assistance programs.

The relationship between agricultural productivity and deforestation is at the heart of the 'Borlaug hypothesis' - specifically, that increasing agricultural productivity may lead to less land in agriculture and thus less deforestation (Angelsen and Kaimowitz, 2001). This fundamentally empirical question has important implications for development policies that subsidize agricultural inputs and otherwise encourage the adoption of yield-improving technologies in countries experiencing significant deforestation. Yet, in a recent review article Villoria et al. (2014) note that there is very little econometric evidence on the relationship between agricultural productivity and deforestation.[2] Our paper fills this gap in the literature by estimating the causal effect of the Malawian agricultural subsidies program on deforestation.

The theoretical work on the Borlaug hypothesis yields mixed results. Economic models of shifting cultivation, such as Takasaki (2006) and Balsdon (2007), predict that improving soil quality and/or land productivity can increase the time a given field is cultivated before shifting to another. In this context, increases in productivity should slow deforestation. However, economic models of land clearing for agriculture, such as Angelsen (1999) -

[2] Villoria et al. (2014) conclude that "the econometric evidence on the relationship between technological progress and land use is generally weak. We can make some broad observations in general contexts, but the number of well-grounded empirical studies that support more context-specific conclusions is grossly inadequate for informing critical policy decisions." (page 214)

among many others, predict that increasing the returns to agriculture should also increase the amount of land cleared for that purpose. These models would predict increased deforestation as a result of fertilizer subsidies. The effect of these subsidies on deforestation remains an empirical question.

The few empirical studies that test the Borlaug hypothesis directly consist of cross-country or global analysis. Two examples are Ewers et al. (2009) and Rudel et al. (2009), which analyze changes in country-level yields and agricultural land area over many years. While these papers provide useful aggregate correlations, they are not informative for development policy as they omit important country-level variables that could potentially have confounding effects on their findings. Moreover, these papers do not directly observe technological increases in agriculture but rather proxy for these advances by using crop yields. A change in crop yields, as noted by Villoria et al. (2014), may come from technological innovation, factor substitution, or both. Thus, simply observing increases in yields may not inform policy that directly addresses technological innovation. Our paper uses data on fertilizer and seeds subsidies to directly measure increases in agricultural productivity and connect them to deforestation outcomes. Assunção et al. (2015) study agricultural intensification in Brazil caused by improvements to the electrical grid and find that electrification led to less deforestation between 1970 and 2006. While our results are consistent with their findings, we study a development policy (agricultural input subsidies) that is very common throughout the developing world.

Some empirical studies have evaluated the impacts of development programs on deforestation. Bulte et al. (2007) analyze the relationship between agricultural subsidies and deforestation using cross-country data in Latin America. They find that subsidies are positively correlated with country-level deforestation. However, the subsidies in their analysis are allocated proportional to land in agriculture. This allocation rule creates an additional incentive beyond an increase in productivity for farmers to shift more land from forest to agriculture. The subsidy program in Malawi provides all recipient farmers with an equivalent fertilizer and seed subsidy, which enables us to isolate the effect of increased productivity on a farmer's decision to deforest. Alix-Garcia et al. (2013) examine the effect of conditional cash transfers on deforestation in Mexico and find increased income led to increased consumption of land-intensive goods and more deforestation. We show that a targeted development program to increase agricultural productivity may have the opposite effect found from the cash transfer program studied in their paper.

Chibwana et al. (2013) and Fisher and Shively (2005) examine the effect of Malawi's seed and fertilizer subsidy program on forest extraction and land use. While these papers find evidence that fertilizer and seed subsidies did lead to less direct forest use, they rely on cross-sectional survey data from smaller, more targeted geographic areas. Our paper uses satellite data on deforestation to overcome potential problems with self-reporting of forest clearing. We study the subsidy program across the country and over time and are thus able to present evidence valid over a larger geographic area and scale than the studies mentioned above.

The final literature related to our paper is that of ethnic and regional favoritism in public resource allocation. Hodler and Raschky (2014) demonstrate that economic activity (as measured by night light) increases in birth region of the current political leader and this is most common in countries with weak political institutions and poorly educated populations. Kramon and Posner (2013) study the role of ethnic favoritism throughout Africa and, while findings vary from country to country, they find evidence that, in Malawi, those sharing the ethnicity of the president in power benefit from improved infant care and educational opportunities.[3] We establish a relationship between ethnic alignment

[3]In a working paper, Ejdemyr et al. (2015) examine ethnic favoritism and targeting of distributive goods in Malawi. In their cross-sectional data, the authors find that there is a significant correlation between receiving a subsidy and ethnic alignment with the local politician. Additionally, the results suggest that local politicians, in areas with more Segregation, are able to target their co-ethnics with public goods while politicians in less segregated areas rely on the use of subsidies, or private goods, to reward co-ethnics.

and receipt of fertilizer subsidies and, while we are not the first to demonstrate ethnic favoritism, we are the first to our knowledge to use favoritism to study the causal effects of a large scale development program.

The paper proceeds as follows. Section 2 provides important background on Malawi, including a discussion on the role ethnicity plays in resource allocation, the fertilizer subsidy program as well as agriculture and deforestation in this setting. In Section 3 we provide empirical evidence that households ethnically aligned with the president are significantly more likely to receive fertilizer subsidies and that districts ethnically aligned with the president receive larger quantities of fertilizer. Moreover, we show that household ethnic alignment with the president has no direct impact on public sector employment or other forms of public assistance. We demonstrate that ethnic alignment of traditional authorities (a local jurisdictional unit) is negatively correlated with deforestation and we estimate district-level elasticities of deforestation and fertilizer subsidies via both ordinary-least-squares and instrumental variables and find them to be negative. We show that hybrid maize yields improved in areas that received fertilizer and that soil quality is negatively related to deforestation. Section 4 concludes with final remarks.

2 Background

Deforestation in Malawi, where the majority of the population are subsistence farmers, is largely caused by slash and burn agriculture. Malawi farmers face declining soil arability due to farming techniques and low land productivity and therefore slash and burn forested land to access more fertile soil. This agricultural practice has resulted in increased levels of deforestation in Malawi compared to the rest of Sub-Saharan Africa (UNFAO, 2010).

2.1 Malawian Input Subsidy Programs

Malawi has historically been vulnerable to food insecurity due to its population density, limited access to resources and dependence on an agricultural sector centered on rain-fed maize. To help increase food security, the government introduced a fertilizer subsidy program during the 1999/2000 season called the Starter Pack that targeted 2.8 million farm households, providing them enough seeds and fertilizer to cultivate about 0.1 hectares of their staple crop maize and were distributed for free (Pauw and Thurlow, 2014). Cost concerns forced the government to revamp the program the next year and, under the new name Targeted Input Program (TIP), they cut the number of beneficiaries in half for the 2000/2001 and 2001/2002 growing seasons. A maize shortage motivated an expansion to 2 million packs for the 2002/2003 growing season.

A severe drought in the 2004/2005 growing season caused yields in Malawi to fall and nearly 5 million families required some form of food aid. In response to the drought, the government created the Farm Input Subsidy Program (FISP), which replaced the TIP program (Pauw and Thurlow, 2014). Under FISP, farmers no longer received fertilizer and seeds directly, rather they received coupons allowing them to purchase these inputs at highly subsidized prices.[4] With a coupon a household could purchase two 50 kg bags of fertilizer (one basal, one urea) and a bag of maize seed (either hybrid or open pollinated variety).[5]

Allocation of the subsidy coupons has always lacked transparency. While a targeted program, there were no established criteria for defining which households qualified until 2007/2008.[6] Criteria introduced after that year were aimed at vulnerable households such

[4]The percentage of market price subsidized varied from approximately 64% in 2005/2006 to 93% in 2011/2012. The variation stems from both changes in market price of fertilizer as well as declining coupon redemption prices (Chirwa and Dorward, 2013).

[5]In later years legume seeds were also offered at subsidized prices upon coupon redemption, but the quantities purchased were much lower than maize seed varieties (Chirwa and Dorward, 2013).

[6]According to Dorward et al. (2008) prior to 2007/2008, eligible households were those who could not afford one or two bags of fertilizer at current market prices and this was determined by local leaders.

as female-headed or orphan-headed households. The criteria were largely interpreted as general guidelines, inconsistently implemented and were largely unsuccessful in targeting poor households (Holden and Lunduka, 2013).

The printing and disbursement of fertilizer coupons is centralized with the Ministry of Agriculture and Food Security, a ministry directly overseen by the president. This point has not been lost on outside observers studying the program. Chinsinga (2012a) notes in a technical report:

> "However, there is some concern that the uptake of technocratic insights has not been as high as one would have expected. This is partly attributed to the fact that the President himself was the Minister of Agriculture and Food Security directly overseeing the implementation of the programme, having a huge imprint on the key parameters of the programme."

The president did officially step down from his position as Minister of Agriculture and Food Security in April of 2010, however many indicate that this was a nominal change and the president still retained great influence over the program. One official from the Ministry of Agriculture and Food Security said:

> "The president has stepped down as Minister of Agriculture and Food Security only in name; he still effectively controls most of the things to do with the FISP. The Minister of Agriculture and Food Security cannot take any major decision on the FISP without consulting the president" (Chinsinga, 2012b, p.19)

The Ministry of Agriculture and Food Security prints coupons each year that are identified by a serial number and recipient district. Nominally, these coupons are printed in proportion to the area in each district planted for maize and tobacco in early years and proportional to number of farm families in each district in later years. However, no records of the number of coupons printed for each district are kept and, as noted by Chirwa and

Dorward (2013, p. 101), "Initial allocations based on crop areas or farm families were commonly modified for a variety of generally undocumented technical administrative, political, and other reasons." After printing, the coupons are distributed to districts and are then distributed to traditional authorities to be given to local families by Chiefs and Village Development Committees.[7] Holden and Lunduka (2013) survey Malawians regarding their perceptions of the FISP program. They find nearly 43% of households perceive corruption, favoritism, and biases in the distribution of targeted coupons to be the most important problem related to the program.

2.2 Presidential Politics and Ethnic Favoritism in Malawi

Malawi is an ethnically diverse nation, comprised of 9 major tribal groups: Chewa, Lomwe, Yao, Ngoni, Tumbuka, Nyanja, Sena, Tonga and Ngonde. The three dominant ethnic groups (Chewa, Lomwe and the Yao) account for approximately two-thirds of Malawi's total population (See Figure 1). Each group has its own language and traditions that continue to play an important role in Malawian society and politics. Existing geographic concentrations of ethnic groups prior to the drawing of national borders largely explain the spatial distribution of ethnicity observed today. Figure 2 presents the the dominant ethnic group in each traditional authority throughout Malawi. The fact that there are few dominant ethnic groups has led to tensions within the political system (Posner, 2004). There is also limited trust of and economic interaction with individuals of other ethnicities in Malawi (Robinson, 2016).

Having established above that the president in Malawi has significant ability to divert input subsidies within the country, it remains to be explained why this should lead to higher reception of fertilizer by ethnically aligned districts and/or households. One

[7] Basurto et al. (2015) study the efficiency of household targeting of FISP vouchers by local chiefs and find evidence of nepotism but also that cheifs consider local productivity and poverty in their allocation decision.

explanation could be that the president may have social preferences over recipients and would prefer that members of his own tribe be beneficiaries over members of other tribes. Another explanation stems from Malawi's simple plurality electoral system in which candidates need only have the largest number of votes to win rather than an absolute majority.[8] Many scholars have recognized that this system encourages politicians to motivate their base of support rather than trying to win over other voters.[9] The simple plurality system allowed Bingu wa Mutharika to win the 2004 election with just under 36 percent of the total vote (Gloppen et al., 2006).

In this paper, we exploit the 2004 election in which the country saw a change in the ethnicity of the president from Bakili Muluzi, a member of the Yao tribe, to Bingu wa Mutharika, a member of the Lomwe tribe.[10] Both individuals were part of the United Democratic Front (UDF) party, which is the dominant party in Southern Malawi. The Yao and Lomwe ethnic groups are both concentrated in Southeast Malawi and hold roughly equal population shares in the country.[11] Importantly, both groups share customary land tenure systems (matrilineal, matrilocal) which have been shown to affect agricultural investment and soil conservation (Place and Otsuka, 2001; Lovo, 2016). In 2004, the Yao tribe lost a connection to the presidency, while the Lomwe gained one. We argue that this change led to important differences in the allocation of fertilizer subsidies, as this resource was targeted to those ethnically aligned with the president and was withheld from opposition ethnic groups. Our empirical evidence for this claim follows.

[8] In Malawi, there are no second ballots or runoff elections for president.

[9] Some notable examples include Myerson (1993), Persson and Tabellini (1999) and Lizzeri and Persico (2001) among many others.

[10] This is the same change used by Kramon and Posner (2013) to study ethnic favoritism.

[11] See Figures 1 and 2.

3 Empirical Analysis

As discussed above, the relationship between agricultural input subsidies and deforestation is theoretically ambiguous and depends on the constraints faced by the agricultural households of interest. Therefore, development programs, such as fertilizer subsidies, designed to improve agricultural productivity could increase or decrease levels of deforestation by raising the marginal productivity of agricultural land. Deforestation would increase if the fertilizer subsidies increased the demand for land clearing through increased productivity. However, in Malawi, where most farmers are subsistence farming on unproductive land, increasing agricultural productivity through fertilizer subsidies may reduce the need to shift cultivation to maintain the desired yields resulting in decreased levels of deforestation. Using data on subsidies, deforestation and ethnicity, we can empirically estimate the underlying relationship between fertilizer subsidies and levels of deforestation.

We provide empirical evidence to demonstrate the following. First, ethnic alignment with the president was a significant factor in receiving fertilizer subsidies. We demonstrate this at both the household level and the district level by estimating OLS regressions as well as implementing a difference-in-differences estimation strategy. Second, ethnic alignment with the president did not have an effect on potentially confounding factors for agriculture and deforestation, such as through public sector employment and other government assistance programs. Lastly, we show that fertilizer allocation and ethnic alignment are associated with decreases in deforestation. At the district level, a larger geographic level, we are able to use ethnic alignment as an instrument for fertilizer allocation to obtain estimates of the elasticity of fertilizer and deforestation. Due to the limited number of districts in Malawi, we proceed to estimate the reduced form relationship between alignment at the local jurisdiction (traditional authority) and deforestation. While we do not observe the fertilizer quantity allocated to the traditional authority, we are able to leverage the larger sample size and show that, in the reduced form, alignment decreased deforestation.

3.1 Ethnic Favoritism and Fertilizer Subsidies

In order to identify the effect of fertilizer subsidies on deforestation in Malawi, we need some allocation criteria of subsidies that is uncorrelated with existing agricultural practices or other unobservable factors that could bias our estimated effects. If all households growing the same crop with the same technology received the same amount of fertilizer subsidies at the same time, it would be difficult to empirically disentangle the effect of the subsidies on deforestation from other systematic changes such as variation in market price of maize, technology adoption, etc. Furthermore, if fertilizer subsidies were allocated based on some unobservable criteria that also effects the demand or cost of clearing forest (for example more productive households are able to get the subsidy easier than less productive ones) simple estimates of the relationship between subsidies and deforestation will be biased and inconsistent. To overcome this problem, we need a time-varying allocation criteria that is orthogonal to changes in the unobservable criteria mentioned above.

We use a strategy similar to that used by Kramon and Posner (2013), exploiting both the role of ethnic favoritism in government resource allocation and the change in the ethnicity of the Malawi president following the 2004 election. If there exist two households identical except for their ethnicity and the outcome of the 2004 election leads to the alignment in ethnicity of one household but not the other, in the presence of ethnic favoritism in subsidy allocation, this change should increase the relative likelihood that the aligned household receives a subsidy coupon. For this to be a valid strategy, we need to show that coethnics before the election, members of or districts aligned with the Yao tribe, received more fertilizer subsidies compared to members of or districts aligned with other tribes prior to the 2004 election. Additionally, we need to show that coethnics after the election, members of or districts aligned with the Lomwe tribe, received more fertilizer subsidies compared to members of or districts aligned with other tribes following the 2004 election.

The data we use for this analysis comes from multiple sources. The first data set contains information on use of agricultural subsidies at the household level and comes from two waves of the Malawi Integrated Household Survey (IHS). The IHS is part of the Living Standards Measurement Study (LSMS), which is a household survey program, run by the World Bank's Development Research Group, in partnership with national statistical offices (NSOs). The IHS waves in Malawi collected information on poverty and income equality, demographic characteristics, health, education, and agriculture. The IHS data used in the analysis comes from the IHS second and third waves for which data was collected in 2004 and 2010. The surveys collected information from a nationally representative sample. The sampling design is representative at both national and district levels. The surveys ask households about agricultural subsidies received during the years 2001, 2002, 2003 and 2009. Additionally, they ask about the tribal language spoken within the household, which allows for the creation of a short household pseudo-panel with household characteristics, household ethnicity and an indicator variable for whether the household received an agricultural subsidy in a given year. Finally, indicator variables are created for both Yao and Lomwe households, as well as when a household is ethnically aligned with the president in power. Table 2 presents the summary statistics for households in the IHS data by ethnicity.

The second source of fertilizer data was provided by the International Food Policy Research Institute (IFPRI) and contains data on fertilizer subsidy allocations by district and year for 2001 through 2012 with the exception of 2006. The data reports the amount of fertilizer subsidies distributed to each district in kilograms. There are 24 districts over

11 years, which results in 264 observations for this part of the analysis.

We obtain geographic ethnic concentrations using the 2008 Malawi Census.[12] The census surveyed 298,607 households and 1,343,078 individuals (10% of the total population) and the ethnicity question allows us to measure tribal populations at the traditional authority level. Table 1 presents summary statistics by traditional authorities from the census data. Figure 3 illustrates the tribal distribution found in the Malawi census. Additionally, we create variables identifying traditional authorities and districts by the share of the population that belong to the Yao tribe, the share of the population that belong to the Lomwe tribe, the tribe that has a plurality, meaning that the tribe that makes up the largest proportion of the population, and the tribe that has a majority, meaning that the tribe that makes up over 50% of the population. Figures 2 and 3 show the ethnic plurality of each traditional authority and the share of population belonging to the Yao tribe and Lomwe tribe respectively. Figure 4 shows the spatial distribution of Yao and Lomwe at the district level. Note that we have significantly fewer districts than traditional authorities, a point we return to later in the analysis. These maps lay out the spatial variation in ethnicity, which we rely on for identification.

Using the pseudo-panel created by combining the IHS surveys, we can estimate the following model to test for ethnic favoritism in the allocation of fertilizer subsidies at the household level:

$$y_{jdt} = \beta_0 + \beta_1 Aligned_{jdt} + \gamma_d + \phi_t + \varepsilon_{jdt} \tag{1}$$

where y_{jdt} is an indicator for whether household j in district d received an agricultural subsidy in year t. $Aligned_{jdt}$ is an indicator for whether a household is ethnically aligned with the president (Yao before 2004 and Lomwe after 2004), γ_j is a district/traditional authority fixed effect, ϕ_t is a year fixed effect and, finally, ε_{jdt} is the household-year error

[12] We accessed the 2008 Malawi Census data via IPUMS.

term.

The coefficient of interest is β_1. If ethnic alignment influences subsidy allocation, then we would expect β_1 to be strictly positive. The results in Table 3 show that ethnic alignment with the president leads to a significant increase in the probability of receiving a fertilizer subsidy by between 10 and 13 percentage points. The result is robust to the inclusion of both year fixed effects and district/traditional authority fixed effects. This result suggests that ethnic favoritism does indeed impact government allocations of fertilizer subsidies at the household level.

Additionally, we estimate a more parameterized model using indicators for Yao households, Lomwe households, Post-2004, and the interactions between them. This strategy estimates the effect of ethnic alignment for the Yao and Lomwe tribes separately. We estimate the following equation:

$$y_{jdt} = \beta_0 + \beta_1 Yao_{jd} + \beta_2 Lomwe_{jd} + \beta_3 Post_t + \beta_4 Yao_{jd} \times Post_t + \beta_4 Lomwe_{jd} \times Post_t + \gamma_d + \varepsilon_{jdt} \quad (2)$$

where y_{jdt} is as noted above, Yao_{jd} is an indicator for whether a household belongs to the Yao tribe (the president's tribe before the 2004 election), $Lomwe_{jd}$ is an indicator for whether a household belongs to the Lomwe tribe (the president's tribe after the 2004 election), $Post_t$ is an indicator for after the election (this variable is dropped when year fixed effects are included), γ_d is a district fixed effect and ε_{jdt} is the household-year error term. The omitted reference group is all households of an ethnicity other than Yao or Lomwe.

The results from estimating the above equation are reported in Table 4. Again, we can see that ethnic alignment with the president prior to the 2004 election led to an increase in the probability of receiving a fertilizer subsidy by between 13 and 14 percentage points for

Yao households. Furthermore, Lomwe households had the same probability of receiving a subsidy as other ethnicities prior to 2004, but had an increased probability of receiving a subsidy between 7 and 11 percentage points after 2004. These results are robust to the addition of year fixed effects and district/traditional authority fixed effects.

As discussed above, our empirical strategy may be undermined if ethnic favoritism influences deforestation through other channels rather than the allocation of fertilizer subsidies. While our identifying assumption is fundamentally untestable, we examine whether we observe the same patterns of ethnic favoritism with respect to other public resources in a way that may indirectly affect deforestation. Using the same IHS survey data, we examine whether ethnic alignment played a role in public sector employment as well as all other public assistance programs. To do so we estimate the two models above, but change the outcome variable to be an indicator of whether the household has a family member working as a government employee in the first two models and then whether the household receives any kind of public assistance from the government in the form of education subsidies, child nutrition subsidies, food for work programs or direct cash transfers. Public sector employment is often used as patronage for political allies given by politicians to earn or reward support. If public sector employment was more attractive than maize farming, it could have the potential to crowd out farming and thus lead to a decrease in observed deforestation. Other forms of public assistance could also be diverted to coethnic groups which may also impact deforestation, for example and education subsidy could lead to fewer children working the fields and clearing land when they instead attend school.

Tables 5 - 8 present results from estimating the relationship between public employment/public assistance and household ethnicity. In Table 5, we see that ethnic alignment is associated with a 1.5 - 2.8 percentage point lower probability of having a family member working in the public sector. While this is the opposite relationship than one that would undermine our story, as seen in Table 8, this effect is largely driven by Yao households who are 3 - 5 percentage points less likely to work in the public sector across both survey periods. Only in column (4) do we see a drop in the estimated post period for Yao households, but across none of the specifications do we see an increase for Lomwe households.[13]

In Table 7 we see that there is no significant relationship between ethnic alignment and other public assistance programs. The same holds in Columns (1), (2) and (4) - column (4) being our preferred specification - of Table 8 where the coefficients that appear statistically insignificant. Only in column (3) is there evidence of a relationship, but the coefficient estimates indicate that Lomwe households may have more likely to receive public assistance prior to 2004 but no more likely than any other ethnic groups to receive assistance with the Lomwe president in power. This effect would be contrary to our ethnic favoritism story. Together, Tables 5 - 8 provide evidence that any effect we find between ethnic favoritism and deforestation will not be driven by political diversion of public employment or other public assistance programs to coethnic groups.

3.2 Fertilizer Subsidies and Deforestation

We now turn to the second part of the analysis and examine deforestation in Malawi from 2001 to 2012. We use recently released data on deforestation from researchers at the University of Maryland that provide estimates of forest cover for the entire terrestrial surface of the earth at a 30m×30m resolution (Hansen et al., 2013). Included in the data set are estimates of the percentage of each 30m×30m grid cell in forest cover in the year 2000.[14] The data set also provides annual indicators from 2001 to 2012 denoting that a

[13]While the early wave of the IHS survey asks households to report previous years and current years response for receiving fertilizer subsidies and other public assistance programs, households only report public sector employment for the year in which the IHS was taken. Therefore we cannot include year fixed effects in the public sector analysis beyond our *Post* indicator. This explains the smaller sample size reported in this table and the lack of a fourth column.

[14]Forest cover is defined as area covered by vegetation greater than 5 meters in height.

grid cell containing nonzero tree cover in 2000 is estimated to have fallen to zero percent tree cover. We limit the sample to cells that had at least 30% forest cover at baseline to reduce the noise in our deforestation measure. From those cells, we count the number of pixels deforested in each year within each traditional authority, thus creating a panel of annual deforestation at the traditional authority level from 2001-2012.[15]

In order to estimate the effect of fertilizer subsidies on deforestation, we use ethnic alignment with the president as an instrument for fertilizer allocation. Having shown that ethnic alignment is positively correlated with receiving fertilizer subsidies at the household level, we now turn to district-level analysis to estimate the relationship between fertilizer and deforestation. The lack of fertilizer allocation data at the traditional authority level restricts our analysis to districts, which are few in number.

Using two-stage least-squares estimation, we estimate the impact of fertilizer subsidies on deforestation using the variation in fertilizer subsidy allocation attributable to ethnic favoritism. We aggregate both deforestation data as well as ethnicity data to the district level due to constraints on fertilizer data. We estimate the following two-stage least-squares model where the first stage is:

$$Fert_{dt} = \beta_0 + \beta_1 Aligned_{dt} + \phi_t + \varepsilon_{dt} \tag{3}$$

and the second stage is:

$$y_{dt} = \alpha_0 + \alpha_1 \hat{Fert}_{dt} + \phi_t + \epsilon_{dt} \tag{4}$$

where $Fert_{dt}$ is the natural log of fertilizer measured at the district-year level, $Aligned_{dt}$ is one of the three measures of alignment with the president discussed above, ϕ_t is a year

[15]It should be noted that this definition of deforestation is not universally accepted. Tropek et al. (2014) point out that classifying forest as vegetation taller than 5 meters can lead to classification of different plantations as forest. Harvesting of these plantations may result in observed deforestation when, in reality, the land had been cleared and planted prior to the beginning of the study period. As deforestation in Malawi is associated with maize and not, for example, palm oil plantations, we feel that these data and this definition of deforestation are appropriate for our setting.

fixed effect, y_{dt} is the natural log of deforestation measured at the district and year level, and finally ε_{dt} and ϵ_{dt} are the district-year error terms.

Table 9 presents estimates of equation (3). Across all measures of ethnic alignment, aligned districts receive more total fertilizer.[16] The F-statistics on the plurality and share instruments are above 10 indicating that they are relevant instruments for fertilizer allocation.

Before estimating the two-stage least squares model, Table 10 presents estimates of (4) from OLS regressions of fertilizer and deforestation. We use the natural log of deforestation and the natural log fertilizer in order to produce more easily interpretable elasticities. If observed fertilizer is endogenous, these estimates will be biased though the direction of the bias is theoretically ambiguous. The OLS results indicate a negative relationship between fertilizer and deforestation.

Table 11 presents estimates using ethnic aligned with the president as the instrument. [17] Columns (1) and (2) contain estimates using the plurality alignment variable as the instrument and columns (3) and (4) use the share alignment variable. These two alignment measures provide adequate first-stage predictive power. The results indicate that fertilizer allocations have a significant impact on deforestation even when aggregated to the district level. The preferred estimates are in columns (1) and (3) and suggest an elasticity of deforestation with respect to fertilizer between −.59 and −.69. Not only are these estimates statistically significant, they are also economically significant numbers. They imply a 10% increase in fertilizer subsidies may cause a 6 to 7% decline in annual deforestation in the corresponding year.

One important consideration is that our instrumental variable estimates should be

[16]See Table A1 for the results using ethnic majority as the instrument. The F-statistic on the majority instrument is low because very few districts contain an ethnic majority.

[17]Because we are using district-level data we have too few districts with a strict majority of Yao or Lomwe to provide sufficient power in the first stage regression. See Table A1 and Table A2 for ethnic majority regressions.

interpreted as the local average treatment effect on districts that are, at some point in this study period, aligned with the president. As both Yao and Lomwe tribes are concentrated in South Eastern Malawi, we are less concerned about omitted climate and agricultural trends (as they are likely to be similar) but these estimated elasticities may be particular to this region.

3.3 Ethnic Alignment and Deforestation

Our analysis at the district level is restricted by a small number of jurisdictions, and an even smaller number of districts with large Yao or Lomwe populations. The small sample size makes it difficult to control for many potential unobserved confounders. For this reason we move our analysis to the traditional authority level and focus on the reduced form effects.

As discussed above, we do not observe realized fertilizer allocation to the traditional authority level, but we do have both census data as well as deforestation data for all traditional authorities. We estimate the following reduced form equation:

$$y_{idt} = \gamma_0 + \gamma_1 Aligned_{idt} + \eta_i + \phi_t + u_{idt} \tag{5}$$

where y_{idt} is the level or natural log of deforestation in traditional authority i in district d and year t. $Aligned_{idt}$ is the measures of the traditional authority's alignment with the president, either whether the plurality is aligned with the president or the share of the local population aligned with the president, η_i is a traditional authority fixed effect, ϕ_t is a year fixed effect and finally u_{idt} is the traditional authority-year error term.[18]

The parameter of interest is γ_1 which does not measure the direct relationship between fertilizer and deforestation but ethnic alignment and deforestation. In this model, γ_1 is

[18]See Appendix Table A3 for results using an indicator for majority aligned.

analogous to the product of β_1 and α_1 in equations (3) and (4). Because we do not observe fertilizer at the traditional authority level, we are unable to separately estimate β_1 for tradition authorities. However, as we have previously demonstrated, β_1 is positive at the household level and at the district level, thus we assume that it will also be positive at the traditional authority level. Under this assumption, we are able to test the hypothesis that increased land productivity through fertilizer led to less deforestation, but we are unable to precisely estimate the elasticity. If $\gamma_1 = \beta_1 \times \alpha_1$ and we assume β_1 is positive, then γ_1 can only be negative if α_1 is negative.

The estimation results are displayed in Table 12. The top panel uses the level of deforestation (as measured by the number of 30 square meter pixels classified as 'deforested' in a given traditional authority in a given year) as the outcome variable and the bottom panel uses the natural log of deforestation as the outcome variable, which provides more intuitive interpretations of the coefficients. Columns (1) - (3) use the tribal ethnic plurality at the traditional authority level to measure alignment. Column (1) includes a district-level fixed effect as well as year fixed effects, Column (2) includes traditional-authority level controls (all variables from Table 1) to make sure that underlying differences in these variables are not driving our findings, and Column (3) includes a traditional authority fixed effect. Columns (4)-(6) use the share of the ethnically aligned tribe at the traditional authority level to measure alignment, phasing controls and traditional authority fixed effects in Columns (5) and (6) respectively.

The estimates indicate that traditional authorities with higher populations of co-ethnics aligned with the president experienced less deforestation when compared to traditional authorities not aligned with the president. Normalizing the level effects to hectares, we find that alignment with the president leads to between 8 and 11 fewer hectares being deforested in each traditional authority in each year. These estimates correspond to a 14 to 18 percent reduction in the average deforested area per traditional authority per year. Our preferred specifications (2) and (3) indicate that alignment with the president decreased deforestation in a traditional authority by 5 to 14 percent. While our estimate with the traditional authority fixed effect is not statistically significant, the result from (2) indicates that the effect is not explained by differences in baseline forest cover, share of population collecting fuel wood, educational difference, etc. As discussed above, data on fertilizer and seeds is not available at the traditional authority level, but having shown that ethnic alignment is positively correlated with fertilizer allocation at the household level and the district level, we assume that this is also the case at the traditional authority level. Under this assumption and the assumption that ethnic alignment impacts deforestation only though allocation fertilizer, these results indicate that the impact of increases in agricultural productivity reduce deforestation. We next provide evidence that fertilizer did improve productivity as measured by maize yields.

3.4 Yields Mechanism

The proposed mechanism for fertilizer subsidies to slow deforestation is through increased land productivity, allowing farmers to maintain total output with less new land cleared. We seek to provide empirical evidence that this is the case, specifically that maize yields increased due to fertilizer allocations. To answer this question, we use data from Malawi's Ministry of Agriculture on hybrid maize yields.[19] These data provide estimates of yields of hybrid maize (metric tons per hectare) at the district level. We take care to note that the data we have, while the best available to us at the time of this study, is incomplete. There are missing years over our sample period and some missing district observations for years in which we have other data. While we present these results, we also interpret our findings with caution.

We estimate a fixed effects model of hybrid maize yield as a function of both log

[19]These data were provided to us by researchers at FEWS.

fertilizer and share of ethnicity aligned with the president. The estimated coefficients are presented in Table 13. The top panel indicates that log fertilizer was associated with increased hybrid maize yields at the district level. The results correspond to an increase in yields between 11.58% and 4.77% as a result of doubling the district-level fertilizer allocation. The bottom panel indicates that the share of ethnicity aligned with the president at the district level is also associated with higher maize yields, although the effect is rendered insignificant with the inclusion of district fixed effects. The results correspond to an increase in yields between 2.88% and 0.68% as a result of increasing the percent of the district-level population aligned with the president by 10 percentage points. While we interpret these results with caution due to issues with the data, we take these results to be further suggestive evidence that the effect of fertilizer on deforestation is operating through agricultural productivity.

3.5 Soil Quality and Deforestation

The theory that increased productivity of agricultural land lowers deforestation assumes that, in our setting, agricultural households clear less land when their soil quality is higher. Agricultural inputs, such as fertilizer, play an important role in the overall productivity and quality of soil. The correct use of fertilizer has been shown to both increase yields and improve overall soil quality. Therefore, if our above assumption holds true, we would expect areas with lower soil quality to have higher levels of deforestation and areas with increased access to agricultural inputs to have lower levels of deforestation. We can test the first hypothesis about soil quality and deforestation by comparing levels of deforestation across areas with varying soil quality in Malawi.

The data for this analysis comes from a data set is compiled by the United Nations Food and Agricultural Organization (FAO) constraints index. The index measures soil quality on a scale from 1-7, where 1 represents high levels of soil quality and 7 represents soil unsuitable for agriculture. These soil quality index is assigned to spatially-explicit grid cells and we take an area-weighted average for each traditional authority in Malawi. Because the scale is not a linear measure of soil quality, we simply seek to provide evidence that better soil is associated with lower deforestation over our sample.

To test the assumption that more deforestation occurs in areas with lower soil quality we estimate correlations using the following regression equation:

$$y_{id} = \beta_0 + \beta_1 Soil_{id} + \beta_3 X_i + \gamma_d + \varepsilon_{id} \tag{6}$$

where y_{id} is the average level of deforestation measured in traditional authority i in district d from 2001 to 2012. $Soil_{id}$ is an index of soil quality measured at the traditional authority level, X_i are additional cross sectional controls at the traditional authority level, including population, population growth, electrification, average household size, fuel wood use, and percent of the population participating in agriculture, γ_d is a district fixed effect, and ε_{id} is the traditional authority error term. Because soil quality does not vary over time, our analysis is limited to within-district cross-sectional variation in soil quality.

Table 14 shows the regression results of soil quality on deforestation. Columns (1) through (3) use the level of deforestation as the outcome variable (as measured in number of pixels) and the results provide evidence that lower soil quality is correlated with significantly higher levels of deforestation. The significant and positive estimates can be interpreted as an increase in the number of soil constraints constraints to agriculture (or a decrease in soil quality) at the traditional authority level is correlated with higher levels of deforestation. The result holds up to the addition of district fixed effects, but becomes insignificant with the addition of cross-sectional control variables. Instead, using the natural log of deforestation as the outcome variable, the results in columns (4) through (6) again show that lower levels of soil quality are correlated with increased deforestation and this time the result is robust to the inclusion of year fixed effects, as well as additional controls. The results in Table 14 support the assumption that deforestation and agricultural productivity are negatively correlated in our setting.

4 Final Remarks

In this paper, we provide evidence that ethnic alignment with the president played an important role in the allocation of fertilizer subsidies in Malawi. We further demonstrate that ethnic alignment with the president leads to a significant decrease in deforestation. At the district level, the elasticity between fertilizer subsidies and deforestation is negative and instrumental variable estimates utilizing ethnic favoritism in fertilizer allocation are larger in magnitude than the OLS estimates in most specifications.

These large and statistically significant effects show the importance of measuring the impacts of environmental spillovers of development programs to conduct an efficient cost benefit analysis. Additionally, policymakers should focus on implementing poverty alleviation programs, such as fertilizer subsidies, that have beneficial environmental impacts because they may be able to provide a 'win-win' scenario.

There is an important caveat to the interpretation of our results. We only observe twelve years of deforestation and the Yao and Lomwe households share a connection to the office of the president for only four and eight years respectively in our sample. We cannot empirically determine what the expectations of these households are with respect to future subsidies. If households believe they will continue to receive the same subsidies as they do now, the deforestation behavior we observe may resemble what we might expect to see in the steady-state under such a subsidy program. If, however, households believe their fortunate access to these subsidies is temporary, we might be observing decreases in deforestation consistent with harvesting behavior, where deforestation is simply postponed while they have access to the fertilizer and then they plan to continue deforestation at higher rates in the future. This might imply different deforestation behavior under a steady-state with expected long-run access to such subsidies.

Many questions remain for future work. Given the spillover effect of avoided deforestation from fertilizer subsidies, how should these subsidies be targeted? The optimal allocation with the joint objective of poverty alleviation and environmental benefits may differ from the optimal allocation with the single objective of poverty alleviation. While we leverage ethnic favoritism in the allocation of fertilizer subsidies to examine their relationship to deforestation, it is likely the case that ethnic favoritism may have welfare consequences by diverting fertilizer away from households or districts where it could have a larger impact on both poverty and deforestation. What are the welfare consequences of this pattern of resource allocation? We look forward to pursuing these questions in future work.

References

Alix-Garcia, J., McIntosh, C., Sims, K. R., and Welch, J. R. (2013). The ecological footprint of poverty alleviation: evidence from mexico's oportunidades program. *Review of Economics and Statistics*, 95(2):417–435.

Angelsen, A. (1999). Agricultural expansion and deforestation: modelling the impact of population, market forces and property rights. *Journal of development economics*, 58(1):185–218.

Angelsen, A. and Kaimowitz, D. (2001). *Agricultural technologies and tropical deforestation*. CABi.

Assunção, J., Lipscomb, M., Mushfiq Mobarak, A., and Szerman, D. (2015). Infrastructure development can benefit the environment: Electrification, agricultural productivity and deforestation in brazil. *Working Paper*.

Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M., et al. (2012). Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. *Nature Climate Change*, 2(3):182–185.

Balsdon, E. M. (2007). Poverty and the management of natural resources: A model of shifting cultivation. *Structural Change and Economic Dynamics*, 18(3):333–347.

Barbier, E. B. and Hochard, J. P. (2014). Poverty and the spatial distribution of rural population. *World Bank Policy Research Working Paper*, (7101).

Basurto, P., Dupas, P., and Robinson, J. (2015). Decentralization and efficiency of subsidy targeting: Evidence from chiefs in rural malawi. Technical report, Working paper.

Bulte, E. H., Damania, R., and Lopez, R. (2007). On the gains of committing to inefficiency: corruption, deforestation and low land productivity in latin america. *Journal of Environmental Economics and Management*, 54(3):277–295.

Chibwana, C., Jumbe, C. B., and Shively, G. (2013). Agricultural subsidies and forest clearing in malawi. *Environmental Conservation*, 40(01):60–70.

Chinsinga, B. (2012a). The future of the farm input subsidy programme (fisp).

Chinsinga, B. (2012b). The political economy of agricultural policy processes in malawi: A case study of the fertilizer subsidy programme.

Chirwa, E. and Dorward, A. (2013). *Agricultural input subsidies: The recent Malawi experience*. Oxford University Press.

Dorward, A., Chirwa, E., Kelly, V. A., Jayne, T. S., Slater, R., and Boughton, D. (2008). Evaluation of the 2006/7 agricultural input subsidy programme, malawi. final report. Technical report, Michigan State University, Department of Agricultural, Food, and Resource Economics.

Ejdemyr, S., Kramon, E., and Robinson, A. L. (2015). Segregation, ethnic favoritism, and the strategic targeting of distributive goods1.

Ewers, R. M., Scharlemann, J. P., Balmford, A., and Green, R. E. (2009). Do increases in agricultural yield spare land for nature? *Global Change Biology*, 15(7):1716–1726.

Fisher, M. and Shively, G. (2005). Can income programs reduce tropical forest pressure? income shocks and forest use in malawi. *World Development*, 33(7):1115–1128.

Gloppen, S., Kanyongolo, E., Khembo, N., Patel, N., Rakner, L., Svåsand, L., Tostensen, A., and Bakken, M. (2006). *The Institutional Context of the 2004 General Elections in Malawi*. Chr. Michelsen Institute.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., Thau, D., Stehman, S., Goetz, S., Loveland, T., et al. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, 342(6160):850–853.

Hodler, R. and Raschky, P. A. (2014). Regional favoritism. *The Quarterly Journal of Economics*, pages 995–1033.

Holden, S. T. and Lunduka, R. W. (2013). Who benefit from malawi's targeted farm input subsidy program? In *Forum for Development Studies*, volume 40, pages 1–25. Taylor & Francis.

Kramon, E. and Posner, D. N. (2013). Who benefits from distributive politics? how the outcome one studies affects the answer one gets. *Perspectives on Politics*, 11(02):461–474.

Lizzeri, A. and Persico, N. (2001). The provision of public goods under alternative electoral incentives. *American Economic Review*, pages 225–239.

Lovo, S. (2016). Tenure insecurity and investment in soil conservation. evidence from malawi. *World Development*, 78:219–229.

Myerson, R. B. (1993). Incentives to cultivate favored minorities under alternative electoral systems. *American Political Science Review*, 87(04):856–869.

Pauw, K. and Thurlow, J. (2014). *Malawi's farm input subsidy program: Where do we go from here?*, volume 18. International Food Policy Research Institute.

Persson, T. and Tabellini, G. (1999). The size and scope of government:: Comparative politics with rational politicians. *European Economic Review*, 43(4):699–735.

Place, F. and Otsuka, K. (2001). Tenure, agricultural investment, and productivity in the customary tenure sector of malawi. *Economic Development and Cultural Change*, 50(1):77–100.

Posner, D. N. (2004). The political salience of cultural difference: Why chewas and tumbukas are allies in zambia and adversaries in malawi. *American Political Science Review*, 98(04):529–545.

Robinson, A. L. (2016). Internal borders: Ethnic-based market segmentation in malawi. *World Development*.

Rudel, T. K., Schneider, L., Uriarte, M., Turner, B. L., DeFries, R., Lawrence, D., Geoghegan, J., Hecht, S., Ickowitz, A., Lambin, E. F., et al. (2009). Agricultural intensification and changes in cultivated areas, 1970–2005. *Proceedings of the National Academy of Sciences*, 106(49):20675–20680.

Takasaki, Y. (2006). A model of shifting cultivation: can soil conservation reduce deforestation? *Agricultural Economics*, 35(2):193–201.

Tropek, R., Sedláček, O., Beck, J., Keil, P., Musilová, Z., Šímová, I., and Storch, D. (2014). Comment on "high-resolution global maps of 21st-century forest cover change". *Science*, 344(6187):981–981.

UNFAO (2010). *Global forest resources assessment 2010: Main report*. Food and Agriculture Organization of the United Nations.

Villoria, N. B., Byerlee, D., and Stevenson, J. (2014). The effects of agricultural technological progress on deforestation: What do we really know? *Applied Economic Perspectives and Policy*, 36(2):211–237.

5 Figures

Figure 1: Share of ethnic groups in Malawi by population

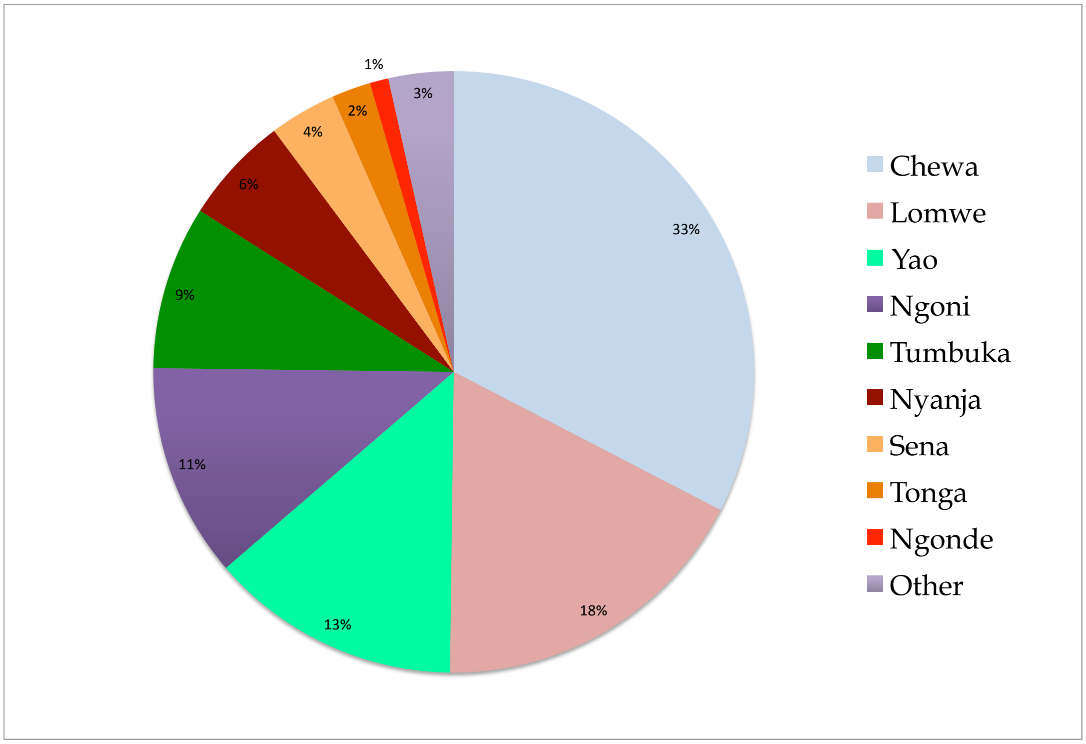


Figure 2: Traditional Authorities by Largest Ethnic Group

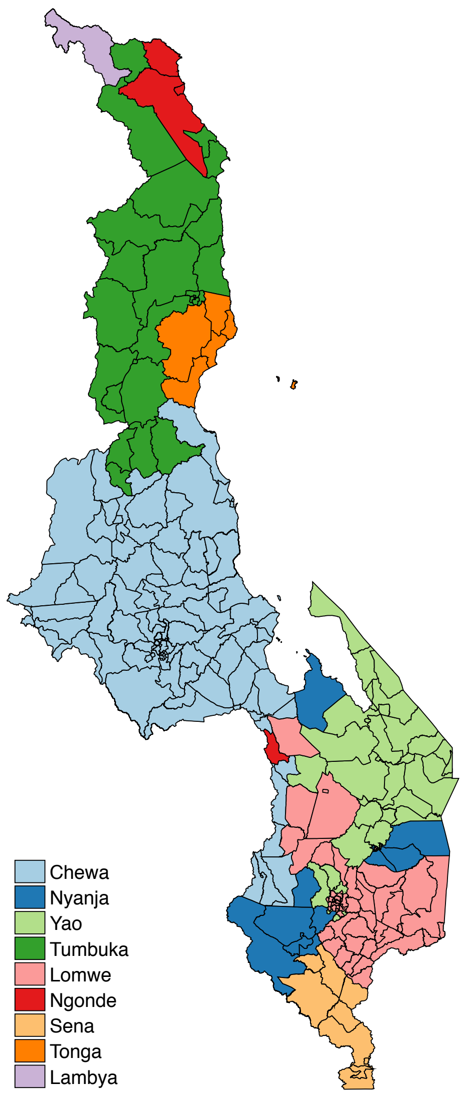


Figure 3: Traditional Authority Share of Ethnicity

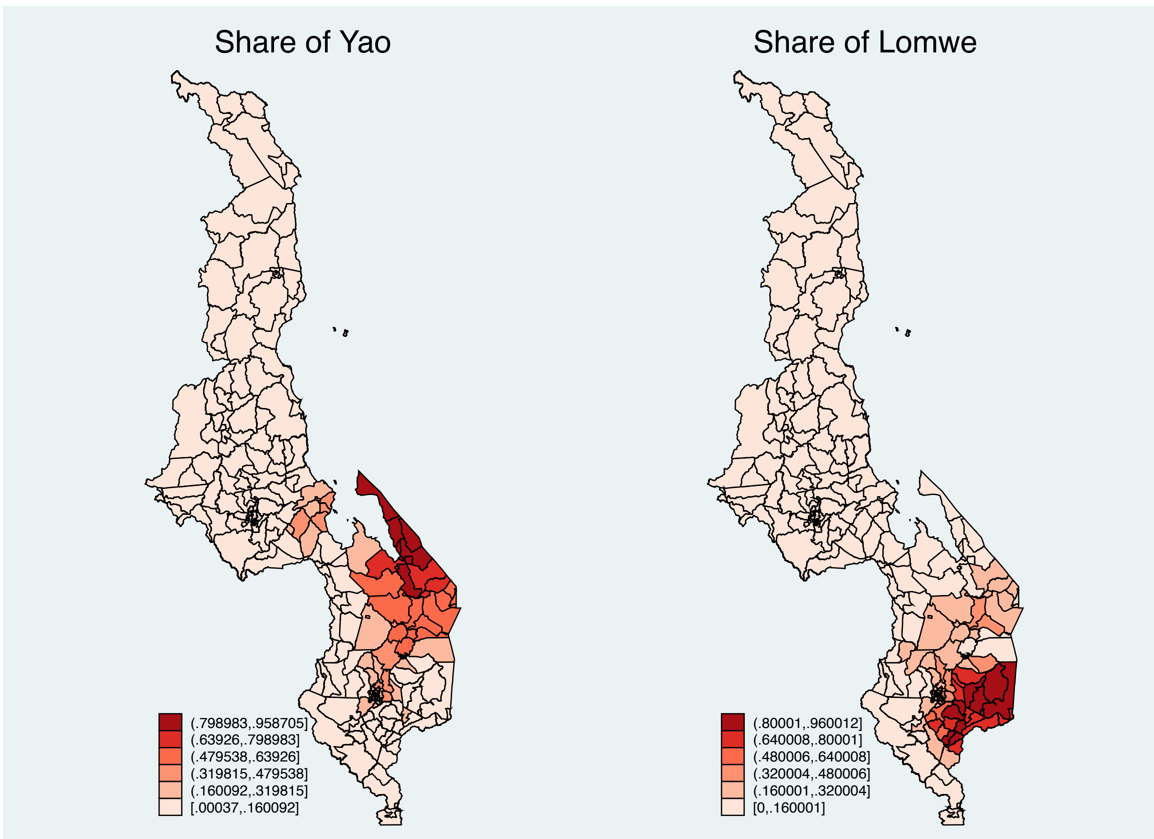
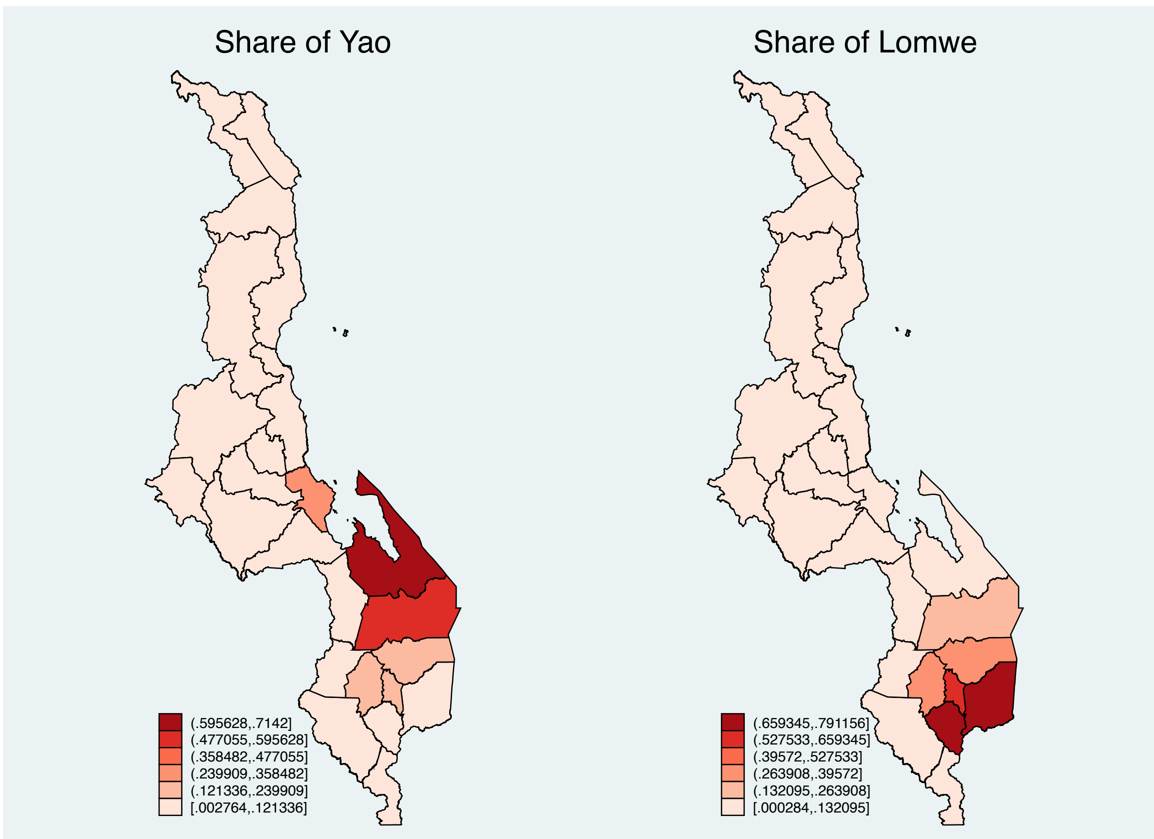


Figure 4: District Share of Ethnicity



6 Tables

Table 1: Summary Statistics by Ethnic Plurality at the Traditional Authority Level

	Yao	Lomwe	Other	Lomwe - Yao	Lomwe-Other	Yao-Other
Baseline Forest Cover	0.151	0.094	0.095	-0.057	-0.001	0.055
	(0.158)	(0.106)	(0.146)	(0.049)	(0.040)	(0.048)
High School	0.844	0.799	0.824	-0.045	-0.025	0.020
	(0.039)	(0.082)	(0.071)	(0.038)	(0.037)	(0.015)
College	0.002	0.008	0.005	0.006	0.003	-0.003
	(0.004)	(0.015)	(0.014)	(0.005)	(0.005)	(0.002)
Female	0.519	0.513	0.505	-0.005	0.008	0.013***
	(0.010)	(0.018)	(0.015)	(0.008)	(0.008)	(0.003)
Electricity	0.055	0.171	0.102	0.116	0.069	-0.048
	(0.102)	(0.224)	(0.173)	(0.101)	(0.094)	(0.035)
Literate	0.499	0.657	0.623	0.158	0.035	-0.123*
	(0.133)	(0.128)	(0.124)	(0.066)	(0.062)	(0.044)
Household Size	5.514	5.454	6.043	-0.059	-0.588***	-0.529***
	(0.259)	(0.280)	(0.554)	(0.112)	(0.122)	(0.108)
Ag Industry	0.686	0.468	0.626	-0.218	-0.158	0.060
	(0.215)	(0.253)	(0.251)	(0.122)	(0.117)	(0.073)
Fuel Wood	0.910	0.688	0.855	-0.222	-0.168	0.054
	(0.131)	(0.350)	(0.226)	(0.174)	(0.163)	(0.052)
Rural	0.876	0.656	0.774	-0.219	-0.118	0.102
	(0.324)	(0.459)	(0.404)	(0.238)	(0.222)	(0.085)
Population 2008	61,845.038	62,646.875	58,184.809	801.837	4,462.066	3,660.230
	(36,245.244)	(39,155.726)	(35,874.388)	(14,284.614)	(12,205.459)	(7,570.388)
Population 1998	48,594.192	49,471.100	43,446.592	876.908	6,024.508	5,147.600
	(29,841.029)	(30,964.032)	(28,049.441)	(11,897.967)	(9,668.404)	(6,332.426)
Population Growth	0.309	0.300	0.385	-0.010	-0.085*	-0.075
	(0.143)	(0.207)	(0.314)	(0.049)	(0.039)	(0.038)
Observations	26	40	157	66	197	183

Note: Standard deviations are in parenthesis for Columns (1)-(3). Standard errors are in parenthesis for Columns (4)-(6). Plurality is defined by the tribe that makes up the largest proportion of the population within a traditional authority. Standard errors clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Summary Statistics by Household Ethnicity

	Yao (1)	Lomwe (2)	Other (3)	All (4)
Received Fertilizer Subsidy	0.534	0.554	0.459	0.470
	(0.499)	(0.497)	(0.498)	(0.499)
Received Other Subsidy	0.103	0.110	0.113	0.112
	(0.304)	(0.304)	(0.317)	(0.316)
Government Worker	0.045	0.066	0.080	0.076
	(0.208)	(0.256)	(0.271)	(0.264)
Non-Agricultural Worker	0.149	0.180	0.190	0.185
	(0.356)	(0.385)	(0.326)	(0.388)
Rural	0.927	0.969	0.879	0.891
	(0.261)	(0.172)	(0.326)	(0.312)
Household Size	4.630	4.272	4.741	4.706
	(2.178)	(2.182)	(2.323)	(2.304)
Observations	2,102	1,014	18,609	21,681

Note: Standard deviations are in parenthesis. Household ethnicity is determined based on household head.

Table 3: Ethnic Alignment and Fertilizer Subsidy

	(1)	(2)	(3)	(4)
Household Ethnically Aligned	0.106***	0.125***	0.0990***	0.0863***
	(0.0238)	(0.0248)	(0.0147)	(0.0186)
Constant	0.399***	0.307***	0.349***	0.397***
	(0.0235)	(0.0244)	(0.0246)	(0.00676)
Year FEs	NO	YES	YES	YES
District FEs	NO	NO	YES	-
TA FEs	NO	NO	NO	YES
Observations	44,241	44,241	44,241	44,241
R-squared	0.004	0.028	0.065	0.088

Note: OLS estimates of a linear probability model. The dependent variable is equal to 1 if a household reports receiving a fertilizer subsidy. Standard errors clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Ethnicity and Fertilizer Subsidy

	(1)	(2)	(3)	(4)
Lomwe Household	-0.00275	-0.00275	0.0108	-0.0479
	(0.0505)	(0.0505)	(0.0351)	(0.0483)
Yao Household	0.128***	0.128***	0.0967***	0.0848***
	(0.0282)	(0.0282)	(0.0180)	(0.0224)
Lomwe*Post 2004	0.107**	0.107**	0.0722*	0.135***
	(0.0478)	(0.0478)	(0.0362)	(0.0460)
Yao*Post 2004	-0.137***	-0.137***	-0.134***	-0.104***
	(0.0311)	(0.0311)	(0.0246)	(0.0290)
Post 2004	0.160***	-	-	-
	(0.0193)			
Constant	0.360***	0.307***	0.347***	0.400***
	(0.0266)	(0.0246)	(0.0244)	(0.00596)
Year FEs	NO	YES	YES	YES
District FEs	NO	NO	YES	-
TA FEs	NO	NO	NO	YES
Observations	44,241	44,241	44,241	44,241
R-squared	0.022	0.028	0.065	0.088

Note: OLS estimates of a linear probability model. The dependent variable is equal to 1 if a household reports receiving a fertilizer subsidy. Standard errors clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Ethnic Alignment and Public Sector Employment

	(1)	(2)	(3)	(4)
Household Ethnically Aligned	-0.0237***	-0.0278***	-0.0262***	-0.0149***
	(0.00834)	(0.00749)	(0.00569)	(0.00501)
Constant	0.0830***	0.0937***	0.161***	0.0713***
	(0.00955)	(0.00791)	(0.0137)	(0.00331)
Year FEs	NO	YES	YES	YES
District FEs	NO	NO	YES	-
TA FEs	NO	NO	NO	YES
Observations	23,551	23,551	23,551	23,551
R-squared	0.001	0.002	0.023	0.052

Note: OLS estimates of a linear probability model. The dependent variable is equal to 1 if a household reports having an individual employed in the public sector. Standard errors clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Ethnicity and Public Sector Employment

	(1)	(2)	(3)
Lomwe Household	0.000478	0.00781	0.0158
	(0.0253)	(0.0219)	(0.0250)
Yao Household	-0.0298***	-0.0472***	-0.0132*
	(0.00991)	(0.00994)	(0.00669)
Lomwe*Post 2004	-0.0284	-0.0310	-0.0370
	(0.0233)	(0.0212)	(0.0233)
Yao*Post 2004	-0.0162	-0.00380	-0.0221**
	(0.0110)	(0.00912)	(0.0103)
Post 2004	-0.0160*	-0.0330***	-0.0211***
	(0.00857)	(0.00765)	(0.00703)
Constant	0.0939***	0.158***	0.0703***
	(0.00817)	(0.0137)	(0.00391)
District FEs	NO	YES	-
TA FEs	NO	NO	YES
Observations	23,551	23,551	23,551
R-squared	0.003	0.025	0.053

Note: OLS estimates of a linear probability model. The dependent variable is equal to 1 if a household reports having an individual employed in the public sector. Standard errors clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Ethnic Alignment and Public Assistance

	(1)	(2)	(3)	(4)
Household Ethnically Aligned	0.0119	-0.000378	0.0100	-0.00836
	(0.0144)	(0.0142)	(0.0129)	(0.0116)
Constant	0.120***	0.107***	0.103***	0.134***
	(0.00742)	(0.00637)	(0.0168)	(0.00456)
Year FEs	NO	YES	YES	YES
District FEs	NO	NO	YES	-
TA FEs	NO	NO	NO	YES
Observations	46,111	46,111	46,111	46,111
R-squared	0.000	0.020	0.039	0.038

Note: OLS estimates of a linear probability model. The dependent variable is equal to 1 if a household reports receiving public assistance in the form of education subsidies, child nutrition subsidies, food for work programs or direct cash transfers from the government. Standard errors clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Ethnicity and Public Assistance

	(1)	(2)	(3)	(4)
Lomwe Household	0.00954	0.00954	0.0500**	0.00148
	(0.0262)	(0.0262)	(0.0217)	(0.0244)
Yao Household	0.00358	0.00358	0.0132	-0.00494
	(0.0170)	(0.0170)	(0.0181)	(0.0143)
Lomwe*Post 2004	-0.0332	-0.0332	-0.0484**	-0.0309
	(0.0262)	(0.0262)	(0.0198)	(0.0243)
Yao*Post 2004	-0.0172	-0.0172	-0.0236	-0.0146
	(0.0167)	(0.0167)	(0.0154)	(0.0144)
Post 2004	-0.0865***	-	-	-
	(0.00756)			
Constant	0.144***	0.106***	0.102***	0.134***
	(0.00969)	(0.00634)	(0.0167)	(0.00453)
Year FEs	NO	YES	YES	YES
District FEs	NO	NO	YES	-
TA FEs	NO	NO	NO	YES
Observations	46,111	46,111	46,111	46,111
R-squared	0.015	0.020	0.039	0.038

Note: OLS estimates of a linear probability model. The dependent variable is equal to 1 if a household reports receiving public assistance in the form of education subsidies, child nutrition subsidies, food for work programs or direct cash transfers from the government. Standard errors clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 9: Ethnic Alignment and Fertilizer Quantities by District

	(1)	(2)	(3)	(4)
Ethnic Alignment	0.899***	0.517***	1.279***	0.887***
	(0.231)	(0.152)	(0.400)	(0.259)
Year FEs	NO	YES	NO	YES
Observations	264	264	264	264
Ethnic Alignment	Plurality	Plurality	Share	Share
IV F-statistic	15.18	11.52	10.24	11.76

Note: Coefficient estimates of district fertilizer quantities (as measured in logs) regressed on district ethnic alignment (plurality and share). These results comprise the first stage of the two-stage least-squares estimation. Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table 10: District-level estimates of the elasticity of fertilizer and deforestation - OLS results

	(1)	(2)	(3)
Log Fertilizer	-0.0304	-0.221**	-0.360**
	(0.0554)	(0.0994)	(0.147)
Year FEs	NO	YES	YES
Controls	NO	NO	YES
Observations	264	264	264
R-squared	0.001	0.125	0.499

Note: Coefficient estimates of district fertilizer quantities (as measured in logs) regressed on annual log of one plus 30x30 meter pixels deforested (the addition of the 1 prevents observations with a log of zero). Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table 11: District-level estimates of the elasticity of fertilizer and deforestation - IV Results

	(1)	(2)	(3)	(4)
Log Fertilizer	-0.583**	-1.202**	-0.688*	-1.093**
	(0.280)	(0.489)	(0.356)	(0.466)
Year FEs	NO	YES	NO	YES
Observations	264	264	264	264
Instrument	Plurality	Plurality	Share	Share
IV F-Statistic	15.18	11.52	10.24	11.76

Note: 2SLS estimates of district fertilizer quantities (as measured in logs) regressed on annual log of one plus 30x30 meter pixels deforested (the addition of the 1 prevents observations with a log of zero) using district ethnic alignment (plurality and share) as the instrument. Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table 12: Ethnic Alignment and Deforestation in Traditional Authorities

Deforestation in Pixels	(1)	(2)	(3)	(4)	(5)	(6)
Plurality Ethnically Aligned	-103.0***	-78.62*	-75.51**			
	(37.53)	(43.96)	(32.02)			
Share of Ethnicity Aligned				-258.2**	-198.3*	-105.7*
				(106.0)	(104.0)	(63.64)
Year FEs	YES	YES	YES	YES	YES	YES
District FEs	YES	YES	-	YES	YES	-
Controls	NO	YES	-	NO	YES	-
TA FEs	NO	NO	YES	NO	NO	YES
Observations	2,676	2,676	2,676	2,676	2,676	2,676
R-squared	0.274	0.374	0.703	0.274	0.375	0.703

Log of Deforestation	(1)	(2)	(3)	(4)	(5)	(6)
Plurality Ethnically Aligned	-0.300*	-0.141*	-0.0538			
	(0.155)	(0.0818)	(0.0721)			
Share of Ethnicity Aligned				-0.829***	-0.224	-0.104
				(0.272)	(0.173)	(0.137)
Year FEs	YES	YES	YES	YES	YES	YES
District FEs	YES	YES	-	YES	YES	-
Controls	NO	YES	-	NO	YES	-
TA FEs	NO	NO	YES	NO	NO	YES
Observations	2,676	2,676	2,676	2,676	2,676	2,676
R-squared	0.423	0.741	0.864	0.425	0.740	0.864

Note: Estimated coefficients from the fixed effects model of deforestation on measures of ethnic alignment. The top panel uses annual counts of 30x30 meter pixels deforested as the outcome variable (average annual deforestation per traditional authority in our sample is 520 pixels) and the bottom panel uses the annual log of one plus 30x30 meter pixels deforested (the addition of the 1 prevents observations with a log of zero). Controls consist of baseline forest cover, education, share with college degree, share literate, share of female population, share of households with electricity, average household size, share of households in agriculture, share of households collecting fuel wood, share of rural population, and population. All standard errors are clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1

Table 13: Estimates of hybrid maize yield model

	(1)	(2)	(3)	(4)
Log Fertilizer	0.213***	0.245***	0.144***	0.101*
	(0.0406)	(0.0539)	(0.0391)	(0.0497)
Controls	NO	YES	YES	NO
Year FEs	NO	NO	YES	YES
District FEs	NO	NO	NO	YES
Observations	191	191	191	191
R-squared	0.156	0.230	0.700	0.795

	(1)	(2)	(3)	(4)
Share of Ethnicity Aligned	0.266	0.661**	0.333*	0.143
	(0.231)	(0.237)	(0.190)	(0.134)
Controls	NO	YES	YES	NO
Year FEs	NO	NO	YES	YES
District FEs	NO	NO	NO	YES
Observations	191	191	191	191
R-squared	0.006	0.068	0.678	0.789

Note: Estimated coefficients of district-level hybrid maize yields (metric tons per hectare) on log fertilizer and share of ethnically aligned population. Note that the 191 observation sample size arises from both missing years as well as some missing district-year observations. Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table 14: Soil Quality and Deforestation 2001-2012

	(1)	(2)	(3)	(4)	(5)	(6)
	Mean Deforestation Pixels			Log of Mean Deforestation		
Soil Constraints	155.2***	209.7**	130.2	0.424***	0.582***	0.259**
	(40.09)	(93.91)	(80.33)	(0.107)	(0.169)	(0.117)
District FE	NO	YES	YES	NO	YES	YES
Controls	NO	NO	YES	NO	NO	YES
Observations	223	223	223	223	223	223
R-squared	0.020	0.386	0.434	0.067	0.509	0.745

Note: Coefficient estimates of the number of soil constraints (as measured on a scale from 1-7) regressed on annual counts of 30x30 meter pixels deforested. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix

Table A1: Ethnic Alignment and Fertilizer Quantities by District

	(1)	(2)
Ethnic Alignment	0.828***	0.416**
	(0.295)	(0.194)
Year FEs	NO	YES
Observations	264	264
Instrument	Majority	Majority
IV F-Statistic	7.878	4.606

Note: Coefficient estimates of district fertilizer quantities (as measured in logs) regressed on district ethnic majority. These results comprise the first stage of the two-stage least-squares estimation. Standard errors are clustered at the district level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A2: District-level estimates of the elasticity of fertilizer and deforestation - IV Results

	(1)	(2)
Log Fertilizer	-0.414	-1.049
	(0.355)	(0.723)
Year FEs	NO	YES
Observations	264	264
Instrument	Majority	Majority
IV F-Statistic	7.878	4.606

Note: 2SLS estimates of district fertilizer quantities (as measured in logs) regressed on annual log of one plus 30x30 meter pixels deforested (the addition of the 1 prevents observations with a log of zero) using district ethnic alignment (majority) as the instrument. Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A3: Ethnic Majority Alignment and Deforestation in Traditional Authorities

	Deforestation Pixels				**Log Deforestation**			
Majority Ethnically Aligned	-245.6**	-81.67	-130.1**	-59.66	0.284	-0.0335	-0.199**	-0.0967
	(118.6)	(49.47)	(60.00)	(41.71)	(0.272)	(0.162)	(0.0991)	(0.0911)
Year FEs	YES	YES	YES	YES	YES	YES	YES	YES
District FEs	NO	YES	YES	-	NO	YES	YES	-
Controls	NO	NO	YES	-	NO	NO	YES	-
TA FEs	NO	NO	NO	YES	NO	NO	NO	YES
Observations	2,676	2,676	2,676	2,676	2,676	2,676	2,676	2,676
R-squared	0.019	0.273	0.374	0.703	0.036	0.422	0.741	0.864

Note: Estimated coefficients from the fixed effects model of deforestation on majority ethnically aligned. Controls consist of baseline forest cover, education, share with college degree, share literate, share of female population, share of households with electricity, average household size, share of households in agriculture, share of households collecting fuel wood, share of rural population, and population. All standard errors are clustered at the traditional authority level. *** p<0.01, ** p<0.05, * p<0.1.