Customary Tenure and Agricultural Investment in Uganda

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1 Introduction

Secure property rights are fundamental to investment and prosperity, and land tenure in particular is critical for poor farmers to make long-term investments and improve agricultural productivity. In much of Sub-Saharan Africa, customary tenure, a socially-created and enforced, typically undocumented traditional form of land rights, predominates. Economists have traditionally focused on the undocumented and therefore theoretically less secure nature of customary tenure when compared with freehold land, where the owner enjoys all rights in perpetuity. Large-scale formalization policies across much of the continent have aimed to address this insecurity to allow farmers to make transformative investments in their own farms. However, empirical work has been more mixed than theory; customary land is not always less secure in farmers' own estimation (nor under-invested relative to freehold land), and formalization has not always unlocked investment. By contrast, qualitative work has emphasized the socially-constructed nature of customary tenure, where multiple individuals may hold overlapping rights over a single piece of land. The distribution of rights can therefore influence the (perceived) security of tenure. Often framed around issues of elite capture, these patterns have been difficult to document in quantitative survey data.

In this paper, I incorporate the social dynamics of land rights into a model of agricultural investment with a binding liquidity constraint. This allows for nuanced predictions about how farmers respond to changing land pressures under different tenure regimes. As land pressures increase, liquidity constraints should relax,

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but local elites may face more incentive to expropriate customary land for sale to outsiders. If farmers begin to worry about elite expropriation, this should impact their investment decisions. In particular, do farmers under-invest in long-term agricultural inputs on customary parcels as land pressures rise?

In order to empirically test the implications of this model, I use data from a survey of 2,189 farmer households in Uganda. In order to capture an exogenous component of land pressures, I use two spatial measures. The first is the inverse travel time to Kampala, the national capital and source of much outsider demand for land, which incentivizes elite expropriation but also relaxes liquidity constraints. The second is the historical decrease in travel time to Kampala due to new or improved roads, relative to the 2005 travel time. This isolates new incentives to expropriate customary land, which play a role in uncertainty and tenure insecurity. These measures should capture the degree to which outsiders are interested in purchasing local land, and therefore the drivers of elite expropriation, but abstract away from other pathways by which land values impact agricultural investment. My primary empirical specification looks at heterogeneous responses to rising land pressures between customary and freehold land for a variety of investments, controlling for farmer group fixed-effects to capture unobserved farmer quality characteristics.[1]

I propose a model which incorporates a liquidity constraint into a standard endogenous model of customary tenure and investment, where long-term investments are lower on (relatively insecure) customary land than on freehold land. In the context of traditional smallholder agriculture, this model implies that optimal investment is an (increasing) function of land values on freehold land. However, I explicitly consider a case common in customary tenure where one household or individual may hold primary use rights, while another, such as a lineage elder, may hold rights of transfer.[2] Additionally, when outsiders struggle to identify land 'owners' in illegible (difficult to parse without deep knowledge of the area and people) local tenure systems, elites have been able to sell land used by other members of the community for their own private benefit. Their incentives to do so are greater in contexts with rapidly increasing land values. This means that rising land values, driven by sales options to outsiders, may lead local elites to assert their historic right to sell land. The farmer, anticipating this, may actually make fewer long-term investments on customary land as land values rise, in contrast to the freehold case.

Testing this model in the Ugandan context, I find that long-term input use responds to rising land values more strongly on freehold land than on customary land. Elite incentives to expropriate rise along with land pressures, causing tenure insecurity on customary land, and this attenuates the impacts of increased liquidity. This divergence in input use between freehold and customary parcels is also present (to a lesser extent) on

[1]These farmer groups were part of the sampling strategy in the data collection process. They extend the intuition of household fixed-effects to control for unobserved heterogeneity as farmer groups are self-selected, but allow for sufficient identifying variation.

[2]I focus on these two rights given their first-order importance for investment incentives, despite the plethora of other secondary rights that may be held by various individuals.

short-term inputs, contrary to the model's predictions. This may be driven by changing cropping patterns, as urban markets increase demand for cash crops that require more intensive input use. Nevertheless, the difference in responses is stronger for long-term inputs, which can be attributed to the tenure-security effect. Additionally, the divergence in investment is more responsive to rising land pressures closer to Kampala.

By incorporating the social nature of customary land rights in a model of agricultural investment, this paper avoids the common conflation of incompleteness of rights with insecurity. Instead, it considers how multiple rights-holders interact in different land value environments to make more nuanced predictions about investment on customary land. In addition to bringing qualitative insights to an economic framework, I use economic modeling to explore how farmers would strategically respond to changing incentives. This model captures how the potential for elite capture affects individual farmers. It thereby returns the focus to the welfare of smallholders, and by examining a broader population allows me to quantitatively document the effects of (potential) elite capture (which historically has been difficult due to the rarity of observed cases). Unlike many previous papers which have conceptually modeled the impacts of tenure *security* but then empirically used tenure *type* as a (poor) proxy, I consider tenure type and the incentives it creates throughout my model, therefore linking more closely to my empirical tests.

The remainder of this paper consists of a review of both the quantitative and qualitative literature on customary tenure and agricultural investment in Sub-Saharan Africa, with a particular focus on Uganda, followed by a model which captures many of the insights explored. I then discuss the context and data used, as well as an empirical strategy with several hypotheses laid out. I present results for a variety of short- and long-term inputs, and conclude by discussing their implications for the model's relevance to the Ugandan context.

2 A Review of the Literature

2.1 Customary Tenure Arrangements in Sub-Saharan Africa

To emphasize the scale of customary tenure regimes, only between 2 and 10 percent of land in Sub-Saharan Africa is formally titled, with the remainder subject to customary tenure, state ownership (including forest reserves and national parks), or other informal arrangements (Cotula et al., 2007). Indeed, "[customary] tenure represents the *major* tenure regime on the continent" (Alden Wily, 2011).

2.1.1 Features of Customary Tenure

There is an enormous diversity in customary systems around the region, as a hallmark of the customary is its very localized, negotiated nature. Nevertheless, there are a few generalizations that tend to hold broadly and have been highlighted by qualitative researchers as key to local understandings of the customary.

The first point to stress is that tenure is not an isolated sphere of life: "customary land tenure is as much a social system as a legal code" (Alden Wily, 2011), embodying local power relations, authority, and access to knowledge and labor (Van Leeuwen, 2014). This embedding of land tenure in social relationships means that it is open to negotiation, which both enables adaptability to changing circumstances but can also marginalize those in weaker bargaining positions (Cotula et al., 2007).

One particular way in which this social nature of customary tenure works is by having "overlapping rights over the same resources held by different users" (Cotula et al., 2007). Ensminger, an anthropologist, specifies that "a common characteristic in almost all African customary systems is for use rights to be assigned at the household level, whereas transfer rights are assigned at a higher level such as the lineage, clan, or chiefdom" (Ensminger, 1997). This means that although individuals may be quite secure in their ability to use a particular plot of land in their lifetime, adaptive reallocation within the community could occur in response to changing circumstances. Customary leaders also are able to allocate (often unused) land to migrants into an area as well as adjudicate any conflicts that may occur between members of the community. Although the particular ways these rights are divided may vary considerably across the region, this 'dis-bundling' of property rights is common and adds a strategic dimension to any decisions about land.[3] It has been argued that "sufficient investment incentives tend to be provided by basic rights of use that, under normal circumstances, are guaranteed to many villagers (including migrants) by the local informal order:" that is, this dispersion of rights is not a cause of instability or under-investment in itself (Brasselle et al., 2002). However, the continual adaptation of customary institutions means that such systems are dynamic and see considerable changes over time. My model explores how outside, market-based pressures on land shape customary tenure security and investment incentives.

2.1.2 Elites and Customary Tenure

I now turn to the role of elites in customary tenure, both in a (somewhat idealized) 'traditional' world as well as in contemporary contexts. As discussed above, a common feature of customary systems is that elites, representing the family or lineage writ large, serve as trustees or administrators of land owned by the family group. Often, they hold transfer rights in order to (re)allocate land within the community in response to

[3]In this paper, I do not explicitly consider pastoralist systems, which are found throughout the region but which entail a whole host of other property rights concerns (as modeled by Goodhue and McCarthy (2008)).

shocks (such as the death of a large landholder without heirs or an influx of new migrants to an area), as well as to prevent the alienation of a communal resource without the consent of the community.

Beginning with colonial administrators, outsiders have attempted to fit Western notions of ownership based on freehold tenure onto customary tenure systems, and this institutional mismatch has created ambiguity about who the 'owners' of land actually are. This ambiguity can be exploited by local elites: "There is a fine line between chiefs as (often self-declared) owners of all land in customary laws, and chiefs as trustee administrators" (Alden Wily, 2011). Elites are able to respond as individuals rather than as guardians of the corporate group, and can thus assert their rights of ownership to outsiders unfamiliar with the complexities of local tenure arrangements.[4]

2.1.3 Customary Tenure and Rising Land Values

The qualitative literature on customary tenure has documented the tensions and conflicts that emerge as customary systems adapt to external pressures such as rising land values. Most cases have considered land values rising due to *non-agricultural* uses, such as urban and peri-urban expansion, or natural resource extraction. Some large scale land acquisitions have been for agricultural purposes, although generally requiring scale or technologies such that local smallholders are unable to participate. Therefore, this should be thought of as an increase in the *marketable* value of land rather than its value to smallholder agriculture.

In a report by the International Institute for Environment and Development and the Food and Agriculture Organization, the stress rising land values put on customary systems is discussed repeatedly: "As land values rise, farmers may be forced or tempted to sell their land. Where land is still under customary chiefs, these may be tempted to sell off lands ... regardless of the views of those actually farming this land" (Cotula et al., 2004, cited in Cotula et al. (2007)). In Ghana, this manifests as the same parcel of land being sold multiple times by and to different people; "many of these multiple sales are by different people in a family lineage, each contending that they have the status to sell under the customary system" (Barry and Danso, 2014). More often, "land scarcity may lead to a redefinition of the land claims of different groups within the extended family... with weaker groups becoming more vulnerable to losing their land access" (Cotula et al., 2007). Despite abundant stories of how "local elites have been able to use their position and the ambiguities of customary law to appropriate land to further their own economic and political interests" (Ubink, 2008), especially in peri-urban areas but also in many rural ones (Ubink and Quan, 2008), this particular facet of how customary tenure adapts to external pressures has been little studied by economists. Economics,

[4]Mattingly (2016) documents a similar process in China: when lineage elites join village political institutions, both public goods provision and the likelihood of land expropriation increase. He argues that "social institutions serve as channels of bottom-up informal accountability *and* top-down political control," depending on the incentive structure. Public goods provision has features of a repeated low-stakes game (inducing cooperation between elites and their communities), but land development is more akin to a one-shot game with higher stakes.

with its ability to explore the strategic interactions between individuals, can therefore contribute to our understanding of this important issue. In particular, economics can model how land users anticipate the changing incentives of local elites, and therefore change their own investment incentives.

2.2 Models of Land Tenure and Investment

I now briefly consider other theoretical treatments of land tenure and investment in order to situate the model presented in this paper. Broadly, land tenure has been thought to encourage investment through three possible mechanisms, going back as far as the discussion in Feder (1988, cited in Place (2009)). These have been termed the assurance, collateralizability, and realizability mechanisms: stronger land rights should provide assurance that the farmer will be able to reap gains from investment, increase access to capital by leveraging the land as collateral, and allow the farmer to sell the land and realize gains sooner (as well as transferring land to those most able or likely to invest) (Besley, 1995, cited in Fenske (2011)).

Each of these mechanisms is the subject of an extensive theoretical and empirical literature, and their relevance to customary tenure in Africa has been long debated. Credit markets have been shown to be thin, farmers may be credit rationed for other reasons, and land markets are often missing or face other restrictions. This discussion will focus on the first of these mechanisms, which does not rely on the existence of functioning complementary markets.

Despite the intuitive appeal of stronger tenure inducing higher investment, the complexities of land rights in Sub-Saharan Africa mean that defining 'stronger land rights' poses difficulty, and the precise way they are defined and empirically measured can have important implications. The simplest models attempt to capture tenure as an exogenous probability of losing the land, along with any fixed investments, before the profits of those investments can be fully realized. These models often make this assumption to instead focus attention on other features of the investment context (Jacoby and Minten, 2006). For instance, Dillon and Voena (2015) focus on intra-household bargaining resulting from tenure insecurity for widows, and so model whether a widow can inherit marital property as a village-level (exogenous) determination.

However, much qualitative evidence on customary tenure regimes in Sub-Saharan Africa has stressed the endogeneity of tenure security (discussed in more detail below), and this endogeneity has then been incorporated into quantitative models. That is, actions taken by the farmer, particularly certain investments in the land, demonstrate responsible use of the land and defend against expropriation by others in the community who recognize these investments as land stewardship (Awanyo, 2009). The following is far from comprehensive, but serves to illustrate the variety of ways investments have been considered to influence tenure security. Robinson (2005) focuses on the state's role in guaranteeing tenure security, while Deininger and Jin (2006) emphasize the visibility of an investment to others in the community as key to its efficacy in securing tenure rights, for tenure security is fundamentally about social recognition of rights. Place and Otsuka (2002) explore this concretely by contrasting three possible investments: planting trees, which is visible and thus reduces the probability of losing the land (a primary input in my model below); management effort, which is invisible and thus has no effect on tenure security; and fallowing, which in a tenure system predicated on land *use*, may actually increase the risk of expropriation.

Goldstein and Udry (2008) focus on this latter effect in their work on tenure security in Ghana, where fallowing is the primary investment in land productivity. They focus on how an individual's social status interacts with these incentives: "farmers who lack political power are not confident of maintaining their land rights over a long fallow. As a consequence, they fallow their land for much shorter durations than would be technically optimal, at the cost of a large proportion of their potential farm output." This effect is driven by non-elite households on their land obtained through customary tenure.[5]

2.3 Empirical Evidence

Despite the seeming clarity of the theoretical relationship between tenure security and investment, the empirical evidence on customary tenure and investment is quite mixed (Place and Hazell, 1993; Fenske, 2011). Although there is some convincing evidence that tenure regimes do influence investment decisions, particularly in West Africa, many other papers have found no statistically significant results or at times results contrary to theory. Goldstein and Udry (2008), find in Ghana that even after controlling for household and spatial fixed effects (as well as plot characteristics), the tenure status of a plot is a significant predictor of how long it is fallowed. The authors argue that this tenure pathway explains much of the gender productivity gap in Ghana, as women are more likely to control customary plots. Fenske (2011), however, notes that a household fixed effects specification may select those households with the greatest differences in tenure security (and thus those households most likely to invest differently across plots); only those households who feel insecure about land allocated through customary mechanisms will purchase other plots.

Other papers have found little or no relationship between tenure insecurity and investment. In Madagascar, for instance, Bellemare (2013) finds that, after controlling for household fixed effects and soil quality, titling has almost no effect on agricultural productivity, and subjective beliefs about rights have at times counter-intuitive implications for productivity. Fenske (2011), in reviewing the dispiriting body of evidence, suggests that perhaps investment is high across all plots because, despite insecurity, returns in agriculture may be that much higher than the outside option. He also conducts a 'quantitative review' of other papers

[5]Social elites do not face the same disincentives to fallow, as they would be the ones to transfer unused land, so empirically they fallow land similarly regardless of how a parcel was acquired.

by similarly analyzing nine data sets from West Africa. He argues that small sample sizes have driven some of the lack of empirical results, as larger samples are more likely to find results. He also takes issue with the use of binary investment measures, which have been often used to deal with frequent zeroes in investment.

Yet another potential issue in the empirical literature lies in precisely defining tenure security, as 'security' could be composed of (multiple) elements of duration of tenure, assurance, and completeness of rights (Place et al., 1994; Doss and Meinzen-Dick, 2020). Although it is theoretically clear, "there is no agreed upon way to measure tenure security and results may be related to choice of proxy" (Place, 2009). Bellemare (2013)'s results in Madagascar highlight this: one measure of tenure security, the presence of title, seems unimportant for investment, while beliefs about rights do matter. Deininger et al. (2021) find in matrilineal areas of Malawi that rights to bequeath and sell land are more important than short-term management rights for investment. Even without 'complete' rights, tenure may be quite secure and persist for generations, and thus empirical measures diverge from the proposed theoretical pathway. Other papers have dealt with this more explicitly, such as Brasselle et al. (2002) who use questions on nine different rights in Burkina Faso to categorize households into five groups based on the (overlapping) sets of rights they have. Other (generally older) papers, e.g. Place and Otsuka (2002), have avoided the question entirely by simply comparing regions with different predominant tenure systems, although it is unclear if other factors could be at work.

Instead of modeling tenure security as the fundamental parameter of interest, and then using land institutions as a (very imperfect) proxy for tenure security, I follow Abdulai et al. (2011) in explicitly modeling particular institutional arrangements and the incentives they create for investment. This seems a more robust treatment: rather than *ex post* justifying results as a product of the 'context,' I account for the tenure context from the start.

2.4 Land Rights in Uganda

Given the enormous diversity of customary tenure arrangements throughout Sub-Saharan Africa, it is worth delving into the particular case of Uganda. Between 12-14% of land is subject to formal title, so customary tenure remains significant throughout the country (Alden Wily, 2011).[6] Customary authorities still play a major role in Uganda: in lab-in-the-field experiments, references to traditional authorities such as the *kabaka* (the king of Buganda, one of the major regions in Uganda) induce higher contributions to public goods games (Goist and Kern, 2018).

Even within Uganda, there is some variation in the relative strength and allocation of bundles of rights. In the west, where population pressures on the land are higher, there is more individualized tenure, while

[6]This is slightly higher than for the continent as a whole, in part due to colonial administration which focused on documenting land allocation in Uganda.

the relatively land-abundant north retains stronger rights for customary authorities (Van Leeuwen, 2014). Qualitative work has documented throughout the country that rights to the land in perpetuity are differentiated from responsibility for managing the land (Adoko and Akin, 2011). Specific land rights regimes can be incredibly precise: Howard and Nabanoga (2007) document that rights are determined for individual people over individual plants on different types of land under different circumstances (for instance, that a woman who is pregnant or sick is allowed to pick certain medicinal plants from someone else's river plot, but not from a home garden). I leave these particularities to the side, focusing on the first-order rights of land use/management and transfer rights, which have the most direct impacts on agricultural investment.

Deininger and Castagnini (2004)'s examination of land-related disputes in Uganda can illustrate how customary tenure functions and the margins at which it breaks down. They estimate that up to 5% of the rural population is involved in a pending land-related conflict at any given time, mostly between neighbors because boundaries have been exceeded. The prevalence of boundary disputes has led to many farmers planting trees to demarcate their land; "boundary trees are useful evidence when the land can be visited during a case by customary authorities, but they are less useful when the case is heard in a court of law far away from the land" (Adoko and Akin, 2011). There has been a push to incorporate customary leaders into statutory court systems, with mixed success (Van Leeuwen, 2014).

Much of the literature on land rights in Uganda has considered the *mailo* system, a remnant of British indirect colonial rule. In 1900, the British signed a treaty with the Kingdom of Buganda which allocated square-mile tracts in the center of the country to Buganda elites for their 'ownership' as absentee landlords. These tracts were then sub-leased to the actual inhabitants and land users (Deininger and Castagnini, 2004). Ever since, there has been a significant tension over government policy towards *mailo* owners and tenants and how to balance the two parties' competing interests (Coldham, 2000).[7]

Historically, proclamations of state ownership of all land under the dictatorship of Idi Amin in 1975 were largely unenforced and ignored by the population (Hunt, 2004). The Land Act of 1998, by contrast, regarded land as the property of the citizens of Uganda and recognized four tenure types: freehold, leasehold, customary, and *mailo* (Joireman, 2007). The law provides for an extensive and decentralized land administration (Tripp, 2004) that could issue titles as well as 'certificates of customary ownership.' These certificates registered rights held by multiple people and could, in time, be converted into freehold titles (Coldham, 2000). Unlike compulsory registration in other countries in the region, registering rights was voluntary. This leads Coldham (2000) to observe that "where the grant of certificates of title is based on individual applications,

[7] The 1998 Land Act attempted to balance these by giving *mailo* owners the powers of a freehold owner, while still recognizing the rights of 'lawful occupants' of the land who had used it for more than 12 years (Coldham, 2000). This guaranteed occupants' tenure security (including inheritance rights and the ability to sub-let with consent of the owner), while requiring continuous possession of the land and a nominal rent payment.

there is always a risk of land-grabbing, that is, that an applicant may lay claim to a larger area of land than that to which he is customarily entitled." Furthermore, the widely-lauded land reform has been largely unfunded and thus little-implemented (Deininger and Castagnini, 2004; Joireman, 2007).

Two previous economic analyses have looked at the impacts of tenure on agricultural investment in Uganda. Deininger and Castagnini (2004) focus on land conflicts, but argue that the intensive multi-cropping system prevalent in much of Uganda implies individual crop production functions are inappropriate for productivity measures or investment. Deininger and Ali (2008) use household fixed effects to control for unobservables such as farming skill and find that households invest in both long-term and short-term inputs significantly more on plots they own outright rather than plots they have only customary rights over. Furthermore, they find that registering customary rights (by acquiring a certificate of customary ownership) has little impact on investment, but legal efforts to strengthen occupancy rights do increase investment.[8]

3 A model of tenure and investment

I now turn to my own theoretical model of tenure and investment, explicitly incorporating changing incentives for expropriation on land under different tenure systems. Consider a two-period model. In the first period, a farmer chooses to apply a short-term input, fertilizer, F_1, and a long-term one, trees, T,[9] to his or her exogenously given land L under tenure system h in order to produce according to $f(F,T)$. The farmer also has some wealth endowment and can choose to borrow B_1 against the value of the land (depending on the tenure system), to be repaid at the end of the period. The farmer faces an exogenous interest rate r and has a discount rate β for second period returns (the optimized expected second-period total profit is given by π_2^*). There is some probability that the farmer's land will be expropriated before the second period, in which case fixed investments (trees) would also be lost. This probability is given by $(1-\phi(T,h,vL))$ (where v is the per-unit value of the land) and may be a function of tree investment, tenure systems, and the value of the land. For convenience, I use the word 'expropriate' to capture both 'horizontal' expropriation (where others in the community take over the farmer's use rights), as well as the exertion of sales rights by local elites without the permission of the land user ('vertical' expropriation). After working through the main features of the model, I consider what different forms of this ϕ function could imply for the farmer's decisions.

[8] They find that investment increases with length of occupancy, with a discontinuity at the 12 year mark when rights become recognized by law.

[9] These inputs stand in for bundles of short and long-term investments, although trees may have particular tenure-enhancing effects not seen for other long-term inputs.

The first period optimization problem faced by the farmer is therefore

$$\max_{F_1,T,B_1} \; p_a f(F_1,T) - p_F F_1 - p_T T - rB_1 + \beta\phi(T,h,vL)\pi_2^*(F_1,T,B_1)$$

$$\text{subject to: } \begin{array}{l} p_F F_1 + p_T T \leq w_1 + B_1 \\ B_1 \leq s(vL,h). \end{array}$$

In the second period, the farmer only chooses fertilizer (F_2) and therefore maximizes according to the following:

$$\max_{F_2} \; p_a f(F_2,T) - p_F F_2$$

$$\text{subject to: } \begin{array}{l} p_F F_2 \leq w_2 \\ w_2 = w_1 + (1-r)B_1 + p_a f(F_1,T) - p_F F_1 - p_T T. \end{array}$$

3.1 Land Values and Investment

To begin with, consider the case where the farmer is certain their land will not be expropriated before the second period (that is, the land is under freehold ($h = 1$), and $\phi(T, vL|h = 1) = 1 \; \forall \; T, vL$).

Figure 1 follows Carter and Olinto (2003) in depicting the constrained solution to the model. The width of the horizontal axis represents the available liquidity, $w + s(vL,h)$. Parameters γ and τ represent the total expected marginal productivity of inputs F and T, respectively. Fertilizer is modeled to only last for one period, while trees continue to produce in both periods, therefore:

$$\begin{aligned} \gamma &= p_a \frac{\partial f}{\partial F_1} - p_F \\ \tau &= p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T}\pi_2^* + \beta\phi \frac{\partial \pi_2^*}{\partial T} \end{aligned}$$

However, as mentioned above, for the moment ϕ is constant with respect to trees, so $\frac{\partial \phi}{\partial T} = 0$.

As in Carter and Olinto (2003), the liquidity-constrained farmer will choose inputs F and T such that the expected rates of return are equal between the two, labeled A in figure 1. These input levels will be necessarily lower than the unconstrained optimums (where γ and τ each cross the dashed line representing the marginal cost of the inputs and summing to more than the available liquidity).

If there is an exogenous increase in the value of the land, $v' > v$, then the available liquidity provided by that land will increase, illustrated as an expansion of the horizontal axis to $w + s(v'L,h)$. This does not necessarily stem from using the land as collateral, but may instead be a function of output markets for

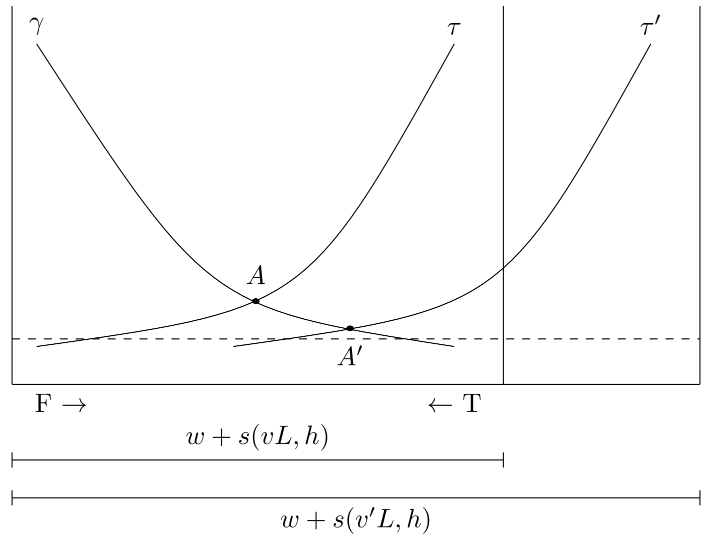

Figure 1: Land Values Increasing Investment

crops grown, such as demand for cash crops. τ is measured from the right-hand axis, and so as the available liquidity space expands, this curve graphically shifts to the right (to τ'). The marginal productivity curves now cross at A', indicating higher investments in both fertilizer and trees. Therefore, increasing land values will allow for increased investment in both short and long-term inputs for liquidity-constrained farmers.

3.2 Customary Tenure and Investment

The threat of future expropriation of the land is real for many farmers, particularly on customary land. The model captures this risk in two ways, as illustrated in figure 2.

Oversimplified models of customary tenure and investment merely consider customary land to have a higher risk of alienation than freehold land: $\phi(T, vL|h = 0) < \phi(T, vL|h = 1) \ \forall \ T, v, L$, with $\frac{\partial \phi}{\partial T} = 0$. That is, for any level of investment in trees or land values, the risk of expropriation is higher on customary land, and this risk does not change in response to investment in the land. This lowers the expected total marginal productivity of investment in trees, as shown by a shift right (towards the origin for T) from τ to τ'', decreasing the investment in trees to the equilibrium shown at A''.

Drawing upon qualitative understandings of customary tenure, though, more subtle models have sought to capture the endogenous nature of tenure security on customary land. Place and Otsuka (2002), for instance, model the probability of losing land as a decreasing function of planting trees, a visible investment in the land. In my model, this implies that $\frac{\partial \phi}{\partial T} > 0$, which would attenuate the rightward shift of the τ curve (and could perhaps even lead to an 'overinvestment' in trees relative to the unconstrained optimum if the tenure-enhancing effect is large, although empirically this is rarely documented). This combined effect leads

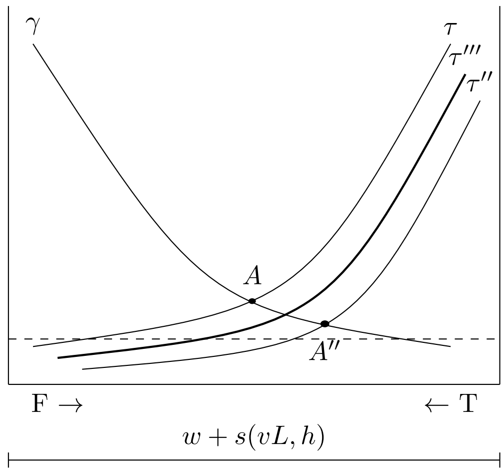

Figure 2: Customary Tenure Influences Long-Term Investment

to the marginal productivity of trees indicated by τ'''.

The equilibrium determined by the marginal productivity of trees under (less-secure) customary tenure, then, likely sees under-investment in trees relative to the allocation under freehold tenure. I will empirically test this using data from Uganda.

3.3 Expropriation Risk under Customary Tenure

Customary tenure is not simply insecure tenure. Earlier, I showed that an attention to the complexities of how customary tenure functions can have important implications: visible investment decisions such as planting trees can demonstrate responsible land use (a condition of tenure), thus endogenously strengthening tenure rights. Recall that by planting trees on a plot, a farmer demonstrates to the community that it is under use. If another member of the community tries to encroach on the plot, these visible investment decisions can be used as evidence of responsible land use, and thus make it more likely that disputes within the community will be resolved in the farmer's favor.

The model so far has ignored the particular bundles of rights and their distribution among individuals that are hallmarks of customary tenure systems. That is, many customary tenure systems in Sub-Saharan Africa, and those in Uganda in particular, do not vest all types of rights over a given piece of land in the same individual or household. Primary use rights may be held by one household, while other members of the lineage or extended family have access rights or even claims to certain plants (Howard and Nabanoga, 2007). Importantly for this analysis, local elites (such as lineage heads or traditional chiefs) often hold transfer rights over large areas of customary land.

The long-term stability of customary tenure systems is evidence that these decentralized rights did not in themselves cause major tenure insecurity (Bruce and Migot-Adholla, 1994). This is perhaps due to mechanisms (such as planting trees) that allow use-holders to demonstrate tenure against other claimants, with local elites serving as arbiters and rights-holders for the community.

However, there has been recent concern in policy spheres about the potential for local elites to make deals with outsiders (often national or international investors) that alienate local rights-holders. While the details of such deals, termed 'Large-Scale Land Acquisitions' (Smalley and Corbera, 2012; Purdon, 2014), are beyond the scope of this model, they represent but one example of local elites using their traditional rights to the land for their own gain.[10] Outside investors often find it difficult to navigate the complex realities of customary rights, and thus they may not realize that they are expropriating land from existing users without their consent.

In the context of this model, it suffices to note that increasing land values may not only increase the value of the asset for the primary land user, but also for other rights-holders. This could increase the value of expropriation for these other individuals (namely, local elites with transfer rights). Local elites may not have found it profitable to exercise their traditional rights in an inactive land market, preferring instead to maintain the traditional status quo. However, as land values rise (whether due to offers from outside investors, population pressures from growing urban areas, or other exogenous forces that introduce potential outside buyers who are less familiar with the customary) they may be more likely to expropriate from the land user in order to alienate the land to others.[11]

Within the model, then, ϕ is written as a function of vL as well as h, the tenure system, and T, tree investment. In particular, $\phi(T, h, vL)$ could have the following properties:

$$\phi(T, h, vL) = \begin{cases} 1 & \text{if } h = \text{Freehold}, \\ g(T, vL) & \text{if } h = \text{Customary}. \end{cases}$$

where $\frac{\partial g}{\partial T} > 0$, as in Place and Otsuka (2002), and $\frac{\partial g}{\partial v} < 0$ following the intuition outlined above.

The land user (farmer/decision-maker) can anticipate these changing incentives for their co-rights-holders, as captured in $\frac{\partial \phi}{\partial v} < 0$. Rising land values may mean that no matter the level of their own investment in production, the risk of expropriation increases. Figure 3 illustrates this: the higher risk of expropriation could outweigh the liquidity constraint-relaxing effects of increasing land values, and perhaps even on net decrease longer-term investments in the land. The shift from A to A' reflects the effect of increasing land

[10] It could be argued that this is in fact a reinterpretation of their customary rights, shifting from custodian of the land to 'owner' in a more Western, exclusive, sense.

[11] An alternate, complementary, understanding of this process (explored in Honig (2022)) is that in isolated communities, returns to elite are primarily social – respect and prestige from their community. But as outsiders penetrate the community, that social prestige may be less valuable or obtainable from a community in flux. This may make the monetary benefits of expropriation seem even more valuable.

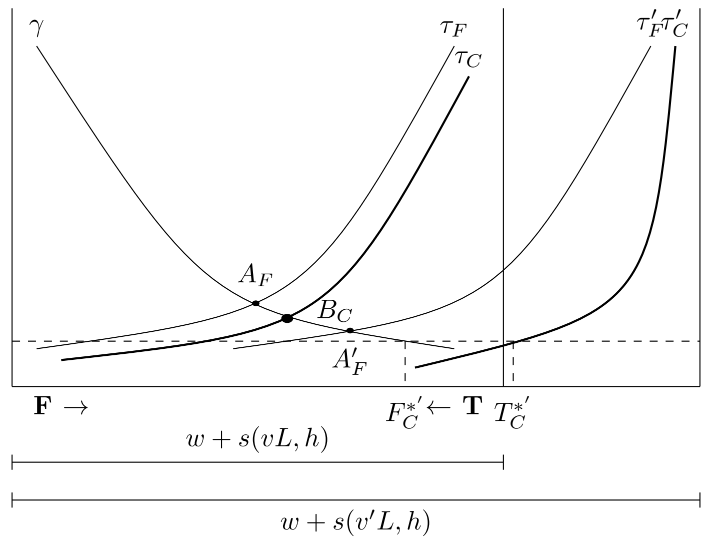

Figure 3: Land Values and Strategic Interactions

values on investment on freehold land: although still bound by the liquidity constraint, investment in both fertilizer and trees increases. For customary land in Figure 3, increasing the value of the land and relaxing the liquidity constraint does not simply shift the marginal productivity of trees rightward, but changes the shape due to the effect of $\frac{\partial \phi}{\partial v}$ discussed above. Graphically, the farmer has actually left the liquidity-constrained case, but investment in trees has decreased to $T_C^{*'}$.

4 Context and Data

To test this model empirically, I use data from the baseline survey I conducted for a proposed impact evaluation of Uganda's Agriculture Cluster Development Project (ACDP).[12] This baseline survey was conducted in early 2019 in four districts throughout Uganda. Respondents were chosen in a two-stage process: first, we randomly selected 133 registered farmer organizations that had at least 20 members in the target districts, and membership rosters were drawn up. Member households were then randomly selected to be interviewed, with a total of 2,189 interviews in the baseline survey used here.

The districts selected for the impact evaluation are located throughout the country and thus encompass

[12]This project, supported by the Government of Uganda and the World Bank, aims to provide farmers in five crop-specific 'clusters' (maize, rice, beans, cassava, and coffee) with the resources needed to move from subsistence farmers to commercialized producers. To that end, the project provides subsidized farm inputs to selected farmers, improves agricultural infrastructure, and supports post-harvest handling technologies. The impact evaluation was planned as part of the pilot phase of the project, focusing on the provision of electronic vouchers for subsidized inputs that are redeemable at certified local agro-input dealers. The impact evaluation was planned in 4 districts throughout Uganda, each assigned one of 4 target crops (maize, rice, beans, and coffee; cassava was omitted as it has a longer growing season). The impact evaluation randomly assigned farmer organizations eligible for the ACDP subsidy to one of two treatment groups (defined by the timing of benefits) or to a 'downstream' control group. Approximately 36 farmer organizations were assigned to each treatment arm, from each of which an average of 20 members were selected to be surveyed throughout the four districts.

some of the diversity of customary tenure arrangements in Uganda. Selected districts are located in the east, southwest, center (where *mailo* land predominates), and north (where instability has led to many internally displaced people).

As part of the impact evaluation, the Ministry of Agriculture, Animal Industry and Fisheries and a team from UC Davis conducted an extensive baseline survey,[13] which has data well-suited to the structure of this model. Given that the program was designed to induce investment in agriculture, the survey has an exhaustive plot-level elicitation of all inputs and outputs as well as continuous measures of the value of investment. Furthermore, the survey asks detailed questions about the tenure status of each agricultural parcel farmed by the respondent household. These questions ask about the tenure system the parcel is under; which individual members of the household are owners; what kind(s) of documentation exist for the parcel, if any, and whose names are on the documentation; who within or outside the household holds particular rights (such as transfer rights); and questions on perceived tenure security. Finally, the survey asks about land rental prices in the region and contains GPS coordinates for the household, allowing me to match households to other geospatial datasets. For most specifications, I use a dataset of 3,076 parcels; most were observed over two seasons, for a total of 5,760 parcel-season observations which I pool.

To some extent, this sample is positively selected in comparison to all farmers in Uganda: they are members of farmer groups, indicating a higher likelihood of participating in output markets and perhaps higher farming skill, although farmer groups are relatively common in Uganda.[14] This positive selection can be seen in rates of input use in the ACDP data when compared with the nationally-representative Living Standards Measurement Survey (LSMS) conducted by the Uganda Bureau of Statistics and the World Bank: only 4.6% of parcels have organic fertilizer applied and 2.6% inorganic fertilizer in the 2019 LSMS, as compared with 11.5% and 10% of parcels in the ACDP data, respectively. This provides sufficient variation to use agricultural inputs as my regression outcomes, but is an important caveat in the external validity of my results.

I use two measures of the external pressure on land values modeled above. First, I use the inverse travel time to Kampala, the national capital, adapted from Muller-Crepon et al. (2021) and Muller-Crepon (2021). This measure is constructed using historical road maps from Michelin, which Muller-Crepon et al. (2021) digitized and created a road atlas for all of Africa from 1966 to 2015, akin to a historical Google Maps. In Muller-Crepon (2021), he then estimates the shortest travel time via roads of different qualities to the

[13]Subsequent mid-line and end-line surveys were planned but were cancelled along with the implementation of the Impact Evaluation in November 2020, due to compliance issues and COVID-19. The baseline data I use was entirely collected pre-intervention, so there should be no impacts of the intervention on input use.

[14]In the 2019 Living Standards Measurement Survey, 28% of communities report having a farmers' group; 43% report a savings & loan group that was identified by subcounty extension workers as serving as a farmers' group for the purposes of ACDP targeting.

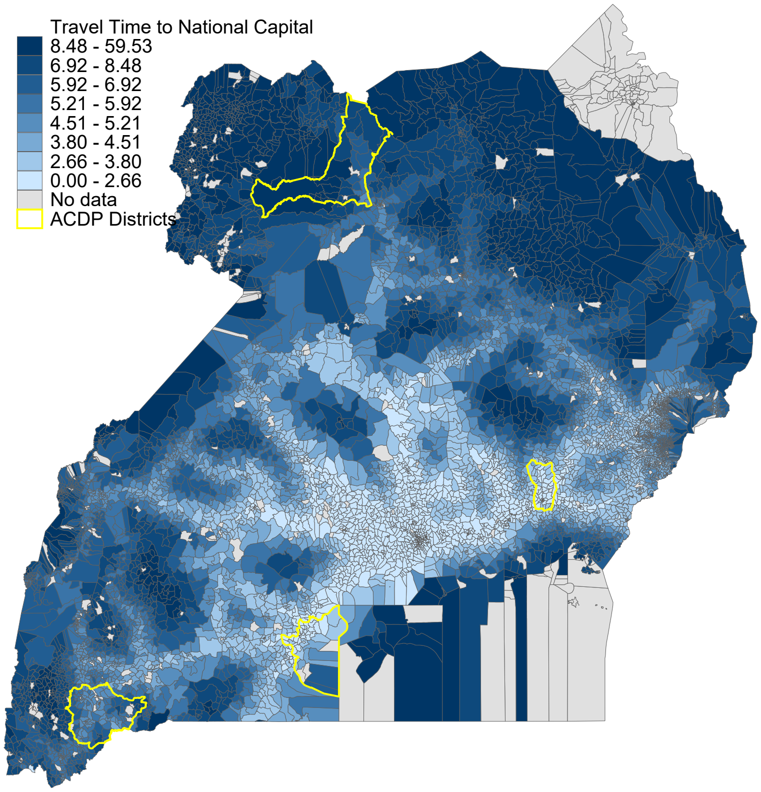

Figure 4: Map of the average travel time in 2015 to Kampala in each Parish in Uganda, with ACDP districts highlighed in yellow. Administrative units in Uganda extend into Lake Victoria to the national border, to include several small islands.

national capital for each 5x5 km grid cell.[15] Both Muller-Crepon (2021) and Muller-Crepon et al. (2021) use the inverse of travel time to the capital as proxy of state reach in a local geography, but it also represents the degree to which outsiders such as urban residents of the capital may be interested in purchasing local land: precisely the concern of customary landowners that creates insecurity. Figure 4 plots the average travel time to Kampala in each parish of the country, with ACDP districts highlighted in yellow.[16]

I match households to a grid cell using GPS locations collected during the survey (taken at the household residence, not at agricultural fields which could be at some remove). Following Muller-Crepon et al. (2021), I then compute the 'access' to the national capital in 2015 for each household as $(1 + time_j)^{-1}$.[17] The correlation between per-acre rental prices and access to Kampala is low (.08) but increases to .21 when I winsorize several outliers in estimated rental prices (among those who own their land and are estimating how much they could rent it out for) and to a very high .93 when I consider district median rental prices,

[15] This is approximately 2.5 arc-minutes at the equator, which Uganda spans.

[16] I focus on travel time to Kampala rather than to regional capitals in this analysis, as I want to isolate away from the politically-driven administrative unit proliferation that has occurred in Uganda in the recent past. Although a new district capital may be identified close to respondents, these new centers do not yet have the population to support substantial outsider demand for land.

[17] This represents the most recent year for which Muller-Crepon (2021) has data on travel time to national capitals, regional capitals, and distance to markets, and thus the closest to the ACDP baseline survey in 2019.

suggesting that it captures broader pressures than individual prices which may be influenced by soil quality or other agricultural value considerations.

The second measure I use attempts to isolate changing pressures on local land, which is a more direct representation of the pressure on local elites to expropriate and sell customary land to outsiders. I use the historical (10-year) decrease in travel time to Kampala, due to the construction or upgrading of roads, relative to the 2005 travel time to Kampala. This measure, also constructed using historical spatial data from Muller-Crepon et al. (2021), captures the extent to which elites face *new* opportunities to expropriate, which should have a strong impact on perceptions of tenure insecurity. I match this measure spatially in the same way as the inverse travel time variable described above.

5 Empirical Strategy

To test the predictions outlined in the model, I examine differential patterns of short- and long-term agricultural investments on parcels under different tenure regimes as land pressures exogenously increase. These predictions go beyond existing models of land tenure and investment by considering how overlapping rights-holders respond to rising land prices, and thus how incentives may change differently on customary land. Commonly-used empirical strategies model tenure *security* (the expected probability of expropriation before realizing the fruits of investment) but then only empirically measure rough proxies such as tenure *type*. Improving over this, I explicitly model the relationship between tenure *type* and investment (operating through tenure security). The theoretical model explored above shows how a rough proxy may be insufficient: in low land-value environments, customary land may be equally secure as freehold, but as land values increase, customary land may become less secure.[18]

Outside this advancement, I use empirical methods generally accepted in the literature. At heart, the empirical specification involves regressing a given investment measure on a continuous measure of land values interacted with a dummy for a parcel being under customary (as opposed to freehodl) tenure. Investments should respond to rising land values on freehold land due to a relaxation of the liquidity constraint; on customary land, however, this effect is attenuated by the rising insecurity caused by local elites' incentives to expropriate newly-valuable land to sell to outsiders.

Several concerns are apparent with this strategy. First, the tenure regime of particular parcels may not be exogenous (for example, households may be more likely to pursue titling for higher-quality plots). Deininger and Ali (2008) argue that Uganda has what amounts to an "exogenous historical assignment of land rights... and the absence of readily available opportunities to change the tenure status of occupied land

[18]The lack of results in previous studies which elide tenure security and tenure type may be understood, then, as an issue of this poor proxy.

to full ownership imply that the case at hand can be considered akin to a natural experiment." Second, there may be unobserved heterogeneity in household farming decisions caused by factors such as household shadow prices or farming skill, which may be correlated with the tenure of parcels farmed by households. Ideally, this would be addressed using a household fixed-effects strategy. Unfortunately, of the 2,189 households surveyed, only 6.5% of respondents reported having parcels under both freehold and customary tenure, which is much lower than the rates observed in the LSMS-ISA in Uganda, a high-quality nationally-representative dataset (Deininger and Ali, 2008). Furthermore, these households are concentrated in two of the four surveyed districts. This limits the power of a household fixed-effects model to detect changing investment patterns as land prices increase.

Despite this, the ACDP data sampling strategy involving farmer groups allows me to extend the intuition of household fixed effects to farmer group fixed effects. These farmer groups are co-located, self-selected groups of farmers who can purchase inputs in bulk, share farming methods, and aggregate outputs in order to receive better output prices, in addition to meeting regularly for mutual support. Therefore, it seems plausible that many unobservable characteristics are shared by members of the same farmer group. By including a farmer group fixed effect, I am able to control for a portion of the unobserved heterogeneity while still retaining some identifying variation. However, this does restrict the identifying variation substantially for regressions using the inverse travel time. This is measured at a fairly coarse geographic scale, meaning that most farmer groups are all within the same probability grid square or parish. Including farmer group fixed effects when using these geographically coarse measures of land pressures would mean I am identifying off of within-group noise from the few groups that have members in grid cells with different travel times, which could give misleading estimates. Therefore, my preferred specification includes farmer group fixed effects (and clusters standard errors at the farmer group level) for regressions using the standardized rental price as the measure of land pressures (column (2) in results tables 1 - 6) but without the fixed effects for regressions using the inverse travel time or changes in travel time (columns (3) - (4) in tables 1 - 6). In interpreting coefficients on rental price with the farmer group fixed effects, I identify off of within-group differences in land pressures; for other measures, the results are more between-groups or regions. In the appendix, I present results with a more traditional parish fixed effects specification with land values for robustness.

The primary results that I present have land pressures entering linearly, with a constant marginal pressure on either customary or freehold land. This may not be the appropriate specification: it may be that elite incentives to expropriate only begin at intermediate or relatively high land pressures, or alternately that in high land pressure environments, the likelihood of expropriation of customary land has been 'priced in' to investment behavior, meaning the marginal effect of increasing pressure is minimal. In order to explore this, I examine whether the relationship differs on either side of a travel time threshold identified in interviews as being relevant for external land demand from Kampala, 2 hours travel time.[19] I separately estimate the responsiveness of investment to land pressures on customary and freehold land on either side of the threshold.

5.1 Hypotheses

First, I illustrate the hypothesized comparative statics from the model represented in figure 3 and identify which terms would capture them in regressions. Consider the following cross-sectional empirical specification which closely follows the model discussed above:

$$I_i^Q = \gamma_0 + \gamma_1^Q D_i + \gamma_2^Q \bar{v} + \gamma_3^Q D_i * \bar{v} + \beta' X_j + \eta_f + \epsilon_{fi} \tag{1}$$

where I_i^Q is a measure of investment of type Q (either short- or long-term) by household j (a member of farmer group f) on parcel i; D_i is a dummy equal to one if the parcel is customary; $\bar{v}$ is the exogenous component of land price in the locality; X_j is a vector of household characteristics (a probability of poverty index, total household landholdings, and dummies for how the parcel was acquired); and η_f controls for farmer-group fixed effects. This equation would be separately estimated for long and short-term inputs.

The particular hypotheses predicted by the model are derived in the mathematical appendix. Here I summarize proposed tests of the predicted signs of the following in cross-sectional data:

1. $\left.\frac{\partial F}{\partial v}\right|_{h=1}$: That is, how does short-term input use vary with respect to land values on freehold land? The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use more short-term inputs as land values increase. This is tested by examining the sign of γ_2^S.

2. $\left.\frac{\partial T}{\partial v}\right|_{h=1}$: That is, how does long-term input use vary with respect to land values on freehold land? The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use more long-term inputs as land values increase. This is tested by examining the sign of γ_2^L.

3. $\left.\frac{\partial F}{\partial v}\right|_{h=0}$: That is, how does short-term input use vary with respect to land values on customary land? The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use more short-term inputs as land values increase. This is tested by examining the sign of $\gamma_2^S + \gamma_3^S$.

4. $\left.\frac{\partial T}{\partial v}\right|_{h=0}$: That is, how does long-term input use vary with respect to land values on customary land? The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use fewer long-term

[19] Although ideally I would also use the Hansen (2000) threshold estimator to statistically identify the location and existence of the threshold, the ACDP data only comes from 4 districts. This means I do not have a continuous support of most measures of land pressure, making the detection noisy and prone to overfitting. In the appendix, I present these results, but they are more difficult to interpret. However, the detected thresholds are close to the two hour point for all outcomes.

inputs as land values increase. This is tested by examining the sign of $\gamma_2^L + \gamma_3^L$.

with the last of these being the primary innovation of this model. Without considering the changing incentives of local elites, the impact of rising land values on customary land would parallel that on freehold. This stems from the qualitative fact that tree planting behavior is effective at securing tenure within the community, but less so to outside investors who find this demonstration of rights illegible.

5.2 Measuring Tenure Security

In taking stock of the body of empirical evidence on tenure security and investment, several papers have noted the variety of definitions of tenure security as well as proxies used empirically (Arnot et al., 2011; Deininger and Ali, 2008). Common empirical measures include the existence of legal title, duration of tenure, method of acquisition, tenure type, existence of a conflict over the land, subjective perceptions of tenure security, and existence of particular rights (often transfer rights) (Arnot et al., 2011). It is often left implicit how these proxies are related to tenure *security*, which is the parameter modeled. Fenske (2011) notes that the choice of proxy does seem to be related to the effect found, and therefore this is a crucial choice.

My model addresses these concerns by explicitly considering the relationship of the empirically observable tenure type to the fundamental parameter of interest, tenure security. The importance of this consideration is illustrated by the final hypothesis, that customary tenure exists in an institutional context that responds differently to changes in land value, and therefore the relationship between tenure type and security is different in high and low land value areas. Arnot et al. (2011) distinguish between the 'content' and 'assurance' aspects of tenure, and rather than eliding between those, I consider how the two are related.

5.3 Measuring Investment

Another point at which many papers allow their model and empirics to diverge is in the measurement of agricultural investment, the outcome of interest. Because many smallholders operate low-input, even subsistence farms, it is difficult to measure investment well. Therefore, many papers have used binary investment outcomes (Fenske, 2011). I present binary outcomes using a linear probability model in order to allow for farmer group fixed effects (much as Deininger and Ali (2008) do).

However, the ACDP data also allows for continuous measures of investment, although these were measured with some error. Fenske (2011) has argued that measuring investment in a continuous way can make a substantial difference to the results. He argues for the trimmed least absolute deviations estimator to deal with the prevalence of zeroes in types of investment. This is the panel equivalent of the Tobit estimator (Honore, 1992); as I only have a cross-section of data in this paper, I use the Tobit for continuous investment measures; results are in the appendix. Coefficients on a Tobit model are interpreted as in a linear model; however, the linear effect is on the uncensored (non-zero) outcome. Broadly, these results are consistent with those in the binary outcomes case.

5.4 Land Values

Importantly, the model presented above takes land values to be an exogenous force shaping the incentives faced by farmers. This modeling choice was driven by the qualitative literature, which has focused on the breakdown of customary institutions caused by outside pressures, such as the rapid urban expansion in much of Africa or international large-scale land acquisitions. In reality, the value of an individual parcel of land is a product of its particular features, including any investments made. In my results, I present some specifications using standardized land rental values (in the appendix, I also use alternate measures of land prices, including predicted prices for all parcels, median village prices, and non-standardized rental value). These results carry the crucial caveat that land prices are likely a result of land quality, which may change optimal investment behavior through pathways other than those modeled.

Therefore, I also present results where I proxy for the exogenous pressures on land values with the inverse travel time to the national capital or the relative 10-year change in travel times to the capital. These measures should impact agricultural investment through the pathways described in the model: certainly, more (peri-)urban areas have more active credit markets, which would relax the credit constraint faced by the household, and a pool of urban buyers is the canonical situation incentivizing local elites to expropriate customary land. The process of urbanization, though, should not impact agricultural investment through other channels, such as via an increase in total factor productivity.

These measures could potentially be used as an instrument for local land values (as seen above, they are correlated with regional patterns in land values and would therefore be valid); however, I choose to treat them as proxies for the underlying phenomenon of interest, external pressures and demand for land. Rental values for individual parcels are perhaps an even more problematic proxy for the forces modeled, so I focus on these more exogenous measures which should be better-identified. Nevertheless, these results may not be strictly causal; however, they can be understood as descriptive of patterns consistent with a theoretical model. I have constructed all measures of land pressures such that higher values represent greater pressure on land: higher standardized rental prices, larger inverse travel times (equivalent to shorter travel times to Kampala), or greater decreases in travel time over the past 10 years relative to 2005 times.

6 Results

In this section, I present results for a variety of agricultural investments, following the empirical strategy in equation (1). The model predicts that long-term inputs respond to rising land values more strongly on freehold land than on customary land due to the attenuating effect of increased insecurity on customary land induced by elite incentives to expropriate.

Before turning to the regressions with individual agricultural inputs, consider figures 5 - 7. Each of these presents the difference in the coefficients for (binary) input use between freehold and customary parcels as a function of land values in the area (measured by rental values in figure 5, the inverse travel time to Kampala in 6, and the 10-year relative decrease in travel time in 7).[20] For short-term inputs such as pesticides and inorganic fertilizer, the model would predict equivalent responses to rising land pressures on all parcels, which would appear as a flat line on these graphs. As can be seen, however, there is a slight divergence in short-term input use on freehold vs. customary parcels as rental prices or the accessibility to Kampala rise, reflected by a positive (although shallow) slope in these figures for short-term inputs. This result, explored further below, can be explained by a shift toward pesticide-intensive crops near urban markets.[21] As urban markets expand, so does the local demand for cash crops (such as vegetables and fruits which are difficult to transport long distances). Farmers facing this increased demand therefore shift their production away from staples and towards cash crops. This shift is stronger on freehold parcels, perhaps because such parcels remain secure.[22] Cash crops, in turn, may have a higher return to inputs, and particularly to pesticides, than staple crops (Riwthong et al., 2017).

If the model holds, this effect of changing crop choices on long-term inputs should be compounded by the direct impact of additional insecurity on customary land prompted by rising land pressures. In figures 5 - 7, there is a stronger response for trees, the most long-term of the inputs measured, than for short-term inputs, as shown by the steeper slope in the difference in predicted input use. Visually, the insecurity effect can be seen in the difference in slopes between the short- and long-term inputs in these figures.

Figures 5 - 7 also depict the difference in reported insecurity between freehold and customary land. This measure is discussed in further detail below, but note that at low land pressures, parcels under customary

[20] I separately regressed input use on the measure of land pressures for customary and freehold parcels, and then plot the difference in coefficients from each of these regressions. This is in contrast to the regression tables below, where I include all parcels and use interactions to model the relationship between land pressures, tenure type, and input use.

[21] An alternate explanation could be different collateralizability of customary and freehold parcels. Farmers may be less able to internalize rising land values to relax their liquidity constraint on customary parcels. This would be less concerning if farmers held parcels under different tenure systems, due to the fungibility of loans. When I examine household credit usage in my sample, those in areas closer to Kampala are actually slightly less likely to take out loans; the relationship between credit usage and normalized individual rental prices is insignificant. This suggests that collateral is not driving the results for short-term inputs.

[22] It may also be that households with freehold parcels are better placed to take advantage of new markets for cash crops; future work with household fixed effects could eliminate this pathway.

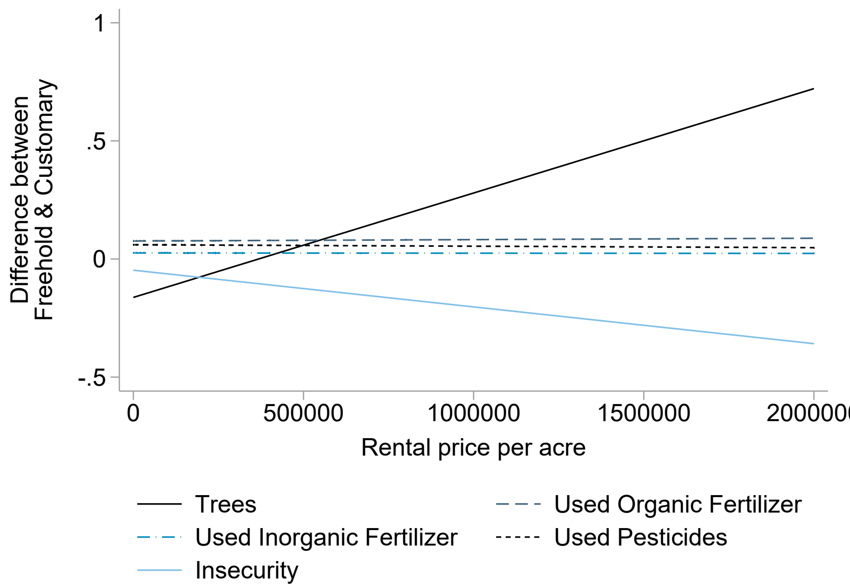

Figure 5: Disparities in tenure types increase with rental values more strongly for long-term than short-term inputs. Customary parcels become relatively more insecure than freehold as rental prices increase.

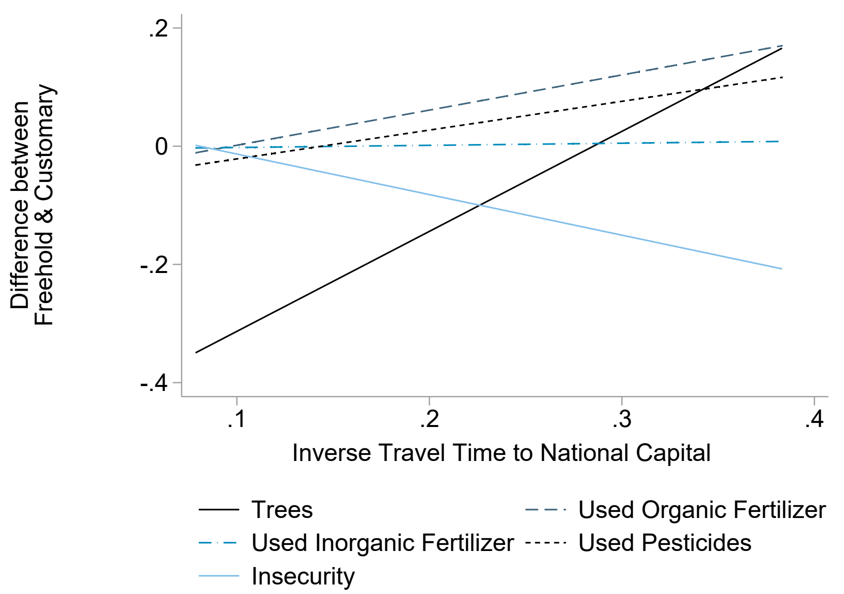

Figure 6: Disparities in tenure types increase with the inverse of travel time to Kampala (and thus demand for land by outsiders who may not understand local customary tenure) more strongly for long-term than short-term inputs.

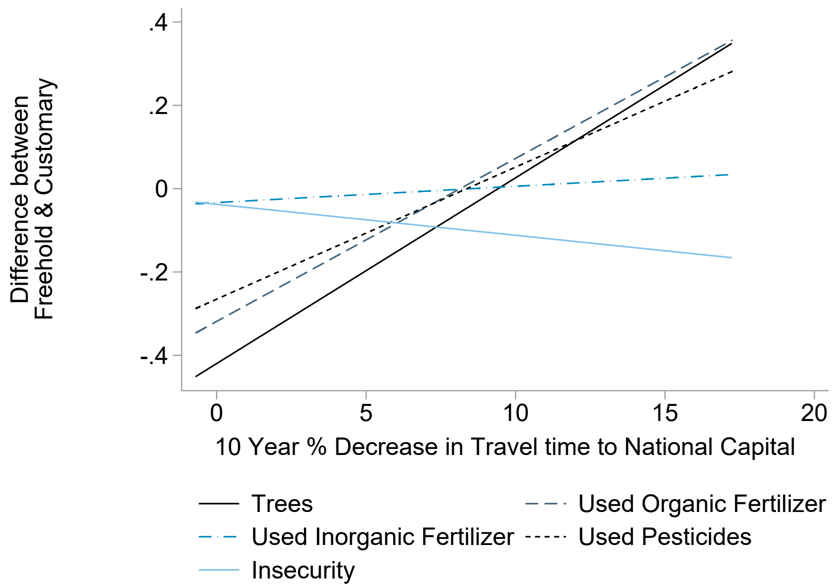

Figure 7: Disparities in tenure types increase with a greater percentage decrease in travel time to Kampala, a measure of increasing demand for land by outsiders, more strongly for longer-term inputs. However, there is a relatively large difference in responses for pesticides.

and freehold tenure are perceived as roughly equivalently secure. As pressures rise, respondents report higher perceived likelihoods of losing their customary parcels without an equivalent rise on freehold parcels.

In each table below, I present several different specifications; additional robustness checks are provided in the appendix. I include three distinct measures of land pressures. First, I use the standardized per-acre rental price in shillings as reported for a given parcel (either actual paid rental price or estimated potential rent if the parcel were rented out, and predicted using similar nearby parcels if the respondent did not report a rental price). As discussed above, this measure is not solely driven by exogenous land market pressures, and it could be capturing unobserved land quality (or even influenced by prior long-term investments in the land).[23] Therefore, I also show results using the inverse travel time to the national capital and 10-year decreases in travel time to Kampala (proportional to 2005 travel time) as proxies for underlying pressures, particularly outsider demand for land. These measures of land values are interacted with a dummy for the tenure status of a parcel, so the coefficient on 'Freehold*Land Value' represents the responsiveness to land values on freehold land, while 'Customary*Land Value' represents the same on customary parcels.[24]

In all regressions shown, I control for household characteristics: the Probability of Poverty Index (PPI)

[23]In the appendix, I show that results are similar when using predicted rental prices for all parcels, predicted using the probability of urbanization, latitude and longitude of the household, tenure status, existence of trees on the parcel, and village fixed effects.

[24]Although conceptually similar to the slopes in figures 5 - 6, they are computed differently, include the addition of controls, and use clustered standard errors.

as well as for a household's total landholdings in acres. The PPI uses low-cost survey indicators to estimate the likelihood that a household has consumption below a given poverty line, and it can be interpreted approximately as a wealth index (with higher values indicating a lower likelihood of poverty) (Schreiner, 2012). Encouragingly, the coefficient on PPI accords with intuition: wealthier farmers are generally more likely to use agricultural inputs, with the exception of trees, which may be more important for their security-enhancing functions for poorer households. I also control for how the parcel was acquired (inherited, purchased, assigned by authorities, loaned, etc), to support the conditional exogeneity of land tenure status. In columns (1) - (3), pooled regressions are run, clustering standard errors at the farmer-group level. In columns (4) - (6), farmer-group fixed effects are added to the clustered model. This final model is the most conservative, but because of relatively low input use and the geographic clustering of farmer groups (restricting the identifying variation particularly for the two spatial measures of land pressures) results are at times insignificant (although patterns are generally consistent with the pooled models presented in earlier columns).

6.1 Tenure Security

Before turning to agricultural inputs used on parcels, recall that exogenous land pressures should influence input decisions through two pathways: increasing inputs by relaxing the liquidity constraint (which should be equally true for all parcels), and increased tenure insecurity (attenuating the liquidity effect, but only under customary tenure). Customary tenure is not necessarily less secure than freehold; rather, it can become less secure if local elites face incentives to expropriate customary land. These incentives, I argue, increase with local land values.

Actual elite expropriation of customary land to sell to outsiders is relatively rare and therefore difficult to detect statistically in random-sample surveys such as this one. However, even if respondents have not personally experienced elite expropriation, they may worry about it, particularly as their community experiences the external pressures that have led to elite expropriation elsewhere. If this pattern holds, I would expect respondents to express greater concern about losing customary parcels as land pressures increase. These land pressures should not affect the perceived security of freehold land to the same extent, as titles provide some legal recourse in case of expropriation.

Table 1 presents regression results using the average perceived insecurity of a parcel as the outcome. That is, for each parcel, respondents were asked first who in the household had rights to that parcel, and what the likelihood was that each rights-holder would involuntarily lose the land (on a scale of 1 to 5, with higher numbers representing a greater chance of losing it). These responses were averaged across all rights-holders to each parcel to measure household-level insecurity about that parcel.

VARIABLES	Average Insecurity (1)	(2)	(3)	(4)
Freehold×Rental Price	0.0292	0.0345*		
	(0.0219)	(0.0187)		
Customary×Rental Price	0.150***	0.146***		
	(0.0316)	(0.0337)		
Freehold×Inverse Travel Time			-0.777*	
			(0.406)	
Customary×Inverse Travel Time			1.174***	
			(0.293)	
Freehold×Decrease in Travel Time				-0.958
				(0.829)
Customary×Decrease in Travel Time				1.561**
				(0.726)
Customary	0.0628	0.0511	-0.447***	-0.177
	(0.0400)	(0.0427)	(0.135)	(0.120)
PPI	0.000173	-0.000769	-0.000578	-0.000323
	(0.00146)	(0.00155)	(0.00149)	(0.00154)
Landholdings	-0.00214**	-0.00196*	-0.00201**	-0.00212**
	(0.000942)	(0.00113)	(0.000899)	(0.000938)
Observations	5,610	5,610	5,537	5,537
R-squared	0.251	0.322	0.252	0.245
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table 1: Tenure insecurity increases on customary land as land pressures rise, as seen in this linear regression of average tenure insecurity across all rightsholders (scale of 1-5) on measures of land pressures.

In table 1, tenure insecurity responds weakly to higher land pressures on freehold land, but demonstrates a statistically significant positive relationship with land pressures on customary land. This implies that customary land becomes more insecure than freehold as land pressures rise. These results suggest that the hypothesized mechanism for agricultural investment (rising insecurity on customary land) does indeed hold in Uganda.

6.2 Tree Planting

Planting trees in Uganda represents a long-term investment in agricultural productivity. In an inter-cropped system, trees provide structure for climbing crops (increasing the productivity of those crops), prevent soil erosion, and produce fruit or coffee themselves (Deininger and Ali, 2008), though their value takes some time to be realized. Therefore, the expected benefits of tree planting are lessened as the risk of expropriation increases, as modeled above.

Trees have a more nuanced relationship with tenure security on customary land. Because trees are such a visible investment in the land, planting trees on a parcel can actually reduce the risk of expropriation, particularly by neighbors who understand the social context of customary tenure. Therefore, it might be expected that in more isolated (low land-pressure areas) where local social dynamics dominate, tree-planting might actually be more valuable on customary land than on freehold. As external land pressures increase and the primary security concern shifts to elite expropriation to sell to outsiders, this security-enhancing effect may not be as strong. Therefore, the model would predict that as external land pressures increase, tree-planting on customary land may increase; on freehold land, tree-planting would increase substantially.

When looking at table 2, this pattern does largely hold. When land pressures are measured using standardized rental prices, there is a small, marginally significant increase in tree-planting on freehold land; when using the inverse travel time or relative decrease in travel time to Kampala to proxy these pressures, freehold land sees more trees as external pressures mount (without farmer-group fixed effects). With all measures, however, the response is attenuated on customary parcels, as predicted by the model.

As a point of interest, note that in figures 5 - 7, tree planting is actually more common on customary plots than freehold at low land values. This stems from the role of trees in establishing tenure in customary systems: trees demonstrate to neighbors effective control and serve as a visible investment in land stewardship, thereby forestalling ‘horizontal’ encroachment. This is less effective when dealing with outsiders to the social system, so the effect reverses as land pressures increase; in this case, trees serve primarily as a long-term investment in the agricultural productivity of the parcel. PPI, our proxy for wealth, actually has a negative relationship with tree-planting; poorer households are more likely to plant trees, perhaps because they serve as a way to signal ownership if other avenues are unavailable to poor households. In contrast, other inputs (particularly those requiring up-front cash purchases such as commercial fertilizers) are more common among wealthier households, in tables 3 - A3.

6.3 Organic Fertilizer Use

Organic fertilizer use both improves agricultural productivity in the season in which it is applied, and can also have medium-term effects by improving soil organic content (Johansen et al., 2015).[25] Indeed, Deininger et al. (2021) follow a long literature in treating organic fertilizer application as a key long-term investment in land productivity in the Sub-Saharan African smallholder context. The model would predict, then, that organic fertilizer use would increase along with land values on freehold land, but the effect will be attenuated on customary land.

[25] Improved soil content can also have complementarities with inorganic fertilizer use, although this is not studied in detail in the current analysis.

	Trees			
VARIABLES	(1)	(2)	(3)	(4)
Freehold×Rental Price	0.0164*	0.0115		
	(0.00940)	(0.0114)		
Customary×Rental Price	-0.0149	-0.0318***		
	(0.0253)	(0.00600)		
Freehold×Inverse Travel Time			1.368***	
			(0.225)	
Customary×Inverse Travel Time			0.605*	
			(0.319)	
Freehold×Decrease in Travel Time				2.015***
				(0.638)
Customary×Decrease in Travel TIme				-1.361*
				(0.701)
Customary	-0.0730**	-0.00681	0.163*	0.264***
	(0.0315)	(0.0272)	(0.0899)	(0.0800)
PPI	-0.00197	0.000389	-0.00454***	-0.00255**
	(0.00123)	(0.000995)	(0.00115)	(0.00115)
Landholdings	-0.00100	-0.00118**	-0.000420	-0.00128*
	(0.000611)	(0.000526)	(0.000526)	(0.000656)
Observations	5,562	5,562	5,483	5,483
R-squared	0.030	0.234	0.062	0.043
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table 2: Linear Probability Model of Tree-planting, a long-term investment, which increases more on freehold land than customary as land pressures increase

	Used Organic Fertilizer			
VARIABLES	(1)	(2)	(3)	(4)
Freehold×Rental Price	0.00192	-0.00140		
	(0.00252)	(0.000962)		
Customary×Rental Price	0.0211***	8.91e-05		
	(0.00780)	(0.00276)		
Freehold×Inverse Travel Time			0.717***	
			(0.138)	
Customary×Inverse Travel Time			0.304***	
			(0.0713)	
Freehold×Decrease in Travel Time				4.040***
				(0.422)
Customary×Decrease in Travel Time				1.239***
				(0.245)
Customary	-0.108***	-0.0291	0.0195	0.210***
	(0.0215)	(0.0186)	(0.0355)	(0.0376)
PPI	0.00542***	0.00142***	0.00421***	0.00170***
	(0.000736)	(0.000470)	(0.000666)	(0.000536)
Landholdings	0.000537	0.000361	0.000936*	0.00104**
	(0.000440)	(0.000311)	(0.000537)	(0.000429)
Observations	5,560	5,560	5,481	5,481
R-squared	0.102	0.286	0.119	0.185
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table 3: Linear Probability Model of organic fertilizer use shows mixed patterns as land pressures increase.

When looking at a binary indicator for the application of organic fertilizer in Table 3, the relationships are somewhat mixed. Organic fertilizer use does seem to respond positively to land pressures on freehold land (especially as measured by travel time; the relationship is less statistically significant for standardized rental prices). On customary land, the relationship with travel-time based measures is qualitatively weaker than for freehold land, although this is not true for rental prices (within-group changes in rental prices in column (2) seem unrelated to organic fertilizer use). Broadly, these results are consistent with the model's predictions for an intermediate-term input that is not immediately visible to potential tenure challengers.

In the appendix, I also use the value of organic fertilizer[26] applied as an outcome, following Fenske (2011)'s suggestion that this is more likely to detect statistically significant relationships with tenure. In these Tobit regressions, results are more sensitive to specification, and the inclusion of farmer group fixed effects makes a large difference.

[26]Standardized from a shilling value; this data is often imputed as many farmers generate and apply their own organic fertilizer including manure outside of the market.

	Used Inorganic Fertilizer			
VARIABLES	(1)	(2)	(3)	(4)
Freehold×Rental Price	0.00440**	0.00529***		
	(0.00215)	(0.00197)		
Customary×Rental Price	0.0186	0.00328		
	(0.0160)	(0.00281)		
Freehold×Inverse Travel Time			0.638***	
			(0.0953)	
Customary×Inverse Travel Time			0.534***	
			(0.0851)	
Freehold×Decrease in Travel Time				1.024***
				(0.286)
Customary×Decrease in Travel Time				0.614**
				(0.236)
Customary	-0.0239	-0.00280	0.0242	0.0299
	(0.0154)	(0.0162)	(0.0272)	(0.0295)
PPI	0.00372***	0.00196***	0.00221***	0.00248***
	(0.000559)	(0.000568)	(0.000531)	(0.000589)
Landholdings	0.000381	0.000588**	0.000905***	0.000660**
	(0.000271)	(0.000267)	(0.000318)	(0.000299)
Observations	5,558	5,558	5,479	5,479
R-squared	0.029	0.126	0.053	0.036
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table 4: Linear Probability Model of inorganic fertilizer, a short-term input, which is slightly more responsive to land pressures on freehold land than customary land.

6.4 Inorganic Fertilizer Use

Inorganic fertilizer, by contrast, largely exhibits short-term returns to agricultural land. The model predicts that for short-term inputs, rising land values will relax the liquidity constraint and thus increase short-term input use equivalently on freehold and customary land. In table 4, inorganic fertilizer use is slightly more common on higher-pressure freehold land than customary land, although the differences are small. However, the differences between customary and freehold parcels are much smaller in magnitude for short-term inputs: compare the estimates from table 3 to those in table 4.

The patterns are slightly more mixed when we look in table A2 at the value of inorganic fertilizer applied for those who do use inorganic fertilizer; application on customary parcels seems more responsive to land pressures particularly as proxied by inverse travel time. This is not inconsistent with the theoretical model's predictions: if long-term input use decreases due to new insecurity, the relaxed liquidity constraint can allow for additional investment in short-term inputs up to their marginal productivity.In figure 3, note that fertilizer investment on freehold land is at A'_F, while fertilizer applied to customary land is higher at $F_C^{*'}$.

	Used Pesticides			
VARIABLES	(1)	(2)	(3)	(4)
Freehold×Rental Price	0.00149	-0.00172		
	(0.00466)	(0.00269)		
Customary×Rental Price	0.0220	-0.0181***		
	(0.0143)	(0.00544)		
Freehold×Inverse Travel Time			0.969***	
			(0.119)	
Customary×Inverse Travel Time			0.547***	
			(0.113)	
Freehold×Decrease in Travel Time				3.215***
				(0.338)
Customary×Decrease in Travel Time				0.651**
				(0.269)
Customary	-0.0751***	-0.0359	0.0599	0.206***
	(0.0250)	(0.0258)	(0.0390)	(0.0399)
PPI	0.00610***	0.00267***	0.00416***	0.00327***
	(0.000683)	(0.000694)	(0.000715)	(0.000681)
Landholdings	0.000637	0.000570	0.00110*	0.000858*
	(0.000521)	(0.000412)	(0.000597)	(0.000443)
Observations	5,556	5,556	5,477	5,477
R-squared	0.064	0.184	0.095	0.105
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table 5: Linear Probability model of the use of pesticides shows a small divergence on freehold and customary parcels, perhaps driven by changing crop patterns.

6.5 Pesticide Use

Pesticides, another short-term input, are generally used as-needed in the Ugandan agricultural sector rather than being applied proactively. The model would predict that use of pesticides responds similarly to land pressures on freehold and customary parcels; however, in table 5 there is a slight pattern on more responsiveness on freehold parcels. This could be driven by changing cropping patterns due to output markets. Cash crops such as vegetables sold to urban markets are particularly vulnerable to pests, so farmers generally use more pesticides on these crops, which in turn are more likely to be planted on freehold land facing urban pressures: many of the primary cash crops grown in Uganda, such as coffee, are perennials which are also subject to long-term expropriation risk. This link between crop choice and land tenure explains the small, significant differences in responses on freehold land apparent in table 5 and the mixed results in table A3 that depend on the particular proxy for land pressures used. These differences are generally smaller than those observed for long-term inputs, as the increasing insecurity on customary land does not impact decisions about pesticide use.

6.6 Crop Choice

In order to understand these slightly surprising results for pesticides and inorganic fertilizer, I examine the primary crops planted on each parcel to determine whether changing cropping patterns may influence input use. In table 6, I present regressions where the outcome of interest is an indicator for at least one plot on the parcel being primarily planted to a high-value cash crop (staple crop production is presented in table A16, and shows the inverse). Overall, cropping patterns do not significantly change on customary parcels as land values increase while cash crops are more common on freehold parcels in higher land-pressure environments. This is unsurprising: nearby urban markets increase demand locally for fragile cash crops such as fruits and vegetables. Farmers are more likely to shift their crop production to meet this demand on freehold parcels. This could be due to the perceived insecurity of customary parcels near urban centers discouraging investment in commercial crops, particularly as many cash crops in Uganda are perennials such as fruit trees or coffee bushes. It also could be that households who own freehold land are more able to take advantage of urban output markets (due to more connections with formal markets, for example, or wealth differences), although the observed effect holds even controlling for a rough measure of household wealth in the PPI. Importantly, the effect of changing crop patterns on input use should be no greater for long-term inputs than short-term ones such as pesticides and inorganic fertilizer (which are more commercial). Therefore, the additional responsiveness of long-term inputs to land pressures on freehold land can be attributed directly to insecurity and is not wholly mediated by crop choice. In the appendix, I also show results for inputs controlling for whether or not any plot on the parcel is primarily devoted to a cash crop. These results show that the effects of insecurity remain for long-term inputs, while those for short-term inputs are reduced.

6.7 Thresholds

In the sections above, I have modeled the relationship between land pressures and agricultural investment as linear on both customary and freehold land. It could be, however, that there are multiple regimes of land pressures where the relationship differs. To explore this empirically, I use a threshold of 2 hours travel time to Kampala; in interviews, this was identified as the distance within which most urban residents are seeking agricultural land, and therefore there should be higher likelihood of elite expropriation of customary land in these areas. I separately run the regressions on either side of the cutoff, to see whether the responsiveness to changes in land pressures differs (regression results in appendix).

It could be that within this 2-hour commute of Kampala, the insecurity stemming from outside pressures has already been 'priced in' to farmers' investment decisions, and therefore investment behavior on customary vs. freehold parcels is relatively unchanging as land pressures increase within this high-pressure environment.

	Planted Cash Crop			
VARIABLES	(1)	(2)	(3)	(4)
Freehold×Rental Price	0.0125**	0.0104***		
	(0.00538)	(0.00366)		
Customary×Rental Price	0.0168	-0.000923		
	(0.0106)	(0.00315)		
Freehold×Inverse Travel Time			0.750***	
			(0.232)	
Customary×Inverse Travel Time			0.327*	
			(0.188)	
Freehold×Decrease in Travel Time				5.452***
				(0.472)
Customary×Decrease in Travel Time				2.551***
				(0.490)
Customary	-0.128***	-0.0156	-0.000478	0.218***
	(0.0224)	(0.0158)	(0.0601)	(0.0531)
PPI	0.00578***	-0.000475	0.00452***	9.75e-05
	(0.00113)	(0.000582)	(0.000992)	(0.000853)
Landholdings	0.00208**	0.000847	0.00224**	0.00268***
	(0.00102)	(0.000860)	(0.00104)	(0.000970)
Observations	5,568	5,568	5,489	5,489
R-squared	0.093	0.386	0.106	0.189
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table 6: Linear probability model for a parcel having at least one plot with a cash crop as the primary crop shows that farmers seem somewhat more likely to plant cash crops on freehold parcels facing higher land pressures.

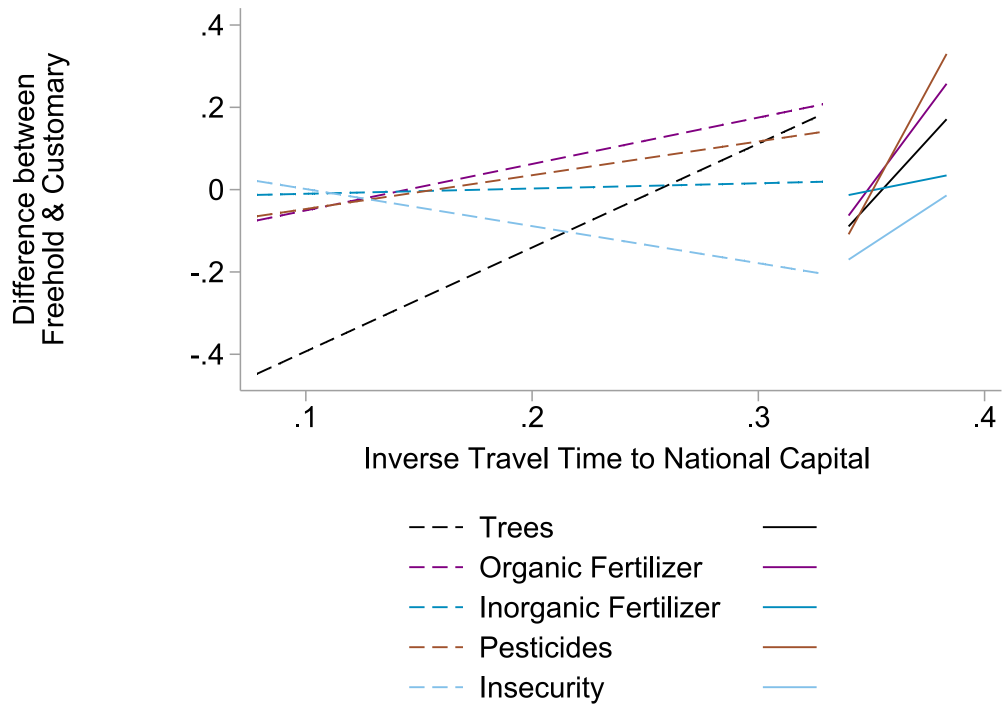

Figure 8: The divergence in input use across customary and freehold parcels is more responsive to land pressures closer to Kampala.

Alternately, in more remote areas, outsider demand for land may not be salient, so customary land is not perceived as any less secure even as land pressures ramp up.

Figure 8 shows, like figures 5 - 7, the difference between freehold and customary parcels as land pressures increase, but models this relationship separately on either side of the two-hour travel time threshold (recall that the inverse travel time measure is $(1 + time_j)^{-1}$, so two hours is located at 1/3 on the x-axis). Interestingly, relative tenure insecurity, which in the previous figures was downwards-sloping (customary parcels became relatively more insecure as land pressures increased) is here upwards-sloping although negative close to Kampala (implying that although customary land is less secure than freehold, the difference narrows closer to Kampala), but downwards-sloping further away. This is in contrast to the various investments, which retain their direction on both sides of the threshold. Perhaps perceptions of tenure insecurity have adapted to external threats close to Kampala. In contrast, investments on customary vs. freehold land diverge more sharply as land pressures increase close to Kampala: note the steeper slopes on the right-hand side of Figure 8, within 2 hours of Kampala. In more remote areas, outsider demand shaping insecurity seems to translate less intensely into patterns of agricultural investment.

This result, in conjunction with the prior linear specifications, has interesting policy implications for where titling may have the greatest benefits. Recall that in general, customary tenure is less secure close to Kampala, where outside demand for land leaves customary parcels vulnerable to elite expropriation. This then leads to an underinvestment in long-term agricultural inputs on customary parcels in these areas. From the threshold analysis, I conclude that investment on customary parcels is more sensitive to land pressures closer to Kampala. Therefore, securing rights to those parcels, such as by titling them and bringing them from the customary realm into freehold, should have larger benefits (such as unlocking agricultural productivity) close to Kampala. This implies that the government should target titling activities in high land pressure environments, such as those easily accessed from Kampala. The net returns to titling are likely even higher here, as the costs of specialized staff such as surveyors are likely lower in more easily accessible areas.

7 Conclusion

In this paper, I developed a theoretical model of short- and long-term agricultural investments on customary and freehold land. This model incorporates how expropriation incentives change as land pressures increase. Local elites, observing outsiders' new demand for land and inability to distinguish between overlapping customary rights, may choose to expropriate land used by non-elites in the community to sell. Even if uncommon in practice, the perception and fear of elite expropriation reduces tenure security on customary tenure parcels. This, in turn, reduces the expected returns to long-term inputs.

The model predicts that long-term input use will diverge between customary and freehold parcels as land pressures increase in an area. Indeed, when I test the model's implications using survey data from four regions of Uganda, I find that long-term inputs (such as trees and organic fertilizer) are used more often on freehold land as land pressures increase, while on customary land this relationship is attenuated by tenure insecurity. Changing cropping patterns due to the proximity of urban markets appears to also influence short-term input use, but the effects on long-term inputs are larger, suggesting an independent effect of tenure security on long-term inputs.

The theoretical model and empirical results together suggest the importance of expanding beyond a simplification of customary tenure as less secure to thinking carefully about the social nature of land rights and the interacting incentives of multiple stakeholders. This insight allows researchers to make more detailed predictions about agricultural investment and may help explain the mixed results in much of the empirical literature. Secure customary tenure may may become less secure as tenure systems intersect. This also suggests targeted policy to document and clarify rights in areas vulnerable to elite expropriation as land pressures mount to protect the rights of the most vulnerable from elites within their communities and without.

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A General Analytical Solution

Consider a two-period model. In the first period, the farmer chooses to apply fertilizer, F_1 and trees, T, to his or her exogenously-given land L under tenure system h. The farmer also has some wealth endowment, but can choose to borrow B_1 against the value of the land (and the tenure system). The farmer faces an exogenous interest rate, r, and has a discount rate of β for second period returns. There is some probability that the farmer's land will be expropriated before the second period, and fixed investments (trees) would be lost then as well. This probability is given by $(1 - \phi(T, h, vL))$ and could be a function of tree investment, tenure systems, as well as the value of the land. After working through the main features of the model, I will consider what different forms of this ϕ function could imply for the farmer's decisions.

The first period problem faced by the farmer is then to:

$$\max_{F_1,T,B_1} p_a f(F_1, T) - p_F F_1 - p_T T - rB_1 + \beta\phi(T, h, vL)\pi_2^*(F_1, T, B_1)$$

$$\text{subject to:} \quad \begin{aligned} p_F F_1 + p_T T &\leq w_1 + B_1 \\ B_1 &\leq s(vL, h) \end{aligned}$$

While in the second period, the farmer only chooses fertilizer (F_2):

$$\max_{F_2} p_a f(F_2, T) - p_F F_2$$

$$\text{subject to:} \quad \begin{aligned} p_F F_2 &\leq w_2 \\ w_2 = w_1 - rB_1 + p_a f(F_1, T) - p_F F_1 &- p_T T \end{aligned}$$

The First Order Conditions of this second stage are:

$$\begin{aligned} \frac{p_a}{p_F}\frac{\partial f}{\partial F_2} - p_F - \lambda_1 p_F &= 0 \\ \lambda_1[p_F F_2 - w_1 + rB_1 - p_a f(F_1, T) + p_F F_1 + p_T T] &= 0 \end{aligned}$$

There are two cases: Either the budget constraint binds in the second stage, or it does not.

A.1 Case A: Unconstrained Second Stage

First consider the case where the budget constraint does not bind in the second stage, $\lambda_1 = 0$

Then F_2^* such that:

$$\frac{\partial f}{\partial F_2} = \frac{p_F}{p_a}$$

Therefore

$$\pi_2^* = p_a f(F_2^*, T) - p_F F_2^*$$

and the derivatives are:

$$\begin{aligned}
\frac{\partial \pi_2^*}{\partial F_1} &= 0 \\
\frac{\partial \pi_2^*}{\partial T} &= p_a \frac{\partial f}{\partial T}\Big|_{F_2^*} \\
\frac{\partial \pi_2^*}{\partial B_1} &= 0
\end{aligned}$$

Turning to the first stage, then:

$$\begin{aligned}
\max_{F_1, T, B_1} p_a f(F_1, T) - p_F F_1 - p_T T - r B_1 + \beta \phi(T, h, vL) \pi_2^*(F_1, T, B_1) \\
\text{subject to } p_F F_1 + p_T T \leq w_1 + B_1 \\
B_1 \leq s(vL, h)
\end{aligned}$$

FOCs are:

$$\begin{aligned}
p_a \frac{\partial f}{\partial F_1} - p_F + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial F_1} - \lambda_2 p_F = 0 \\
p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T = 0 \\
-r + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial B_1} + \lambda_2 - \lambda_3 = 0 \\
\lambda_2 (p_F F_1 + p_T T - w_1 - B_1) = 0 \\
\lambda_3 (B_1 - s(vL, h)) = 0
\end{aligned}$$

Which simplify to:

$$
\begin{aligned}
p_a \frac{\partial f}{\partial F_1} - p_F - \lambda_2 p_F &= 0 \\
p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T &= 0 \\
-r + \lambda_2 - \lambda_3 &= 0 \\
\lambda_2 (p_F F_1 + p_T T - w_1 - B_1) &= 0 \\
\lambda_3 (B_1 - s(vL, h)) &= 0
\end{aligned}
$$

A.1.1 Case 1A: Totally Unconstrained

As a benchmark, consider a farmer who has a sufficient initial endowment of wealth w_1 that neither the borrowing nor the budget constraint bind ($\lambda_1 = \lambda_2 = \lambda_3 = 0$

The FOCs are then:

$$
\begin{aligned}
p_a \frac{\partial f}{\partial F_1} - p_F &= 0 \\
p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) p_a \frac{\partial f}{\partial T}\Big|_{F_2^*} &= 0
\end{aligned}
$$

This then gives us:

$$
\frac{\partial f}{\partial F_1} = \frac{p_F}{p_a}
$$

Therefore, in the totally unconstrained case, $F_1^* = F_2^*$. Furthermore, if I assume that under freehold tenure, $\phi = 1$ and $\frac{\partial \phi}{\partial T} = 0$ (tenure is perfectly secure and planting trees has no effect on tenure security), then

$$
\frac{\partial f}{\partial T}\Big|_{h=1} = \frac{p_T}{p_a} \frac{1}{(1+\beta)}
$$

However, if $\phi < 1$, such as is possible under customary tenure, then the marginal productivity of trees in equilibrium would be higher, and therefore investment in trees would be lower. This effect would be attenuated by $\frac{\partial \phi}{\partial T} > 0$, as would be the case if planting trees helped secure tenure.

This is only a benchmark case, as our real interest is in the liquidity-constrained farmer (where the borrowing constraint, and therefore the budget constraint, bind). However, it demonstrates that our model accords with most theoretical models of tenure and long-term investments.

A.1.2 Case 2A: Binding Budget Constraint

Now consider a world in which the farmer is not constrained in their ability to borrow, but they do exhaust their budget constraint ($\lambda_1 = \lambda_3 = 0$; $\lambda_2 \neq 0$)

The FOCs in this case are:

$$\begin{aligned} p_a \frac{\partial f}{\partial F_1} - p_F - \lambda_2 p_F &= 0 \\ p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T &= 0 \\ -r + \lambda_2 &= 0 \\ p_F F_1 + p_T T - w_1 - B_1 &= 0 \end{aligned}$$

I now have fertilizer use in the first stage determined by setting the marginal product not equal to the relative price, as in the totally unconstrained case, but instead to a (higher) shadow price determined by the interest rate, and thus lower than optimal fertilizer usage.

$$\frac{\partial f}{\partial F_1} = \frac{p_F}{p_a}(1 + r)$$

Similarly, in the freehold case, where tree planting has no effect on (full) tenure security,

$$\left.\frac{\partial f}{\partial T}\right|_{h=1} = \frac{p_T}{p_a} \frac{(1 + r)}{(1 + \beta)}$$

Which mirrors the unconstrained case, but has the marginal product of trees (discounted across both periods) equal to a shadow price which is higher than the true price and thus tree planting will be lower than in 1A. Furthermore, as in 1A, if tenure security was incomplete ($\phi < 1$), but unresponsive to tree planting, the condition would be:

$$\frac{\partial f}{\partial T}\Big|_{h=0} = \frac{p_T}{p_a}\frac{(1+r)}{(1+\beta\phi)} > \frac{p_T}{p_a}\frac{(1+r)}{(1+\beta)} = \frac{\partial f}{\partial T}\Big|_{h=1}$$

Therefore, the marginal productivity of trees is higher under customary tenure and thus under normal assumptions of diminishing marginal returns, the level of investment in trees is lower on customary land than freehold. If $\frac{\partial \phi}{\partial T} > 0$, that would attenuate this result somewhat (as the marginal product of trees in equilibrium would be reduced by the (positive) term $\beta \frac{\partial \phi}{\partial T}\pi_2^*$), for reasonable parameter values the net effect would be similar to that found empirically: that investment in trees on customary land is no higher than on freehold.

A.1.3 Case 3A: Binding Borrowing Constraint

This case will never occur, as the farmer would not exhaust the (costly) borrowing option if wealth was high enough for the budget constraint not to bind.

A.1.4 Case 4A: Both Constraints Binding

Finally, consider a liquidity-constrained farmer who faces both a binding borrowing and budget constraint: $\lambda_1 = 0, \lambda_2 \neq 0, \lambda_3 \neq 0$

This is the case depicted in Figures 1-3, so I will devote particular attention to it.

Working with the constraints, the FOCs are:

$$\begin{aligned}
p_a \frac{\partial f}{\partial F_1} - p_F - \lambda_2 p_F &= 0 \\
p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T}\pi_2^* + \beta\phi(T, h, vL)\frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T &= 0 \\
-r + \lambda_2 - \lambda_3 &= 0 \\
p_F F_1 + p_T T - w_1 - s(vL, h) &= 0 \\
B_1 &= s(vL, h)
\end{aligned}$$

First, consider the freehold case ($\phi = 1$). Then the equilibrium condition is:

$$\frac{\partial f}{\partial T}\Big|_{F_1^*} + \beta \frac{\partial f}{\partial T}\Big|_{F_2^*} = \frac{p_T}{p_F}\frac{\partial f}{\partial F_1}$$

Despite not being able to solve this explicitly for F_1 and T, I can use the implicit function theorem to see how input choices respond to the parameters of interest. The Jacobian for choice variables is the following:

$$D_x = \begin{bmatrix} \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} & \frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1^*} \\ p_F & p_T \end{bmatrix}$$

and its inverse is:

$$D_x^{-1} = \frac{1}{|D_x|}\begin{bmatrix} p_T & -\frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*} + \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1^*} \\ -p_F & \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} \end{bmatrix}$$

Where the determinant, $|D_X|$, is given by:

$$\begin{aligned} |D_x| &= (\frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2})p_T - (\frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1^*})p_F \\ &= \left(2p_T \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta p_T \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T^2}{p_F}\frac{\partial^2 f}{\partial F_1^2} - p_F \frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta p_F \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*}\right) \end{aligned}$$

or equivalently,

$$D_x^{-1} = \frac{1}{|D_x|}\begin{bmatrix} p_T & -\frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*} + \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1^*} \\ -p_F & \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} \end{bmatrix}$$

And for the parameters (v is the primary parameter of interest for the empirical hypotheses):

$$D_q = \begin{bmatrix} 0 \\ -\frac{\partial s}{\partial v L} L \end{bmatrix}$$

The product is therefore:

$$\frac{-1}{\left(2p_T \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta p_T \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T^2}{p_F}\frac{\partial^2 f}{\partial F_1^2} - p_F \frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta p_F \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*}\right)} \begin{bmatrix} (-\frac{\partial s}{\partial v L} L)[-\frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*} + \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1^*}] \\ (-\frac{\partial s}{\partial v L} L)[\frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2}] \end{bmatrix}$$

In order to sign these, I need to specify reasonable assumptions about signs. First, many inter-cropping systems such as are commonly used in Uganda mean that the cross-partials are positive: $\frac{\partial^2 f}{\partial F \partial T} > 0$. Prices are all positive, as is β. The borrowing constraint is increasing in the value of land used as collateral, so

$\frac{\partial s}{\partial vL} > 0$. Finally, diminishing marginal returns implies that $\frac{\partial^2 f}{\partial i^2} < 0$, for $i \in F, T$.

These assumptions allow me to sign the matrix: the determinant is negative (therefore the fraction is positive), and both terms inside the matrix are positive. Therefore I can say that $\frac{\partial F_1}{\partial v} > 0$ and $\frac{\partial T}{\partial v} > 0$: both optimal fertilizer and tree investment are increasing in the value of land if the freeholder farmer is liquidity constrained. This allows me to make hypotheses (3) and (4).

$$\frac{1}{\left(2p_T \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta p_T \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T^2}{p_F}\frac{\partial^2 f}{\partial F_1^2} - p_F \frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta p_F \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*}\right)} \begin{bmatrix} \left(\frac{\partial s}{\partial vL} L\right)\left[-\frac{\partial^2 f}{\partial T^2}\Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2}\Big|_{F_2^*} + \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1^*}\right] \\ \left(\frac{\partial s}{\partial vL} L\right)\left[\frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2}\right] \end{bmatrix}$$

If I instead consider customary tenure, the equilibrium condition is:

$$p_a \frac{\partial f}{\partial T}\Big|_{F_1^*} + \beta \frac{\partial \phi}{\partial T}(p_a f(F_2^*, T) - p_F F_2^*) + \beta \phi p_a \frac{\partial f}{\partial T}\Big|_{F_2^*} = \frac{p_T p_a}{p_F}\frac{\partial f}{\partial F_1}$$

Which can also be written as:

$$\frac{\partial f}{\partial T}\Big|_{F_1^*} + \beta \frac{\partial \phi}{\partial T}(f(F_2^*, T) - \frac{p_F}{p_a} F_2^*) + \beta \phi \frac{\partial f}{\partial T}\Big|_{F_2^*} = \frac{p_T}{p_F}\frac{\partial f}{\partial F_1}$$

I can again use the implicit function theorem on this condition, along with the budget constraint. The Jacobian for choice variables is:

$$\begin{bmatrix} \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} & \frac{\partial^2 f}{\partial T^2}\Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2}\left[f(F_2^*, T) - \frac{p_F}{p_a}F_2^*\right] + 2\beta \frac{\partial \phi}{\partial T}\frac{\partial f}{\partial T}\Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2}\Big|_{F_2} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1} \\ p_F & p_T \end{bmatrix}$$

Which I invert:

$$D_x^- 1 = \frac{1}{|D_x|}\begin{bmatrix} p_T & -\left[\frac{\partial^2 f}{\partial T^2}\Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2}\left[f(F_2^*, T) - \frac{p_F}{p_a}F_2^*\right] + 2\beta \frac{\partial \phi}{\partial T}\frac{\partial f}{\partial T}\Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2}\Big|_{F_2} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1}\right] \\ -p_F & \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} \end{bmatrix}$$

Where $|D_x|$ is the determinant,

$$|D_x| = \left[\frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta\phi \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} \right] p_T$$
$$- \left[\frac{\partial^2 f}{\partial T^2}\Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2} \left[f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + 2\beta \frac{\partial \phi}{\partial T}\frac{\partial f}{\partial T}\Big|_{F_2} + \beta\phi \frac{\partial^2 f}{\partial T^2}\Big|_{F_2} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1} \right] p_F$$

The Jacobian with respect to land values is:

$$D_q = \begin{bmatrix} \beta \frac{\partial^2 \phi}{\partial T \partial v} \left[f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + \beta \frac{\partial \phi}{\partial v}\frac{\partial f}{\partial T}\Big|_{F_2} \\ -\frac{\partial s}{\partial v L} L \end{bmatrix}$$

The product is therefore:

$$\frac{-1}{|D_x|} \begin{bmatrix} p_T \left[\beta \frac{\partial^2 \phi}{\partial T \partial v} \left[f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + \beta \frac{\partial \phi}{\partial v}\frac{\partial f}{\partial T}\Big|_{F_2} \right] + \left[\frac{\partial^2 f}{\partial T^2}\Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2} \left[f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + 2\beta \frac{\partial \phi}{\partial T}\frac{\partial f}{\partial T}\Big|_{F_2} + \beta\phi \frac{\partial^2 f}{\partial T^2}\Big|_{F_2} - \frac{p_T}{p_F}\frac{\partial}{\partial F} \\ -p_F \left[\beta \frac{\partial^2 \phi}{\partial T \partial v} \left[f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + \beta \frac{\partial \phi}{\partial v}\frac{\partial f}{\partial T}\Big|_{F_2} \right] - \left[\frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta\phi \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} \right] \frac{\partial s}{\partial v L} L \end{bmatrix}$$

It is convenient to make a few further minor assumptions:

- $\frac{\partial^2 \phi}{\partial T \partial v} = 0$ Without substantial loss of generality, assume the risk of elite expropriation (which responds to land values) is unrelated to the risk of neighbor expropriation (which responds to trees), so the cross-partial of ϕ is zero.
- $\frac{\partial \phi}{\partial v} < 0$: tenure security is decreasing in land values as risk of elite expropriation increases, the fundamental new insight of this model
- $\frac{\partial^2 \phi}{\partial T^2} = 0$ For the current purposes, assume the risk of expropriation by neighbors is a linear function of tree investment, or a close enough approximation.

This matrix product then simplifies to:

$$\frac{-1}{|D_x|} \begin{bmatrix} \beta \frac{\partial \phi}{\partial v}\frac{\partial f}{\partial T}\Big|_{F_2} + \left[\frac{\partial^2 f}{\partial T^2}\Big|_{F_1} + 2\beta \frac{\partial \phi}{\partial T}\frac{\partial f}{\partial T}\Big|_{F_2} + \beta\phi \frac{\partial^2 f}{\partial T^2}\Big|_{F_2} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1 \partial T}\Big|_{F_1} \right] \frac{\partial s}{\partial v L} L \\ -p_F \left[\beta \frac{\partial \phi}{\partial v}\frac{\partial f}{\partial T}\Big|_{F_2} \right] - \left[\frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_1^*} + \beta\phi \frac{\partial^2 f}{\partial T \partial F_1}\Big|_{F_2^*} - \frac{p_T}{p_F}\frac{\partial^2 f}{\partial F_1^2} \right] \frac{\partial s}{\partial v L} L \end{bmatrix}$$

The top component of the matrix is then positive under reasonable parameter values (the determinant is also generally positive). This implies that, as in Hypothesis (5), a liquidity-constrained farmer on customary land will increase fertilizer application as land values increase and the liquidity constraint relaxes.

The sign of the second term, however, depends on the relative magnitudes of the different mechanisms. If tenure insecurity responds drastically enough to rising land values (captured by the term $\frac{\partial \phi}{\partial v}$) to counteract the increasing ability to invest given by the second term, then net investment in trees will actually decrease. This is noted in Hypothesis (6).

Finally, comparing the equilibria conditions for customary and freehold tenure allows me to show that the marginal productivity of tree investment will be higher in the customary case, meaning that liquidity-constrained farmers plant fewer trees on customary land than on freehold. This also means, because the budget constraint binds, that they invest more in fertilizer. This speaks to hypotheses (1) and (2).

A.2 Case B: Constrained Second Stage

A detailed solution to Case B, where the budget constraint binds in the second period, does not add substantively to the understanding and so is omitted here.

B Continuous Measures of Input Use

Fenske (2011), in his quantitative review of existing evidence on tenure and agricultural investment in West Africa, finds that using binary measures of investment limits identifying variation and makes it more likely to find insignificant results. Above, I do find statistically significant relationships between tenure and binary investment outcomes, particularly when I explicitly consider the land pressure environment. Nevertheless, the ACDP survey's detailed agricultural production module allows me to construct continuous measures of long- and short-term investment: the value of fertilizer or pesticides applied. Unfortunately, I cannot construct a similar measure for the most long-term of my inputs, tree planting.

Due to the relatively rare use of agricultural inputs, I adapt Fenske (2011)'s suggestion to use the trimmed LAD estimator to my cross-sectional data and use Tobit estimation. These results can be interpreted as in a linear model, although the linear effect represented by the coefficient is the slope on the uncensored (non-zero) outcome. Tables A1 - A3 are generally consistent with the binary outcome results presented in the main text, with a greater divergence between customary and freehold parcels on longer-term inputs (organic fertilizer) than short-term inputs. However, I do not prioritize these results due to the lack of precision in reported valuations of inputs, which in the ACDP survey do not accord with those from other sources in Uganda.

VARIABLES	(1)	(2)	(3)	(4)
	Value Organic Fertilizer Used			
Freehold×Rental Price	0.124	-0.0248***		
	(0.104)	(0.00600)		
Customary×Rental Price	0.616	-17.15***		
	(0.377)	(0.499)		
Freehold×Decrease in Travel Time			15.93*	
			(9.139)	
Customary×Decrease in Travel Time			7.025	
			(5.647)	
Freehold×Decrease in Travel Time				64.17*
				(33.49)
Customary×Decrease in Travel Time				45.26
				(29.62)
Customary	-1.866***	-0.480***	0.941	1.158
	(0.644)	(0.114)	(1.656)	(1.398)
PPI	0.195**	0.120***	0.171**	0.131**
	(0.0945)	(0.00226)	(0.0828)	(0.0644)
Landholdings	0.0227	0.0510***	0.0314	0.0370
	(0.0184)	(0.00767)	(0.0209)	(0.0250)
Observations	5,565	5,565	5,486	5,486
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A1: Tobit results show a more negative relationship between land pressures and the value of organic fertilizer applied on customary parcels than freehold

	(1)	(2)	(3)	(4)
VARIABLES		Value Inorganic Fertilizer		
Freehold×Rental Price	0.0941**	0.0945***		
	(0.0452)	(0.00252)		
Customary×Rental Price	0.362	1.544***		
	(0.313)	(0.257)		
Freehold×Inverse Travel Time			2.429***	
			(0.800)	
Customary×Inverse Travel Time			2.662***	
			(0.886)	
Freehold×Decrease in Travel Time				1.766
				(1.332)
Customary×Decrease in Travel Time				2.453*
				(1.271)
Customary	-0.226	-0.211***	-0.0654	-0.0829
	(0.448)	(0.0590)	(0.192)	(0.163)
PPI	0.0877*	0.0773***	0.00759**	0.0100***
	(0.0471)	(0.00181)	(0.00337)	(0.00387)
Landholdings	-0.0349	-0.00747	-0.000296	-0.00258
	(0.0288)	(0.00479)	(0.00302)	(0.00367)
Observations	5,565	5,565	5,486	5,486
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A2: The value of inorganic fertilizer among those who use it (from Tobit estimation) is more responsive to land pressures on customary land.

VARIABLES	(1)	(2)	(3)	(4)
	Value Pesticides			
Freehold×Rental Price	0.127	0.0915***		
	(0.137)	(0.00187)		
Customary×Rental Price	0.367***	-0.355***		
	(0.113)	(0.0152)		
Freehold×Inverse Travel Time			10.72**	
			(4.916)	
Customary×Inverse Travel Time			15.01**	
			(7.649)	
Freehold×Decrease in Travel Time				34.81***
				(13.35)
Customary×Decrease in Travel Time				16.71**
				(7.716)
Customary	-1.150***	-0.580***	-2.168	1.257
	(0.383)	(0.0772)	(1.532)	(1.029)
PPI	0.0878***	0.0535***	0.0615***	0.0491**
	(0.0279)	(0.000950)	(0.0222)	(0.0192)
Landholdings	-0.00363	-0.0133***	0.00655	-0.00573
	(0.0129)	(0.00386)	(0.0114)	(0.0166)
Observations	5,565	5,565	5,486	5,486
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A3: Tobit estimation of the value of pesticides used for those who did apply pesticides display mixed results which are more sensitive to the measure of land pressures used.

C Probability of Urbanization

As an alternate proxy for the external pressures on land that I model, I considered using data from the Global Grid of Probabilities of Urban Expansion to 2030 (Seto et al., 2012, 2016). For each 2.5 arc-minute[27] grid cell that was non-urban in 2000, the data include an estimated probability of becoming urban by the year 2030, forecast using a population density driver map. This map is primarily driven by patterns of urbanization, and thus is reasonably exogenous to local agricultural patterns of land values; instead, it isolates the dimension of land values that will also create pressure on local elites to expropriate and sell customary land to outsiders.

However, this data is remarkably bimodal in Uganda, with sparse support of values of the probability of urbanization in the four districts where the baseline study occurred. Thirty-eight percent of parcels fall in a grid cell with a 100% probability of urbanization; another 19% have a 99% probability. There is another grouping at very low levels of predicted urbanization, including the entire northern district of Amuru which has a probability of zero, and then only a few parcels are assigned a probability between .5 and .8. This makes the probability of urbanization not my preferred proxy, but I present regression results with this measure in tables A4 and A5.

I match households to a grid cell using GPS locations collected during the survey (taken at the household residence, not at agricultural fields which could be at some remove). This measure is correlated with the per-acre rental values households reported for their land; the correlation is low across the whole sample (.0450), but when I winsorize several outliers in estimated rental price (among those who own their land and are estimating how much they could rent it out for), this correlation increases to .1492. When I look instead at the median rental price in a given district, the correlation with the probability of urbanization jumps to .6556,[28] implying (as expected) that this measure is more closely related to broader trends than individual parcel values which may be influenced by soil quality or other agricultural value considerations. Results in table A4 for binary outcomes and A5 for continuous Tobit estimation are relatively consistent with those obtained using either normalized rental values, inverse travel time to Kampala, or the 10-year reduction in travel times, as shown above.

[27] 2.5 arc-minutes contain approximately 5km at the equator, which Uganda spans

[28] Similarly, the correlation with median village rental prices is .6697.

VARIABLES	(1) Trees	(2) Used Organic	(3) Used Inorganic	(4) Used Pesticides	(5) Insecurity
Freehold×Urbanizataion	0.200***	0.0962***	0.0488**	0.112***	-0.0261
	(0.0464)	(0.0333)	(0.0226)	(0.0335)	(0.0684)
Customary×Urbanization	0.0444	0.0148	0.0345	0.0323	0.0974
	(0.0670)	(0.0189)	(0.0213)	(0.0242)	(0.0655)
Customary	0.0660	-0.0360	-0.00581	-0.00454	-0.0239
	(0.0556)	(0.0295)	(0.0202)	(0.0327)	(0.0881)
PPI	-0.00292**	0.00514***	0.00330***	0.00556***	-0.000298
	(0.00123)	(0.000735)	(0.000616)	(0.000722)	(0.00148)
Landholdings	-0.000705	0.000770	0.000596*	0.000805	-0.00228**
	(0.000563)	(0.000511)	(0.000308)	(0.000550)	(0.00102)
Observations	5,523	5,521	5,519	5,517	5,578
R-squared	0.044	0.106	0.030	0.071	0.244
Fixed Effect	None	None	None	None	None
Cluster	Group	Group	Group	Group	Group

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

Table A4: Linear Probability Model for different investments, using the probability of urbanization as a proxy for land pressures. Results are similar to those found with alternate measures.

VARIABLES	(1) Value Organic	(2) Value Inorganic	(3) Value Pesticides
Freehold×Urbanization	2.885	0.123	0.904*
	(1.769)	(0.123)	(0.498)
Customary×Urbanization	0.760	0.393***	-0.193
	(1.366)	(0.152)	(0.843)
Customary	0.104	-0.251	-0.203
	(1.155)	(0.157)	(0.668)
PPI	0.185**	0.0109**	0.0827***
	(0.0891)	(0.00433)	(0.0313)
Landholdings	0.0296	-0.00186	-0.00396
	(0.0212)	(0.00345)	(0.0142)
Observations	5,526	5,526	5,526
Fixed Effect	None	None	None
Cluster	Group	Group	Group

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

Table A5: Tobit results using the probability of urbanization as a proxy for land pressures are similar to those found with alternate measures.

D Robustness Checks

D.1 Predicted Rental Prices

Given that parcel rental prices may be endogenous to soil quality or past agricultural investment, I also explore alternate measures of land values. First, I predict per-acre rental prices using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. This should strip away noise in the estimated rental prices, and follows the intuition of a hedonic model for land values. Second, I use the median per-acre rental price in a village, to eliminate parcel-level heterogeneity in rental values. Finally, I use a non-standardized version of per-acre rental prices, which exhibits considerable skewness, but can be interpreted as the shilling value.

	(1)	(2)	(3)	(4)	(5)
VARIABLES			Average Insecurity		
Freehold×Predicted Price	2.54e-07**	3.50e-07*			
	(1.10e-07)	(1.79e-07)			
Customary×Predicted Price	4.11e-07*	5.88e-07**			
	(2.13e-07)	(2.97e-07)			
Freehold×Village Price			-2.13e-06***		
			(8.13e-07)		
Customary×Village Price			2.19e-06***		
			(5.04e-07)		
Freehold×Rental Price (UGX)				5.61e-08	6.63e-08*
				(4.21e-08)	(3.59e-08)
Customary×Rental Price (UGX)				2.89e-07***	2.81e-07***
				(6.06e-08)	(6.46e-08)
Customary	0.0227	-0.0232	-0.715***	0.0171	0.00884
	(0.0635)	(0.0711)	(0.176)	(0.0435)	(0.0463)
PPI	-0.000501	-0.000479	-0.000756	0.000173	-0.000769
	(0.00149)	(0.00153)	(0.00150)	(0.00146)	(0.00155)
Landholdings	-0.00225**	-0.00211*	-0.00224**	-0.00214**	-0.00196*
	(0.00102)	(0.00118)	(0.000951)	(0.000942)	(0.00113)
Observations	5,628	5,628	5,635	5,610	5,610
R-squared	0.245	0.316	0.253	0.251	0.322
Fixed Effect	None	Group	None	None	Group
Cluster	Group	Group	Group	Group	Group

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

Table A6: Linear regression of average tenure insecurity (across all rightsholders) on alternate measures of parcel rental values.

VARIABLES	(1)	(2)	(3) Trees	(4)	(5)
Freehold×Predicted Price	3.29e-07**	4.24e-07**			
	(1.59e-07)	(1.98e-07)			
Customary×Predicted Price	-1.21e-07	5.63e-08			
	(1.37e-07)	(1.67e-07)			
Freehold×Village Price			3.33e-06***		
			(3.96e-07)		
Customary×Village Price			1.36e-06**		
			(5.64e-07)		
Freehold×Rental Price (UGX)				3.15e-08*	2.20e-08
				(1.80e-08)	(2.19e-08)
Customary×Rental Price (UGX)				-2.87e-08	-6.11e-08***
				(4.85e-08)	(1.15e-08)
Customary	0.0354	0.0723*	0.330***	-0.0612*	0.00955
	(0.0552)	(0.0410)	(0.112)	(0.0347)	(0.0281)
PPI	-0.00218*	0.000445	-0.00439***	-0.00197	0.000389
	(0.00120)	(0.000984)	(0.00112)	(0.00123)	(0.000995)
Landholdings	-0.000932	-0.00106*	5.00e-05	-0.00100	-0.00118**
	(0.000593)	(0.000539)	(0.000516)	(0.000611)	(0.000526)
Observations	5,576	5,576	5,587	5,562	5,562
R-squared	0.038	0.243	0.078	0.030	0.234
Fixed Effect	None	Group	None	None	Group
Cluster	Group	Group	Group	Group	Group

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

Table A7: Linear Probability Model regression of tree planting on parcel on alternate measures of parcel rental values.

D.2 Parish Fixed Effects

My preferred specification makes use of the farmer group recruitment structure of the ACDP data to account for unobserved heterogeneity in farmer quality, which is likely to be shared among comembers of a self-selected farmer group. However, here I also present regressions using the more traditional administrative unit (parish in this case, given inconsistent identification of villages in the data) clustered standard errors and fixed effects. Results are consistent with those presented in the body of the paper.

D.3 Crop Change

One notable divergence between the model and empirical results is the patterns of short-term input use increasing somewhat as land pressures increase, which I argued is likely due to changing in cropping patterns. In particular, many cash crops in Uganda are perennials, meaning that the likelihood of expropriation also affects the returns from these crops; at the same time, many cash crops require higher input use (pesticides in particular) in order to receive a market premium. However, I argue that the divergence in long-term

	(1)	(2)	(3)	(4)	(5)
VARIABLES			Used Organic Fertilizer		
Freehold×Predicted Price	2.04e-07**	1.26e-08			
	(9.86e-08)	(8.67e-08)			
Customary×Predicted Price	1.50e-07**	-3.48e-08			
	(5.95e-08)	(9.47e-08)			
Freehold×Village Price			1.29e-06***		
			(2.12e-07)		
Customary×Village Price			4.73e-07***		
			(1.28e-07)		
Freehold×Rental Price (UGX)				3.68e-09	-2.70e-09
				(4.84e-09)	(1.85e-09)
Customary×Rental Price (UGX)				4.06e-08***	1.71e-10
				(1.50e-08)	(5.30e-09)
Customary	-0.0971***	-0.0176	0.0561	-0.115***	-0.0297
	(0.0339)	(0.0260)	(0.0391)	(0.0220)	(0.0188)
PPI	0.00518***	0.00142***	0.00461***	0.00542***	0.00142***
	(0.000738)	(0.000475)	(0.000724)	(0.000736)	(0.000470)
Landholdings	0.000778	0.000432	0.00101*	0.000537	0.000361
	(0.000511)	(0.000337)	(0.000568)	(0.000440)	(0.000311)
Observations	5,574	5,574	5,585	5,560	5,560
R-squared	0.109	0.286	0.116	0.102	0.286
Fixed Effect	None	Group	None	None	Group
Cluster	Group	Group	Group	Group	Group

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

Table A8: Linear Probability Model regression of organic fertilizer use on parcel on alternate measures of parcel rental values.

input use between customary and freehold parcels as land pressures increase is not due entirely to changing cropping patterns; there is an additional tenure security effect. Therefore, I ran additional regressions (below), controlling for a dummy for if there is a cash crop as the primary crop on any of the plots on a given parcel.

Unsurprisingly, more inputs (except for inorganic fertilizer) are used on parcels that contain cash crops. Interestingly, cash crops are not correlated significantly with average insecurity on the parcel, however, and the general patterns of input responsiveness to land pressures remain.

D.4 Splitting Sample

The relationship between land pressures and input use on customary vs. freehold land may not be linear, as modeled in my primary specifications. Therefore, I also look at binary splits in the various land pressure measures, and compare outcomes on customary vs. freehold parcels in low vs. high land pressure environments using interactions.

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Used Inorganic Fertilizer				
Freehold×Predicted Price	-1.55e-08	-1.62e-08			
	(4.84e-08)	(7.20e-08)			
Customary×Predicted Price	2.58e-08	-3.78e-08			
	(5.88e-08)	(7.15e-08)			
Freehold×Village Price			1.27e-06***		
			(1.29e-07)		
Customary×Village Price			8.95e-07***		
			(1.52e-07)		
Freehold×Rental Price (UGX)				8.46e-09**	1.02e-08***
				(4.13e-09)	(3.78e-09)
Customary×Rental Price (UGX)				3.57e-08	6.30e-09
				(3.08e-08)	(5.40e-09)
Customary	-0.0358*	0.00241	0.0641**	-0.0293*	-0.00204
	(0.0198)	(0.0207)	(0.0273)	(0.0160)	(0.0163)
PPI	0.00375***	0.00192***	0.00256***	0.00372***	0.00196***
	(0.000566)	(0.000564)	(0.000576)	(0.000559)	(0.000568)
Landholdings	0.000491	0.000690**	0.00101***	0.000381	0.000588**
	(0.000305)	(0.000314)	(0.000337)	(0.000271)	(0.000267)
Observations	5,572	5,572	5,583	5,558	5,558
R-squared	0.029	0.125	0.052	0.029	0.126
Fixed Effect	None	Group	None	None	Group
Cluster	Group	Group	Group	Group	Group

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

Table A9: Linear Probability Model regression of inorganic fertilizer use on parcel on alternate measures of parcel rental values

First, in table A22, I create a dummy variable equal to one for all parcels that have an estimated rental price per acre above the median rental price in their district, and consider those parcels to be facing higher land pressures. The results accord with those above: input use is lower on customary parcels, particularly for long-term inputs such as organic fertilizer; higher land pressure parcels are more likely to have inputs applied; but this effect is attenuated on customary parcels. A similar pattern emerges with the value of inputs applied for those who do use inputs, in table **??**. I check, in table A23, that these results are not just driven by the distribution of customary vs freehold parcels across low vs. high land value areas, but the distribution is relatively similar.

Then, in tables A24 and **??**, I compare across districts, considering those close to Kampala (Masaka & Iganga) as facing high land pressures and those further away (Amuru & Ntungamo) having lower land pressures. This distinction is somewhat similar to the prior threshold of two hours travel time that I use in my threshold analysis. Here again, results are consistent with my model: input use is generally less common on customary parcels, more likely in districts near Kampala, but the difference between customary

VARIABLES	(1)	(2)	(3) Used Pesticides	(4)	(5)
Freehold×Predicted Price	2.24e-07***	4.98e-08			
	(6.63e-08)	(6.71e-08)			
Customary×Predicted Price	8.41e-08	-1.09e-07			
	(6.06e-08)	(8.60e-08)			
Freehold×Village Price			1.75e-06***		
			(2.09e-07)		
Customary×Village Price			8.45e-07***		
			(1.88e-07)		
Freehold×Rental Price (UGX)				2.85e-09	-3.31e-09
				(8.94e-09)	(5.17e-09)
Customary×Rental Price (UGX)				4.22e-08	-3.47e-08***
				(2.75e-08)	(1.04e-08)
Customary	-0.0425	0.00368	0.114***	-0.0828***	-0.0298
	(0.0310)	(0.0314)	(0.0386)	(0.0259)	(0.0262)
PPI	0.00582***	0.00273***	0.00472***	0.00610***	0.00267***
	(0.000699)	(0.000689)	(0.000729)	(0.000683)	(0.000694)
Landholdings	0.000728	0.000520	0.00120*	0.000637	0.000570
	(0.000531)	(0.000388)	(0.000638)	(0.000521)	(0.000412)
Observations	5,570	5,570	5,581	5,556	5,556
R-squared	0.072	0.183	0.090	0.064	0.184
Fixed Effect	None	Group	None	None	Group
Cluster	Group	Group	Group	Group	Group

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

Table A10: Linear Probability Model regression of pesticide use on parcel on alternate measures of parcel rental values.

and freehold parcels is significantly different in districts near Kampala. Once again, customary and freehold parcels are distributed across both sets of districts, as seen in table A25.

	(1)	(2)	(3)	(4)
VARIABLES		Average Insecurity		
Freehold×Rental Price	0.0290	0.0288		
	(0.0255)	(0.0252)		
Customary×Rental Price	0.150***	0.144***		
	(0.0295)	(0.0360)		
Freehold×Inverse Travel Time			-0.777**	
			(0.305)	
Customary×Inverse Travel Time			1.174***	
			(0.276)	
Freehold×Decrease in Travel Time				-0.958
				(0.794)
Customary×Decrease in Travel Time				1.561*
				(0.777)
Customary	0.0673	0.0656	-0.447***	-0.177
	(0.0519)	(0.0530)	(0.108)	(0.121)
PPI	0.000203	-5.56e-05	-0.000578	-0.000323
	(0.00137)	(0.00137)	(0.00167)	(0.00155)
Landholdings	-0.00205**	-0.00197*	-0.00201**	-0.00212**
	(0.000955)	(0.00109)	(0.000908)	(0.000965)
Observations	5,560	5,560	5,537	5,537
R-squared	0.255	0.278	0.252	0.245
Fixed Effect	None	Parish	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A11: Regression of average tenure insecurity on measures of land pressures, with standard errors clustered at the parish level and parish fixed effects in columns (4) - (6).

	(1)	(2)	(3)	(4)
VARIABLES		Trees		
Freehold×Rental Price	0.0164	0.0134		
	(0.0110)	(0.0121)		
Customary×Rental Price	-0.0161	-0.0396***		
	(0.0347)	(0.00801)		
Freehold×Inverse Travel Time			1.368***	
			(0.399)	
Customary×Inverse Travel Time			0.605	
			(0.526)	
Freehold×Decrease in Travel Time				2.015*
				(1.049)
Customary×Decrease in Travel Time				-1.361
				(0.945)
Customary	-0.0735	-0.0149	0.163	0.264**
	(0.0552)	(0.0388)	(0.136)	(0.104)
PPI	-0.00218	-0.000479	-0.00454***	-0.00255**
	(0.00162)	(0.000946)	(0.00116)	(0.00107)
Landholdings	-0.00103	-0.00109*	-0.000420	-0.00128
	(0.000853)	(0.000577)	(0.000527)	(0.000794)
Observations	5,505	5,505	5,483	5,483
R-squared	0.030	0.177	0.062	0.043
Fixed Effect	None	Parish	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A12: Regression of trees on parcel on measures of land pressures, with standard errors clustered at the parish level and parish fixed effects in columns (4) - (6).

	(1)	(2)	(3)	(4)
VARIABLES		Used Organic Fertilizer		
Freehold×Rental Price	0.00190	0.000162		
	(0.00264)	(0.000780)		
Customary×Rental Price	0.0209**	0.00278		
	(0.00931)	(0.00247)		
Freehold×Inverse Travel Time			0.717***	
			(0.248)	
Customary×Inverse Travel Time			0.304***	
			(0.0817)	
Freehold×Decrease in Travel Time				4.040***
				(0.420)
Customary×Decrease in Travel Time				1.239***
				(0.215)
Customary	-0.106***	-0.0329*	0.0195	0.210***
	(0.0288)	(0.0181)	(0.0450)	(0.0422)
PPI	0.00538***	0.00161***	0.00421***	0.00170***
	(0.000958)	(0.000399)	(0.000860)	(0.000590)
Landholdings	0.000543	0.000417	0.000936*	0.00104**
	(0.000414)	(0.000386)	(0.000543)	(0.000426)
Observations	5,503	5,503	5,481	5,481
R-squared	0.100	0.263	0.119	0.185
Fixed Effect	None	Parish	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A13: Regression of organic fertilizer use on parcel on measures of land pressures, with standard errors clustered at the parish level and parish fixed effects in columns (4) - (6).

VARIABLES	(1)	(2)	(3)	(4)
	Used Inorganic Fertilizer			
Freehold×Rental Price	0.00437*	0.00345		
	(0.00223)	(0.00240)		
Customary×Rental Price	0.0183	-0.00742***		
	(0.0169)	(0.00243)		
Freehold×Inverse Travel Time			0.638***	
			(0.0824)	
Customary×Inverse Travel Time			0.534***	
			(0.0833)	
Freehold×Decrease in Travel Time				1.024***
				(0.342)
Customary×Decrease in Travel Time				0.614*
				(0.309)
Customary	-0.0213	-0.00451	0.0242	0.0299
	(0.0205)	(0.0230)	(0.0233)	(0.0187)
PPI	0.00357***	0.00247***	0.00221***	0.00248***
	(0.000517)	(0.000680)	(0.000569)	(0.000646)
Landholdings	0.000364	0.000693*	0.000905**	0.000660*
	(0.000367)	(0.000356)	(0.000402)	(0.000376)
Observations	5,501	5,501	5,479	5,479
R-squared	0.027	0.074	0.053	0.036
Fixed Effect	None	Parish	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A14: Regression of inorganic fertilizer use on parcel on measures of land pressures, with standard errors clustered at the parish level and parish fixed effects in columns (4) - (6).

	(1)	(2)	(3)	(4)
VARIABLES		Used Pesticides		
Freehold×Rental Price	0.00151	-0.000809		
	(0.00469)	(0.00312)		
Customary×Rental Price	0.0215	-0.0109**		
	(0.0140)	(0.00449)		
Freehold×Inverse Travel Time			0.969***	
			(0.130)	
Customary×Inverse Travel Time			0.547***	
			(0.164)	
Freehold×Decrease in Travel Time				3.215***
				(0.371)
Customary×Decrease in Travel Time				0.651*
				(0.350)
Customary	-0.0768	-0.0321	0.0599**	0.206***
	(0.0506)	(0.0500)	(0.0296)	(0.0355)
PPI	0.00601***	0.00312***	0.00416***	0.00327***
	(0.00104)	(0.000898)	(0.00115)	(0.00104)
Landholdings	0.000644	0.000803	0.00110*	0.000858*
	(0.000566)	(0.000497)	(0.000593)	(0.000438)
Observations	5,499	5,499	5,477	5,477
R-squared	0.063	0.151	0.095	0.105
Fixed Effect	None	Parish	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A15: Regression of pesticide use on parcel on measures of land pressures, with standard errors clustered at the parish level and parish fixed effects in columns (4) - (6).

	(1)	(2)	(3)	(4)
VARIABLES		Planted Staple		
Freehold×Rental Price	-0.0125**	-0.0118***		
	(0.00482)	(0.00368)		
Customary×Rental Price	0.00120	0.00393		
	(0.00609)	(0.00396)		
Freehold×Inverse Travel Time			-0.521***	
			(0.186)	
Customary×Inverse Travel Time			0.0136	
			(0.149)	
Freehold×Decrease in Travel Time				-3.830***
				(0.417)
Customary×Decrease in Travel Time				-1.161**
				(0.466)
Customary	0.0625***	-0.00229	-0.0868*	-0.239***
	(0.0164)	(0.0146)	(0.0461)	(0.0412)
PPI	-0.00321***	0.000462	-0.00262***	0.000348
	(0.000956)	(0.000656)	(0.000856)	(0.000763)
Landholdings	-0.000731	0.000428	-0.000784	-0.00107**
	(0.000472)	(0.000522)	(0.000478)	(0.000433)
Observations	5,568	5,568	5,489	5,489
R-squared	0.046	0.251	0.053	0.103
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A16: Linear probability model for a parcel having at least one plot with a staple crop as the primary crop shows that freehold parcels are less likely to be planted with staple crops as land pressures rise.

	(1)	(2)	(3)	(4)
VARIABLES		Average Insecurity		
Freehold×Rental Price	0.0287	0.0347*		
	(0.0217)	(0.0186)		
Customary×Rental Price	0.149***	0.148***		
	(0.0316)	(0.0343)		
Freehold×Inverse Travel Time			-0.835*	
			(0.422)	
Customary×Inverse Travel Time			1.185***	
			(0.299)	
Freehold×Decrease in Travel Time				-1.271
				(0.979)
Customary×Decrease in Travel Time				1.486**
				(0.745)
Customary	0.0683*	0.0515	-0.460***	-0.196
	(0.0402)	(0.0427)	(0.136)	(0.124)
PPI	-5.48e-05	-0.000912	-0.000873	-0.000427
	(0.00150)	(0.00157)	(0.00150)	(0.00155)
Landholdings	-0.00217**	-0.00190*	-0.00208**	-0.00222**
	(0.000957)	(0.00110)	(0.000933)	(0.000972)
Cash Crops	0.0262	-0.0140	0.0414	0.0464
	(0.0326)	(0.0424)	(0.0357)	(0.0432)
Observations	5,538	5,538	5,468	5,468
R-squared	0.253	0.324	0.253	0.246
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A17: Regression of average tenure insecurity on a parcel on land values, controlling for cash crops as the primary crop on at least one plot on the parcel.

	(1)	(2)	(3)	(4)
VARIABLES		Trees		
Freehold×Rental Price	0.0150*	0.0104		
	(0.00888)	(0.0112)		
Customary×Rental Price	-0.0168	-0.0317***		
	(0.0246)	(0.00600)		
Freehold×Inverse Travel Time			1.304***	
			(0.224)	
Customary×Inverse Travel Time			0.577*	
			(0.320)	
Freehold×Decrease in Travel Time				1.502**
				(0.675)
Customary×Decrease in Travel Time				-1.599**
				(0.711)
Customary	-0.0589*	-0.00522	0.163*	0.244***
	(0.0311)	(0.0271)	(0.0898)	(0.0794)
PPI	-0.00261**	0.000436	-0.00492***	-0.00256**
	(0.00122)	(0.00100)	(0.00113)	(0.00114)
Landholdings	-0.00123*	-0.00127**	-0.000613	-0.00154**
	(0.000655)	(0.000539)	(0.000544)	(0.000705)
Cash Crops	0.110***	0.104***	0.0853***	0.0934***
	(0.0238)	(0.0236)	(0.0235)	(0.0255)
Observations	5,562	5,562	5,483	5,483
R-squared	0.038	0.240	0.067	0.049
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A18: Linear probability model of tree planting on a parcel on land values, controlling for cash crops as the primary crop on at least one plot on the parcel.

VARIABLES	(1)	(2)	(3)	(4)
	Used Organic Fertilizer			
Freehold×Rental Price	-0.000349	-0.00182**		
	(0.00182)	(0.000897)		
Customary×Rental Price	0.0181***	0.000129		
	(0.00643)	(0.00277)		
Freehold×Inverse Travel Time			0.587***	
			(0.112)	
Customary×Inverse Travel Time			0.248***	
			(0.0665)	
Freehold×Decrease in Travel Time				3.376***
				(0.403)
Customary×Decrease in Travel Time				0.932***
				(0.233)
Customary	-0.0847***	-0.0285	0.0190	0.183***
	(0.0200)	(0.0187)	(0.0316)	(0.0352)
PPI	0.00437***	0.00144***	0.00343***	0.00169***
	(0.000627)	(0.000467)	(0.000588)	(0.000509)
Landholdings	0.000158	0.000328	0.000547	0.000716**
	(0.000301)	(0.000290)	(0.000384)	(0.000338)
Cash Crops	0.182***	0.0399**	0.172***	0.121***
	(0.0189)	(0.0188)	(0.0184)	(0.0171)
Observations	5,560	5,560	5,481	5,481
R-squared	0.155	0.288	0.166	0.207
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A19: Linear probability model of organic fertilizer use on a parcel on land values, controlling for cash crops as the primary crop on at least one plot on the parcel.

VARIABLES	(1)	(2)	(3)	(4)
		Used Inorganic Fertilizer		
Freehold×Rental Price	0.00421*	0.00515**		
	(0.00221)	(0.00199)		
Customary×Rental Price	0.0183	0.00329		
	(0.0159)	(0.00282)		
Freehold×Inverse Travel Time			0.636***	
			(0.0957)	
Customary×Inverse Travel Time			0.533***	
			(0.0852)	
Freehold×Decrease in Travel Time				1.057***
				(0.280)
Customary×Decrease in Travel Time				0.629***
				(0.230)
Customary	-0.0219	-0.00258	0.0242	0.0312
	(0.0153)	(0.0161)	(0.0272)	(0.0294)
PPI	0.00363***	0.00196***	0.00220***	0.00248***
	(0.000564)	(0.000571)	(0.000528)	(0.000589)
Landholdings	0.000349	0.000576**	0.000900***	0.000676**
	(0.000272)	(0.000266)	(0.000319)	(0.000300)
Cash Crops	0.0153	0.0143	0.00234	-0.00591
	(0.0135)	(0.0123)	(0.0132)	(0.0126)
Observations	5,558	5,558	5,479	5,479
R-squared	0.029	0.127	0.053	0.036
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A20: Linear probability model of inorganic fertilizer use on a parcel on land values, controlling for cash crops as the primary crop on at least one plot on the parcel.

	(1)	(2)	(3)	(4)
VARIABLES		Used Pesticides		
Freehold×Rental Price	-0.000402	-0.00252		
	(0.00414)	(0.00259)		
Customary×Rental Price	0.0194	-0.0180***		
	(0.0132)	(0.00543)		
Freehold×Inverse Travel Time			0.865***	
			(0.104)	
Customary×Inverse Travel Time			0.503***	
			(0.119)	
Freehold×Decrease in Travel Time				2.622***
				(0.323)
Customary×Decrease in Travel Time				0.375
				(0.291)
Customary	-0.0555**	-0.0347	0.0599	0.182***
	(0.0237)	(0.0258)	(0.0365)	(0.0386)
PPI	0.00522***	0.00270***	0.00353***	0.00326***
	(0.000612)	(0.000693)	(0.000645)	(0.000658)
Landholdings	0.000322	0.000505	0.000789	0.000567
	(0.000405)	(0.000374)	(0.000479)	(0.000368)
Cash Crops	0.151***	0.0769***	0.138***	0.108***
	(0.0187)	(0.0162)	(0.0179)	(0.0182)
Observations	5,556	5,556	5,477	5,477
R-squared	0.093	0.189	0.119	0.119
Fixed Effect	None	Group	None	None
Cluster	Group	Group	Group	Group

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

Table A21: Linear probability model of pesticide use on a parcel on land values, controlling for cash crops as the primary crop on at least one plot on the parcel.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Trees		Organic Fertilizer		Inorganic Fertilizer		Pesticides		Insecurity	
Customary	-0.0503	0.00110	-0.0712***	-0.00539	-0.0154	0.0122	-0.0353	0.000947	0.118**	0.100**
	(0.0377)	(0.0297)	(0.0196)	(0.0165)	(0.0202)	(0.0207)	(0.0266)	(0.0260)	(0.0467)	(0.0478)
Higher Price	0.107***	0.0979***	0.106***	0.0244*	-0.0276**	-0.0220	0.0514***	0.00636	0.0876	0.0812
	(0.0242)	(0.0247)	(0.0162)	(0.0124)	(0.0138)	(0.0136)	(0.0169)	(0.0168)	(0.0533)	(0.0535)
Customary×Higher Price	-0.0428	-0.0319	-0.0711***	-0.0443**	-0.0186	-0.0225	-0.0870***	-0.0779***	-0.104	-0.1000
	(0.0397)	(0.0366)	(0.0163)	(0.0180)	(0.0190)	(0.0197)	(0.0214)	(0.0244)	(0.0634)	(0.0637)
Constant	0.589***	0.0492	-0.0324	-0.0204	-0.0608	-0.101*	-0.00432	-0.0253	1.338***	1.220***
	(0.0870)	(0.0687)	(0.0443)	(0.0358)	(0.0506)	(0.0532)	(0.0464)	(0.0496)	(0.120)	(0.124)
Observations	5,528	5,528	5,526	5,526	5,524	5,524	5,522	5,522	5,583	5,583
R-squared	0.038	0.240	0.116	0.291	0.031	0.128	0.066	0.186	0.245	0.315
Fixed Effect	None	Group	None	Group	None	Group	None	Group	None	Group
Cluster	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group

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

Table A22: Linear Probability Model regression of a binary for input use on binaries for customary tenure, the parcel having an estimated rental value above the district median, and the interaction of the two. Controls include dummies for how the parcel was acquired, a proxy for household wealth, and total household landholdings. Columns (2) (4) and (6) include farmer-group fixed effects.

Tenure Status	Low Rental Price	High Rental Price	Total
Freehold	2,003	1,905	3,908
Customary	1,203	900	2,103
Total	3,206	2,805	6,011

Table A23: Customary and Freehold parcels are found in relatively similar proportions in low and high rental value environments.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Trees		Organic Fertilizer		Inorganic Fertilizer		Pesticides		Average Insecurity	
Customary	0.115*	-0.0193	-0.0244	-0.0113	0.0206	0.00649	0.0195	-0.00586	-0.303***	-0.350***
	(0.0599)	(0.0462)	(0.0221)	(0.0182)	(0.0143)	(0.0132)	(0.0233)	(0.0219)	(0.0900)	(0.0901)
Near Kampala	0.355***	-0.115	0.135***	0.00309	0.130***	0.0498	0.178***	0.0200	-0.215**	-0.519**
	(0.0391)	(0.153)	(0.0216)	(0.0222)	(0.0129)	(0.0438)	(0.0215)	(0.0244)	(0.0855)	(0.227)
Customary×Near Kampala	-0.168***	0.0146	-0.0819***	-0.0228	-0.0299	-0.0127	-0.0848***	-0.0379	0.453***	0.507***
	(0.0639)	(0.0530)	(0.0234)	(0.0179)	(0.0189)	(0.0166)	(0.0257)	(0.0253)	(0.0960)	(0.101)
Constant	0.451***	0.0766	-0.0561	-0.0111	-0.132**	-0.103*	-0.0686	-0.0256	1.594***	1.403***
	(0.0876)	(0.0685)	(0.0476)	(0.0360)	(0.0504)	(0.0533)	(0.0493)	(0.0498)	(0.140)	(0.126)
Observations	5,587	5,587	5,585	5,585	5,583	5,583	5,581	5,581	5,635	5,635
R-squared	0.085	0.232	0.117	0.286	0.052	0.125	0.089	0.182	0.252	0.323
Fixed Effect	None	Farmer Group	None	Farmer Group	None	Farmer Group	None	Farmer Group	None	Farmer Group
Cluster	Group	Farmer Group	Group	Farmer Group	Group	Farmer Group	Group	Farmer Group	Group	Farmer Group

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

Table A24: Linear Probability Model regression of a binary for input use on binaries for customary tenure, being in a district closer to Kampala, and the interaction of the two. Controls include dummies for how the parcel was acquired, a proxy for household wealth, and total household landholdings. Columns (2) (4) and (6) include farmer-group fixed effects.

Tenure Status	Far from Kampala	Near Kampala	Total
Freehold	835	3,948	4,783
Customary	962	1,364	2,326
Total	1,797	5,312	7,109

Table A25: Caption

D.5 Threshold Analysis

In this section, I present the regression results looking separately on either side of a threshold of 2 hours travel time from Kamapala (identified in interviews as being a reasonable radius for external demand for land), as well as detecting thresholds following Hansen (2000) in the lower panel of each table. However, these detected thresholds are not my preferred specification, as both the inverse travel time and the change in travel time lack a continuous support in the geographically concentrated sample of ACDP. Therefore, the simultaneous detection of the existence and location of thresholds is very noisy and prone to overfitting, making them difficult to interpret.

	(1)	(2)	(3)	(4)	(5)	(6)
A; Prior Threshold			Average Insecurity			
Freehold×Rental Price	0.0249	-0.0692				
	(0.0206)	(0.394)				
Customary×Rental Price	0.137***	9.863***				
	(0.0206)	(1.858)				
Freehold×Inverse Travel Time			-0.902*	-0.126		
			(0.525)	(2.926)		
Customary×Inverse Travel Time			1.155***	-6.055		
			(0.338)	(4.909)		
Freehold×Decrease in Travel Time					-0.321	-1.948
					(1.072)	(1.265)
Customary*Decrease in Travel Time					1.197	-1.831
					(0.823)	(2.279)
Observations	4,301	1,213	4,321	1,216	4,321	1,216
R-squared	0.309	0.141	0.303	0.133	0.296	0.136
Fixed Effect	None	None	None	None	None	None
Cluster	Group	Group	Group	Group	Group	Group
Sample	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala
B: Detected Threshold						
Freehold×Rental Price	-3.318***	0.0270				
	(0.842)	(0.0184)				
Customary×Rental Price	-2.711**	0.104***				
	(1.371)	(0.00888)				
Freehold×Inverse Travel Time			12.59	-0.435**		
			(9.252)	(0.185)		
Customary×Inverse Travel Time			-1.344	1.337***		
			(1.920)	(0.149)		
Freehold×Decrease in Travel Time					-6.615***	0.211
					(1.927)	(0.693)
Customary×Decrease in Travel Time					1.147*	-3.421***
					(0.682)	(0.978)
Observations	5,610	5,610	5,537	5,537	5,537	5,537
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.0897 StD Price	> -0.0897 StD Price	< 0.120 $(1+time)^{-1}$	> 0.120 $(1+time)^{-1}$	< 0.0878 $\Delta time$	> 0.0878 $\Delta time$

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

Table A26: Regression of average tenure insecurity on a parcel on land pressures. In panel A, regressions were run separately within and outside 2 hours of Kampala, in paired sets of columns. In panel B, thresholds were simultaneously detected and regressions run on either side of the detected threshold in the land pressure variable.

	(1)	(2)	(3)	(4)	(5)	(6)
A: Prior Threshold			Trees			
Freehold×Rental Price	0.0158*	0.0551				
	(0.00907)	(0.159)				
Customary×Rental Price	-0.00979	1.549				
	(0.0255)	(0.955)				
Freehold×Inverse Travel Time			1.994***	1.164		
			(0.267)	(3.381)		
Customary×Inverse Travel Time			0.989**	-4.189		
			(0.391)	(4.368)		
Freehold×Decrease in Travel Time					2.498***	0.857
					(0.705)	(1.224)
Customary×Decrease in Travel Time					-1.487*	-0.947
					(0.855)	(1.474)
Observations	4,263	1,197	4,283	1,200	4,283	1,200
R-squared	0.036	0.085	0.091	0.089	0.052	0.089
Fixed Effect	None	None	None	None	None	None
Cluster	Group	Group	Group	Group	Group	Group
Sample	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala
B: Detected Threshold						
Freehold×Rental Price	-2.016***	0.00778**				
	(0.430)	(0.00360)				
Customary×Rental Price	-12.88***	-0.0470***				
	(1.461)	(0.00369)				
Freehold×Inverse Travel Time			-8.229***	-0.783***		
			(2.125)	(0.216)		
Customary×Inverse Travel Time			-15.00***	-1.477***		
			(1.182)	(0.308)		
Freehold×Decrease in Travel Time					-6.959***	1.399***
					(0.974)	(0.330)
Customary×Decrease in Travel Time					-10.66***	-1.224**
					(0.674)	(0.550)
Observations	5,562	5,562	5,483	5,483	5,483	5,483
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.186 StD Price	> -0.186 StD Price	< 0.139 $(1+time)^{-1}$	> 0.139 $(1+time)^{-1}$	< 0.0675 $\Delta time$	> 0.0675 $\Delta time$

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

Table A27: Linear probability model of tree planting on a parcel on land pressures. In panel A, regressions were run separately within and outside 2 hours of Kampala, in paired sets of columns. In panel B, thresholds were simultaneously detected and regressions run on either side of the detected threshold in the land pressure variable.

	(1)	(2)	(3)	(4)	(5)	(6)
A: Prior Threshold			Used Organic Fertilizer			
Freehold×Rental Price	0.00179	0.0660				
	(0.00238)	(0.101)				
Customary×Rental Price	0.0215***	-0.376				
	(0.00644)	(0.502)				
Freehold×Inverse Travel Time			1.219***	11.03***		
			(0.176)	(2.312)		
Customary×Inverse Travel Time			0.370***	5.039**		
			(0.0996)	(2.204)		
Freehold×Decrease in Travel Time					4.830***	4.664***
					(0.498)	(0.901)
Customary×Decrease in Travel Time					1.291***	1.879**
					(0.313)	(0.846)
Observations	4,260	1,198	4,280	1,201	4,280	1,201
R-squared	0.120	0.057	0.162	0.150	0.223	0.162
Fixed Effect	None	None	None	None	None	None
Cluster	Group	Group	Group	Group	Group	Group
Sample	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala
B: Detected Threshold						
Freehold×Rental Price	-1.103***	-0.000876				
	(0.205)	(0.000641)				
Customary×Rental Price	-0.919**	0.0106***				
	(0.357)	(0.00147)				
Freehold×Inverse Travel Time			1.232***	9.357***		
			(0.0769)	(1.361)		
Customary×Inverse Travel Time			0.385***	4.816**		
			(0.0791)	(2.093)		
Freehold×Decrease in Travel Time					1.411***	-0.747
					(0.197)	(0.964)
Customary×Decrease in Travel Time					0.609***	-2.001
					(0.174)	(1.652)
Observations	5,560	5,560	5,481	5,481	5,481	5,481
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.186 StD Price	> -0.186 Price	< 0.328 $(1+time)^{-1}$	> 0.328 $(1+time)^{-1}$	< 0.119 $\Delta time$	> 0.119 $\Delta time$

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

Table A28: Linear probability model of organic fertilizer use on a parcel on land pressures. In panel A, regressions were run separately within and outside 2 hours of Kampala, in paired sets of columns. In panel B, thresholds were simultaneously detected and regressions run on either side of the detected threshold in the land pressure variable.

	(1)	(2)	(3)	(4)	(5)	(6)
A; Prior Threshold			Used Inorganic Fertilizer			
Freehold×Rental Price	0.00475**	0.0681				
	(0.00238)	(0.113)				
Customary×Rental Price	0.0164	-1.366**				
	(0.0123)	(0.665)				
Freehold×Inverse Travel Time			0.641***	-0.434		
			(0.105)	(2.134)		
Customary×Inverse Travel Time			0.531***	-2.449		
			(0.118)	(2.106)		
Freehold×Decrease in Travel Time					1.267***	-0.704
					(0.269)	(0.711)
Customary×Decrease in Travel Time					0.563**	-1.318
					(0.279)	(0.878)
Observations	4,261	1,195	4,281	1,198	4,281	1,198
R-squared	0.028	0.025	0.051	0.024	0.038	0.027
Fixed Effect	None	None	None	None	None	None
Cluster	Group	Group	Group	Group	Group	Group
Sample	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala
B: Detected Threshold						
Freehold×Rental Price	-1.382***	0.00322				
	(0.330)	(0.00615)				
Customary×Rental Price	-0.603*	-0.00173				
	(0.366)	(0.00195)				
Freehold×Inverse Travel Time			0.598***	-5.389***		
			(0.0535)	(1.811)		
Customary×Inverse Travel Time			0.531***	-5.338**		
			(0.0694)	(2.526)		
Freehold×Inverse Travel Time					0.636***	-0.242
					(0.223)	(0.337)
Customary×Inverse Travel Time					0.634**	-1.661***
					(0.298)	(0.486)
Observations	5,558	5,558	5,479	5,479	5,479	5,479
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.173 StD Price	> -0.173 StD Price	< 0.350 $(1+time)^{-1}$	> 0.350 $(1+time)^{-1}$	< 0.0878 $\Delta time$	> 0.0878 $\Delta time$

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

Table A29: Linear probability model of inorganic fertilizer use on a parcel on land pressures. In panel A, regressions were run separately within and outside 2 hours of Kampala, in paired sets of columns. In panel B, thresholds were simultaneously detected and regressions run on either side of the detected threshold in the land pressure variable.

	(1)	(2)	(3)	(4)	(5)	(6)
A: Prior Threshold			Used Pesticides			
Freehold×Rental Price	0.00199	0.127				
	(0.00458)	(0.111)				
Customary×Rental Price	0.0154*	-0.0583				
	(0.00860)	(0.725)				
Freehold×Inverse Travel Time			1.156***	8.611***		
			(0.144)	(1.924)		
Customary×Inverse Travel Time			0.446***	-3.242		
			(0.126)	(3.527)		
Freehold×Decrease in Travel Time					3.464***	3.014***
					(0.488)	(0.772)
Customary×Decrease in Travel Time					0.483	-2.443**
					(0.299)	(1.145)
Observations	4,259	1,195	4,279	1,198	4,279	1,198
R-squared	0.075	0.040	0.113	0.073	0.123	0.071
Fixed Effect	None	None	None	None	None	None
Cluster	Group	Group	Group	Group	Group	Group
Sample	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala	> 2 hours from Kampala	< 2 hours from Kampala
B: Detected Threshold						
Freehold×Rental Price	0.0562	-0.00633***				
	(0.151)	(0.00227)				
Customary×Rental Price	-0.884**	-0.00145				
	(0.446)	(0.00239)				
Freehold×Inverse Travel Time			1.169***	6.991***		
			(0.0794)	(1.424)		
Customary×Inverse Travel Time			0.459***	-2.249		
			(0.0892)	(1.978)		
Freehold×Decrease in Travel Time					-0.270	2.982***
					(0.262)	(0.431)
Customary×Decrease in Travel Time					0.132	-2.175***
					(0.309)	(0.577)
Observations	5,556	5,556	5,477	5,477	5,477	5,477
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Threshold	< -0.0321	> -0.0321	< 0.328	> 0.328	< 0.0878	> 0.0878
	Price	Price	$(1+time)^{-1}$	$(1+time)^{-1}$	$\Delta time$	$\Delta time$

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

Table A30: Linear probability model of pesticide use on a parcel on land pressures. In panel A, regressions were run separately within and outside 2 hours of Kampala, in paired sets of columns. In panel B, thresholds were simultaneously detected and regressions run on either side of the detected threshold in the land pressure variable.