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ABSTRACT

Customary Land Conversion in African Cities*

We propose an urban land use model to discuss the conversion of customary agricultural land to formal and informal residential land in a developing country city. Because customary land sales are insecure, migrant buyers face a risk of eviction, which affects land markets in non-trivial ways. Both tenure risk and asymmetric information cause the city extent and population to be too small. Empirical tests of the model for Bamako, Mali, confirm the existence of tenure insecurity and information asymmetry in the primary but not in the secondary land market, consistently with information revelation after initial sales by customary holders.

JEL Classification: O12, R14, P14

Keywords: urbanization, land markets, property rights, land tenure formalization, market failure

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1 Introduction

Cities are growing at an unprecedented pace in Sub-Saharan Africa and the trend is expected to continue over the first half of the twenty-first century. The United Nations estimate that the region's urban population increased from 300 to 450 million residents between 2010 and 2020 and shall more than double by 2050, reaching 1.250 billion people (United Nations, 2018). As a consequence, 35% of the global urban population growth over the next three decades will be concentrated in that region. By 2015, almost one out of five urban residents will live in Sub-Saharan Africa. This implies that the land area of sub-Saharan African cities is also expected to more than double.[1] As countries in the region are still largely rural, urban expansion thus involves a massive process of land use conversion whereby peri-urban agricultural land is transformed into urban residential areas (Locke and Henley, 2016, Camara, 2017).

Yet, a major characteristic of those peri-urban areas is that they are overwhelmingly governed by a customary system of land allocation (Durand-Lasserve et al., 2015, World Bank, 2020).[2] This has two major implications: First, as peri-urban land is purchased from customary owners by urban residents[3], it exits the non-monetary customary system and becomes tradeable individual property, a phenomenon described in the anthropological literature as the "commodification of land" or the "emergence of land markets" (Wehrmann, 2005). Second, land individualization involves the conversion of land tenure[4] from customary rights to either formal or informal individual rights. Formal rights—which we will refer to as statutory rights—can be established by a deed or a title registered in a land registry or a cadaster, or by a use right (permit to occupy) granted by public authorities. In most instances, formalization—i.e., the conversion of tenure from a non-statutory to a statutory right—does not occur. Land plots purchased from customary owners are supplied on the land market without any formal right, which can be a source of strong inefficiencies.

It is indeed notable that purchasing a plot from a customary owner is risky. For instance, a land plot may be sold by an illegitimate owner, or it may be sold to different buyers simultaneously. Conflicts over land purchased from customary owners are very frequent (Magigi and Drescher, 2010, Neimark et al. 2018, Tembo and Sommerville 2018, Kaiser et al. 2019). A 2022 survey of individuals residing in the Bamako area showed that 38 percent of respondents either knew someone in their inner circle or had experienced a land conflict (Letrouit and Selod, 2022). This is why buyers of customary land may prefer to pay a formalization cost to convert land tenure to a statutory property right that shall significantly reduce the risk of an ownership conflict (Barry and Danso, 2014). Because purchasing customary land is risky and formalizing it is

[1] Combes et al. (2023) report a cross-section elasticity of urban land area with respect to urban population of 0.9.

[2] Customary land systems refer to systems of land allocation according to traditional norms and institutions. Customary land systems still govern land allocation in rural and peri-urban Sub-Saharan Africa. Under these customary systems, land is allocated to users by customary authorities (such as village chiefs or land chiefs within each village) in exchange for a symbolic gift (for instance a few cola nuts). Because no money is involved in the exchange, there are no land markets.

[3] See Mends and De Meijer (2006), Naab et al. (2013) and Durand-Lasserve et al. (2015).

[4] Land tenure refers to the way land is owned or occupied by individuals or groups (Knight, 2010).

costly without a guarantee of success, the process of land use and land tenure conversion may happen in inefficient ways. Hence, the first objective of this paper is to understand the conversion process from customary agricultural use to statutory and non-statutory residential use in urban areas that are surrounded by customary agricultural land (which is the overwhelming situation throughout sub-Saharan Africa). The second objective of the paper is to analyze the implications of tenure insecurity and possible asymmetric information between buyers and sellers of customary land. Because tenure insecurity and information asymmetry are indeed prone to generate inefficient urbanization, this could reduce the overall economic surplus generated by cities. The third objective of the paper is to implement an empirical methodology to detect the existence and assess the effects of tenure risks and information asymmetry when urban areas include customary parcels as well as statutory and non-statutory land plots.

Our paper, firstly, provides a novel theoretical analysis of customary land sales and land tenure conversion. Using a monocentric urban economics framework, our theoretical model studies how tenure insecurity and information asymmetry affect the conversion of land use and tenure as the city comes into shape. In this framework, all the land is initially in the hands of customary owners who practice agriculture. Land plots are purchased by urban residents such as merchants and employees in the public and private sectors, who have enough education and/or wealth to attempt to formalize tenure as a means to reduce their land tenure insecurity. Those transactions between customary sellers and urban buyers define the primary land market. A key feature of the model is that buyers are able to convert tenure while customary sellers are not. As noted by Durand-Lasserve et al. (2015) from extensive fieldwork in Bamako, Mali, this is because customary owners are often agricultural laypersons who do not have the skills and social networks to navigate the land administration. The tenure formalization attempts of buyers, however, are not always successful, as competing claims over land ownership may emerge and derail the process before a formal property right can be established. These competing claims may arise for a variety of reasons, including disputed inheritance among family members or local disputes regarding the allocation of the plot by village customary authorities. Furthermore, land plots are heterogeneous in the probability of land tenure formalization, an assumption that reflects different intensities of conflict over land ownership. Although buyers cannot avoid the risk of formalization failure, they may be able to assess it to some extent.

We first analyze the case where buyers and sellers have symmetric information on land tenure risk. Buyers obtain this information before acquiring land from customary sellers and attempting to establish a statutory right on the plot they purchased. If successful, they have to pay a formalization fee, which covers various expenses ranging from land surveying fees to registration. We show that the share of customary land smoothly increases with distance from the city center and that the presence of tenure reduces the city's population and welfare. We then contrast this with the case where buyers are unable to obtain information on the risk of a formalization failure. This is typically caused by the inherent difficulty of inspecting and uncovering all the different stakes in the ownership of a land plot before purchasing it. We show that, in this case, buyers face an additional problem of adverse selection as customary

sellers may choose to offer the riskiest plots for sale. The information asymmetry causes a land market failure, as transactions fail to take place beyond a specific distance from the city center. We show that this issue further reduces the city's population and welfare.

The paper also extends the analysis to the secondary market where land plots are subsequently exchanged between urban workers. We focus on the non-statutory residential plots that sellers could not convert to statutory rights but wish to resell to other urban residents. We show that, when buyers on the secondary market are able to evaluate land tenure risks, they are unwilling to purchase non-statutory plots that are located near the urban fringe. The city periphery may then never include plots with statutory rights.

The paper also provides a methodological framework for an empirical analysis of land tenure formalization in Sub-Saharan African cities. From the theoretical analysis, we derive several empirical tests to assess the presence of risk and asymmetric information. We apply them to a unique survey of land plots in Bamako, Mali, that were transacted between 2009 and 2012 and that were unbuilt at the time of the transaction but might have been formalized by the time of the survey. The empirical analysis shows that the prevalence of statutory plots decays with distance from city center. Furthermore, we find that prices are 67% and 57% lower for plots purchased without statutory rights from customary and non-customary sellers, respectively. This confirms the existence of a large tenure-security premium, caused by a very strong land-tenure risk and leading to large welfare implications for migrant workers in Sub-Saharan cities.

We also implement and discuss three tests about the presence of information asymmetry between buyers and sellers. The three tests are positive in the case of sales by customary sellers, which reveals that customary sellers have private information in the primary market. We also apply the same tests in the secondary market for the transactions of non-statutory plots resold by non-customary owners. Results show conclusive evidence about the absence of sellers' private information in two of the three tests, the third test providing ambiguous evidence. To sum up, our results are consistent with the absence of information sharing outside customary communities when land is first put into circulation (primary market) and with better access to risk information after plots have been subsequently transacted (secondary market).

Related literature Our approach builds on the mainstream literature on land property rights and the emerging urban economics literature that studies the land market and land use implications of tenure insecurity. The effects of land tenure informality have been identified early on in the literature (see in particular Besley, 1995, on reduced investment in land, Field, 2007, on reduced labor market participation, or Galiani and Schargrodsky, 2010, and Galiani et al., 2017, on exposure to crime and negative health and human capital externalities from living in slum areas). By contrast, the causes of land tenure informality and the mechanisms leading to it have been much less studied. To our knowledge, Jimenez (1985) provides the seminal theoretical model about land tenure informality where squatters use land invasions as a coordinated action that protects them from the threat of eviction. The idea of an endogenous determination of a city's informal zone was extended to a general equilibrium setting by Brueckner and

Selod (2009) who showed how squatting "squeezes" the formal sector and consequently raises formal prices in the context of an inelastic urban land supply.[5] In contrast, our paper does not focus on the violation of an existing property right as highlighted in squatting models. Instead, we study the conversion of customary right to other types of informal and formal rights. A handful of models have recently embedded tenure conversion and insecurity in urban economics frameworks. In particular, Selod and Tobin (2018) model informal land markets where land is purchased without well-established property rights and agents choose what property right to purchase from a land administration among a menu of tenure situations that provide various degrees of tenure security. They show that property rights are more formal and more secure at the proximity of the city center, a prediction similar to ours. Cai et al. (2018) simplify Selod and Tobin's (2018) spatial approach but embed it in a discrete dynamic stochastic model with internal migration. After calibrating their model to a developing country context, they simulate the long-term trajectory of formal and informal land uses in a city and study the persistence of informal urban land use over time. Brueckner et al. (2019) further delve into the specificities of informal land markets by focusing on the rental market for backyard structures, an important phenomenon that has emerged in various countries. They derive the conditions for this sub-market to emerge and predict the location patterns of "backyarding" within cities. Pfeiffer et al. (2019) extend the latter framework to a dynamic land-use model with formal and informal housing, which they calibrate to the city of Cape Town, South Africa, and use for various policy simulations. Other recent contributions study the coexistence of formal and informal housing in cities focusing on the role played by various determinants of slum formation including internal migration to cities and the elasticity of formal housing supply (Alves, 2021, Henderson et al., 2018, Cavalcanti et al., 2019). Djankov et al. (2020) provide theoretical and empirical evidence that costly protection of rights affects land use patterns by reducing the spatial extent of cities. Finally, Bird and Venables (2020) provide a quantitative estimation of the impacts of land tenure conversion from traditional tenure to a statutory right in the city of Kampala, Uganda. Unlike in our paper, however, land tenure conversion in their paper is an exogenous shock in the simulation while risk and information asymmetry are neither assessed nor discussed.

As in this recent literature, our paper studies the coexistence of formal/statutory and informal/non-statutory land uses within the same urban economy. Our paper, however, innovates in two important ways: First, our model is the first to explicitly account for customary land rights as part of the urban land system. Customary land use is omnipresent in West African cities and coexists alongside statutory and non-statutory land uses, a situation known in the legal literature as "legal pluralism". This is absent from the previous theoretical urban economics literature. Second, our paper provides an analysis of information asymmetry between buyers and sellers, an important feature that is missing from previous models. Indeed, because land customary rights are not recognized by any official documentation but rely instead on the col-

[5]Extensions of that model include Brueckner (2013) who introduces a rent-seeking organizer, and Shah (2014) who focuses on squatting on public land as opposed to private land.

lective recognition of traditional rights of possession, they are characterized by imprecision and local interpretation, which gives customary sellers strong private information about the level of insecurity associated with their undocumented tenure. To our knowledge, the only other paper studying information asymmetry in urban land markets is that of Lanjouw and Levy (2002) in a non-spatial framework.[6] Their model makes it possible to study differences in the transferability of claims regarding transactions of formal and informal housing, and to analyze how transferability affects land price differentials. In our framework, although information asymmetry also influences transaction prices, it plays a very different role by potentially affecting land market participation and the structure of the city.

Section 2 briefly details the co-existence of customary and statutory land regimes and the transition of land tenure from the first regime to the second. Section 3 presents the model while sections 4 and 5 study the cases where urban buyers are informed or not informed about the levels of tenure insecurity of the customary plots they purchase. Section 6 extends the discussion to the properties of the secondary land market. Section 6 describes the empirical strategy and presents the testable predictions inspired by the model. Section 7 implements the empirical analysis with data on the urban area of Bamako. The last section concludes. Appendices contain mathematical details, a theoretical welfare analysis, information on data sets, and robustness checks on empirical results.

2 Land tenure, legal pluralism and tenure insecurity

In this section we provide a short description of customary and statutory land-rights systems, their co-existence and implication on the legal status of land plots.

Customary land tenure refers to "a set of rules and norms that govern community allocation, use, access and transfer of land" (Freudenberg, 2013, p.1). Customary regimes are organized at the level of the local community and derive their legitimacy from communities' customs and norms and in the claim that they have been applied from time immemorial (Alden Wily 2012; Cotula, 2007). Under customary systems, land is allocated by village or land chiefs to farming households within the village. Land is only held under the common understanding that the ultimate owner of the land is the local community (Paaga, 2013). In theory, land can be taken back in the future by customary authorities and reallocated to other users. Because land is regarded as belonging to the collectivity, it cannot be sold.

Customary systems are widespread in sub-Saharan Africa and customary land tenure is the most common way land is held in rural and peri-urban areas. In Ghana, for instance, Akaateba (2019) reports that more than 80 percent of landholdings are held under customary land tenure. In Sub-Saharian Africa, it is estimated that 1.4 billion hectares are held under customary land tenure (Alden Wiley, 2012). Customary systems, however, are not restricted to sub-Saharan

[6] In the agricultural land tenancy context, Macours et al. (2010) propose a theory in which landlords do not observe their tenants' idiosyncratic propensity to squat.

Africa as various forms of customary land tenure are also common in Asia, in the Middle East and North Africa, and in Latin America: Studies from the early 2010s estimated that between 1.5 and 2 billion people lived under customary regimes (RRI, 2015, Freudenberg, 2013). In some countries, customary tenure is not recognized in state law. In other countries, customary tenure is recognized in the law but is often only recognized in principle and mentioned in generic terms without a legal provision for the issuance of a property right.[7]

Some authors argue that customary land can be viewed as informal because it is almost never granted a formal property right in the form of a legally recognized document (Deininger et al., 2012). Others argue that customary land should not be regarded as informal to the extent that customary rules "enjoy social sanction by a polity" (Bruce et al, 2007, p. 13).

In contrast to customary tenure, statutory rights are organized and enforced by the state and by state law. Statutory rights are most often provided an official documentation that can be registered with authorities. Statutory rights provide recognition of ownership (freehold titles) or of occupancy or use (leaseholds, permits to occupy). In Africa, statutory rights were initially introduced during the colonial period (FAO, 2002) to serve the interest of the settlers and the indigenous elites to appropriate land. At the same time, neither colonizers nor post-independence states suppressed traditional regimes, leading to the coexistence of customary and statutory regimes, a situation often described as "legal pluralism". At the same time, a large fraction of the land is neither recognized by the customary regime nor by the state law. In our analysis, we will distinguish three types of land: statutory land, and non-statutory land sold by either customary or non-customary holders. The last type corresponds to land which has exited the customary tenure system but has not been formalized.

Several authors note that large movements between these three tenure categories are involved in the process of land use and land tenure conversion at the periphery of sub-Saharan African cities. These movements accompany a gradual (but massive) conversion of farming land to residential land, along with a shift from community control to individualization and commodification of land (see Wehrman, 2005, and Wamukaya and Mbathi, 2019, in the cases of Mali and Kenya). Studies report that the demand for the purchase of peri-urban customary land largely comes from urban migrants (see USAID, n.d., and Fosu, 2022, for Zambia and Ghana), especially when they lack tribal connections to request land from local customary authorities (Kinght, 2010). In some cases, customary tenure is converted to statutory rights (USAID, n.d.), whereas plots whose formalization failed fuel the pool of land without such rights. A series of World Bank studies on 24 sub-Saharan African countries[8] confirms that urban areas host a mix of statutory and non-statutory rights, in contrast to rural places that have very little land under statutory rights. In this respect, it has been noted that "urban elites tend to use the statutory system while rural citizens, the less educated, and the poor typically rely on the customary system" (Freudenberg, 2013, p. 1).

[7]Exceptions include Tanzania who delivers CCROs (Certificates of Customary Rights of Occupancy) and Mozambique who delivers DUATs (Direito de Uso e Aproveitamento dos Terras) to individuals and groups.

[8]See the land typologies in the World Bank's Land Governance Assessment Framework (LGAF), described in Deininger et al. (2012).

The literature also reports widespread tenure insecurity on customary land. Within the customary system, insecurity is greater for plots held by more vulnerable family members, women, younger generations who do not control land access, and importantly migrants and their descendants who had previously been allocated land by autochtons (Cotula, 2007 and Fosu, 2020). Insecurity in the customary system is exacerbated by the weak recognition of customary systems in legal and institutional frameworks. Customary systems have inherent conflicts due to the unclear spatial boundaries of customary domains that generate tensions between villages (Alden Wiley, 2012). They are also weakened whenever urbanization raises land values (Freudenberg, 2013, Teklemarian and Cochrane, 2021). The insecurity within the customary system then carries over to the non-statutory plots that have been purchased from customary holders. In addition, because such sales are forbidden in the legislation, they are not publicized and not accompanied by a legal proof of ownership (Mathieu, 2006). Furthermore, traditional chiefs and farmers often engage in multiple land sales without the consent of other claimants who can subsequently challenge the validity of the transaction (Knight, 2010). This is the source of unresolved conflicts that can linger on indefinitely (Asafo, n.d.).

We now import the most relevant elements of this context into an urban economics model of land tenure conversion.

3 Model

We consider an open city with perfectly mobile and risk-neutral individuals locating at various distances $x \geq 0$ from a central business district (CBD) with land available in quantity $m(x)$ at location x.[9] Individuals are endowed with identical preferences over consumption of residential land and a homogeneous good. For simplicity, we assume a unit demand for residential land, so that utility is simply given by the consumption of the homogeneous good z. The price of the homogeneous good is normalized to one.

Individuals can be categorized into four possible cases of economic activities and land use and tenure. In the first category, individuals reside and work outside the city, hold no customary land right in the considered city and obtain the outside utility, u. In the second category, individuals are "customary farmers" who reside within the city extent, farm a piece of land there and sell their farming goods at the CBD. As it is indeed the case under customary systems, customary farmers have a customary right to use the land, which allows them to not pay any land rent. Their land plot includes a unit of residential land and s additional units for their farming activities. Farms produce farming goods at productivity α per unit of land, which yields a farm production equal to αs. We normalize the price of farming goods to one so that the value of farming goods is also equal to αs. Customary farmers incur a transport cost $\tau > 0$ per unit of distance for carrying to and trading their production at the CBD. Their net income from selling their farming production from their location x is therefore a function

[9] For instance, $m(x) = 2\pi x$ in a circular city or $m(x) = 1$ in a linear city with unit width.

which increases in αs and decreases in τx. For conciseness, we summarize this in the function $a(x)$ with $a' < 0$. This generic notation encompasses various specifications for transportation costs of the agricultural good, including linear costs or iceberg-type costs.[10] After trading their production, customary farmers consume the homogeneous good in quantity

$$z = a(x).$$

As customary land holders, farmers hold their land plots under a customary tenure right, which provides a certain level of customary right enforcement. The enforcement level under the customary system is given by the probability q of keeping the land (given possible challenges that may emerge over land use within the customary system).[11] This probability is known by the land holder and is idiosyncratic and distributed with cumulative distribution function G on the support $[\underline{q}, \overline{q}]$, $0 < \underline{q} < \overline{q} \leq 1$. With probability $1 - q$, the plot is reallocated by customary authorities to another customary farmer at the same location. The evicted farmer leaves the city or becomes an urban worker (see below). Given this uncertainty, the expected utility of customary farmers is given by $qa(x) + (1 - q)\, u$, which decreases with distance x to the agricultural product market located at the CBD. Customary farmers are free to leave the city and obtain the outside utility u. They remain in the city if the expected utility is larger than u, or equivalently if $a(x) \geq u$. Hence, the "last" customary farmer in the city area is indifferent between living in the city and in the rural area and therefore lives at distance x_a from the CBD where

$$a(x_a) = u$$

Therefore, x_a gives the border of the city area, inclusive of the farming hinterland.

The two other categories of individuals include urban workers who reside in the city and work at the CBD. All urban workers have identical work productivity and therefore identical wages w while they incur the same commuting cost $t > 0$ per unit of distance. We differentiate between urban workers according to the statutory or non-statutory tenure of their land plots.

Urban workers with statutory land tenure reside on formalized land plots with fully-secure statutory rights (i.e., with a legally recognized formal document) so that they do not face any risk of eviction. They work at the city center, earn a wage and incur a commuting cost. Their net disposable income increases with wage, w, and decreases with the cost of commuting to the CBD, tx . Again, for conciseness we denote the income net of commuting cost by $y(x)$ with $y'<0$. This formulation encompasses the linear and exponential commuting costs mostly found in the literature. The willingness of urban workers to pay for a risk-free unit of land is given by their net income minus their expenditure on the commodity good: $v_S(x) = y(x) - z$. Since urban workers are perfectly mobile and free to migrate in and out of the city, their utility

[10] It also encompasses any other value created by proximity to the city center for customary owners such as access to shopping, public administration, informal work, etc.

[11] As documented in the anthropological literature, conflicts within the customary system can stem from inheritance disputes, disputes with neighbors or herders, or because the rights of "migrants" who received land from the village or whose ancestors received land are contested.

should be equal across locations. This free mobility condition imposes that $u = z$. Hence, their value for a unit of statutory land is equal to

$$v_S(x) = y(x) - u, \tag{1}$$

which falls with distance from the CBD.

By contrast, urban workers holding no statutory right live on land plots without a legally recognized formal document and face tenure insecurity. Because their land ownership is not documented, they are exposed to the same sources of conflict as customary farmers. Let $\theta(q) \in (0,1)$ be the probability that they enforce their land right. Given that enforcement is affected by the same sources of conflict, this enforcement probability rises with the level of tenure security under customary ownership, implying $\theta'>0$. Then, with probability $\theta(q)$, those workers commute and work at the CBD for the wage w. Their gain from migration into the city is given by $y(x) - u$. With probability $1 - \theta(q)$, they are evicted and lose their land which is no longer used. They leave the city and have zero gain from having migrated to the city. Their expected net gain from migrating to the city and residing on a non-statutory land piece is therefore

$$v_N(x,q) = \theta(q)\,[y(x) - u] = \theta(q)\, v_S(x) < v_S(x).$$

Observe that the value v_N is a function of both location x and the probability q of keeping the land. Also observe that non-statutory residential land plots is valued at a discount factor equal to the worker's probability of not being evicted $\theta(q)$. Equivalently, $1/\theta(q)$ reflects the tenure security premium also expressed as a multiplicative factor.

In sub-Saharan African cities, land tenure conversion from customary to statutory rights is done by educated buyers working in the city in the private and public sectors (typically employees, merchants and civil servants). They acquire customary land plots, attempt to establish statutory rights, and retain those plots for their own residential use. Land buyers face potential conflicts over land that affect their likelihood of successfully obtaining a statutory property right. Formally, a land buyer acquires a unit of customary land and faces the tenure formalization probability $\pi(q) \in (0,1)$. This probability rises with q ($\pi' > 0$) because conflicts over customary land ownership carry over after land purchases. Buyers may also use their higher social status and larger social network to prevent conflicts from materializing and jeopardizing formalization. With probability $\pi(q)$, the buyer's ownership of the plot is not contested, allowing him to pay the formalization cost c and obtain a statutory property right from the land administration. This property right is fully transferable and secure (there is no more risk of eviction for its holder). The value of the formalized land plot is therefore given by $v_S(x)$. With probability $1 - \pi(q)$, however, unresolved contestation of ownership prevents the buyer from formalizing the land plot. In that case, he does not incur any formalization cost but obtains a non-statutory residential plot whose value is given by $v_N(x,q)$.

Benchmark case

Before proceeding with the rest of the analysis, it is interesting to discuss the benchmark case of free and secure property rights. Uncertainty in land property rights can be eliminated through setting up and enforcing an exhaustive registration system (e.g., land registry)which extinguishes competing claims and unequivocally assigns a statutory property right to each land plot. If the registry is costless to operate and free to access ($c = 0$), we can consider a model where all landowners can freely obtain a statutory right or, equivalently, where there is no tenure insecurity (with $q = \theta(q) = \pi(q) = 1$). Plots are thus purchased at a price $p_S(x) = v_S(x)$. A farmer obtains utility $a(x)$ from his farm production or $p_S(x) + u$ from selling the land and leaving the city (or becoming an urban worker). A land transaction between a farmer and an urban worker takes place if and only if

$$p_S(x) + u \geq a(x) \iff y(x) \geq a(x).$$

To match reality, we consider that urban residences are close to the CBD, which requires that the LHS of the above inequality falls more rapidly with x than the RHS. That is,

$$\frac{y'(x)}{a'(x)} > 1. \tag{2}$$

Under the above assumption, commuting costs should be greater than the costs of transporting farming goods to the CBD.[12]

The above condition, when binding, then determines the following unique residential border, which separates the residential area occupied by urban workers from the urban farming area: $\widetilde{x}$ such that

$$y(\widetilde{x}) = a(\widetilde{x}). \tag{3}$$

In the benchmark case, the city includes urban workers' residences on the interval $[0, \widetilde{x}]$ and urban farms on $(\widetilde{x}, x_a]$. There is no mix of land uses and all the land occupied by urban workers is formalized. It is intuitive and easy to show that the residential border $\widetilde{x}$ expands with larger urban wages, smaller commuting cost and larger unit transportation cost of farming goods.[13]

The welfare surplus generated in the benchmark city consists of the net surplus generated by urban workers $y(x) - u$ on the land interval $[0, \widetilde{x}]$ and the net surplus of customary farmers $a(x) - u$ on $(\widetilde{x}, x_a)$. Using the definition of $v_S(x)$, the welfare can be written as

$$W^0 = \int_0^{\widetilde{x}} v_S(x) \mathrm{d}M(x) + \int_{\widetilde{x}}^{x_a} [a(x) - u] \, \mathrm{d}M(x),$$

[12]For example, in the case of iceberg transport costs for both workers and goods, $y(x) = w\,exp(-tx)$ and $a(x) = \alpha s(1 - \tau x)$, this condition boils down to $(t/\tau)(w/\alpha s)\,exp(-tx) > 1$. With linear transport costs, $y(x) = w - tx$ and $a(x) = \alpha s - \tau x$, it boils down to $t > \tau$.

[13]Formally, $d\widetilde{x}/dw = -(\partial y/\partial w)/(y'-a') > 0$; $d\widetilde{x}/dt = -\partial y/\partial t/(y'-a') < 0$ and $d\widetilde{x}/d\tau = (\partial a/\partial \tau)(y'-a') > 0$, where $y' - a' < 0$.

where $\mathrm{d}M(x) = m(x)dx$ and $m(x) > 0$ measures the city expansion dimension ($m(x) = 2\pi x$ in a circular city while $m(x) = 2$ in a symmetric linear city with unit width). The expression of welfare sums the land value of urban workers' dwellings with statutory rights and the net surplus of customary farmers. Urban working population is given by $L^0 = \int_0^{\widetilde{x}} \mathrm{d}M(x)$.

4 Informed buyers of customary land

In this section, we study the city structure when there is symmetric information between buyers and customary land sellers. In other words, buyers of customary land are perfectly informed about the enforcement probability of the customary right. We first determine and discuss the price that buyers are willing to pay for land plots conditional on the level of customary right enforcement. We then discuss how the land market and risk heterogeneity affect the city structure. We finally present properties about land tenure conversion and welfare.

Buyers pay the land price p to customary land sellers, attempt to formalize the plot and obtain value $v_S(x)$ or $v_N(x)$ depending on the outcome of their formalization attempt. Under symmetric information, buyers know the customary enforcement level q of a given plot. The value of the purchased plot is equal to the expected gain of a buyer accounting for the probability of a successful formalization. That is, $(v_S(x) - c)\,\pi(q) + v_N(x,q)\,(1 - \pi(q))$. After re-arrangement, this gives the price offered to customary land sellers:

$$p^o(x,q) = v_S(x)\Pi(q) - c\pi(q) \tag{4}$$

where

$$\Pi(q) \equiv \pi(q) + \theta\,(q)\,(1 - \pi(q)) \leq 1 \tag{5}$$

is the probability that a buyer keeps his plot after the tenure formalization attempt. This is a compounded probability that takes into account the likelihoods of both formalization success and non-eviction on a non-statutory plot.[14] Intuitively, because π and θ are increasing functions of q, this probability rises with customary enforcement q (formally, we have: $\Pi' = (1-\theta)\,\pi' + \theta'\,(1-\pi) > 0$). Finally, because v_S falls with distance to the CBD, x, the price offered by buyers to customary land owners $p^o(x,q)$ also decreases when moving towards the city edge.

Transactions take place only if customary land holders accept the prices offered by buyers. On the one hand, customary farmers obtain a utility $p^o(x,q) + u$ when they sell their land and leave the city (or become urban workers). On the other hand, they obtain utility $qa(x) + (1-q)u$ ($\geq u$) when they farm their customary land with tenure insecurity. This implies that they must at least obtain utility level $u + q\,[a(x) - u]$ to transact. Transactions take place if and only if

$$p^o(x,q) \geq q\,[a(x) - u]\,. \tag{6}$$

[14] Indeed, $\pi(q)$ is the probability that the the buyer manages to formalize the plot, while $\theta\,(q)\,(1-\pi(q))$ is the probability that the plot could not be formalized and the buyer of the non-statutory plot is not evicted.

For the sake of realism, we consider that urban workers live closer to the CBD, or equivalently, that customary land sales take place closer to the CBD. Toward this aim, we assume that, for any q, the LHS of condition (6) falls more rapidly with x than the RHS, which is equivalent to imposing that

$$\frac{y'(x)}{a'(x)} \geq \max_{q \in [\underline{q}, \overline{q}]} \frac{q}{\Pi(q)}. \tag{7}$$

This sufficient condition requires that commuting costs are large enough compared to the cost of moving farming goods to the city's marketplace. Then, there exists a unique location $\widehat{x}(q)$ such that buyers and customary farmers with enforcement level q make a transaction for all locations $x \leq \widehat{x}(q)$ and none otherwise. The location $\widehat{x}(q)$ solves the identity

$$p^o(\widehat{x}, q) = q\,[a(\widehat{x}) - u] \tag{8}$$

The function $\widehat{x}(q)$ is continuous and accepts minimum and maximum values $\underline{x}$ and $\overline{x}$. This implies that all the land remains under customary rights and is used for farming at $x \geq \overline{x}$. For $x \leq \underline{x}$, all the customary land is purchased: A fraction $\pi(q)$ of land with customary enforcement probability q is formalized and becomes residences with statutory rights, and a fraction $1-\pi(q)$ becomes residences with non-statutory rights. On the interval $(\underline{x}, \overline{x}]$, three types of land use and tenure coexist: customary farm land and workers' residences with and without statutory rights.

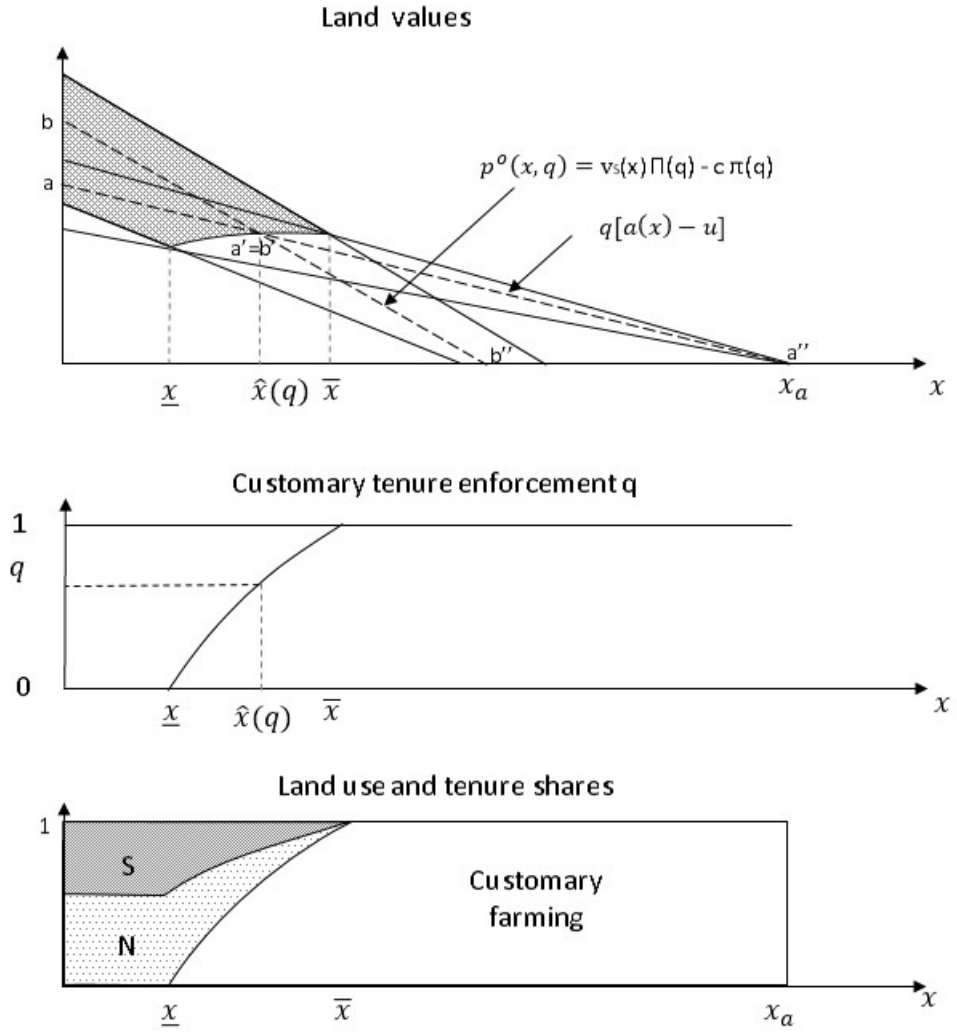
This is presented in the top panel of Figure 1 where the values of land for customary farmers and buyers and for all tenure risks q are plotted on the vertical axis, while the distance to the city center is displayed on the horizontal axis. To understand the figure, fix the probability of keeping the land to a specific value q. Then, the dashed line $aa'a''$ represents the reservation values of customary farmers who own a plot with enforcement probability q (as expressed by condition (6)) while the dashed line $bb'b''$ corresponds to the reservation values of buyers with tenure formalization probability $\pi(q)$ (as expressed by condition (4)). The two lines intersect at $a' = b'$, which defines the distance threshold $\widehat{x}(q)$ to the left of which all plots with customary enforcement probability q are transacted. Because of competition between buyers, the transaction prices for plots of customary enforcement probability q lie on the line segment bb'. There is no transaction on the segment $b'b''$ because customary farmers prefer holding on to their land. The same argument applies to plots with higher enforcement probability levels q, in which cases the line $aa'a''$ rotates clockwise around point a and $bb'b''$ is shifted upwards and pivots to the right at the same time. Considering the case where $\widehat{x}(q)$ is monotonically increasing in q so that $\widehat{x}(\underline{q}) = \underline{x}$ and $\widehat{x}(\overline{q}) = \overline{x}$, the upper and lower continuous lines on Figure 1 represent the reservation values of sellers for $q = \overline{q}$ and $q = \underline{q}$. The gray zone represents the locations and prices at which buyers acquire customary land for all values of the customary enforcement probability q.

The middle panel of Figure 1 is derived from the upper panel and shows for each q (represented on the y axis), the location $\widehat{x}(q)$ up to which plots with enforcement probability q are

transacted. In our example, $\widehat{x}(q)$ is an increasing function, meaning that transactions involving large customary enforcement probability occur on an interval that extends farther away from the CBD. Reciprocally, the graph also shows for each location, the underlying values of customary tenure enforcement of transacted plot. In our example, the set of transacted plots narrows down to increasingly include more secure plots when moving away from the city center.

The bottom panel of Figure 1 represents the shares of land use and tenure situations. As explained above, no transaction occurs for $x > \overline{x}$ while each plot is transacted and converted with probability $\pi(q)$ for $x < \overline{x}$. For $x \in (\underline{x}, \overline{x}]$, land mixes customary, statutory and non-statutory tenures and is used for residential and farming purposes.

Figure 1: Land use conversion and formalization under full information



Note: The top panel displays the reservation values of customary farmers and buyers as functions of distance from the CBD, x. The shaded area represents the set of locations and prices for transactions between customary farmers and buyers. The middle panel shows the values of the enforcement probabilities of customary sellers for which there is a transaction in each location x. $\hat{x}(q)$ is the maximal distance from the CBD of a transaction with enforcement probability q. The bottom panel shows the shares of land use and tenure status after buyers' attempt to formalize. S and N and stand for statutory and non-statutory residential land after the attempt to formalize.

Finally, to shorten our discussion and make it more realistic, we assume that $\overline{x} < x_a$ as shown on Figure 1. This is a natural assumption that accounts for the presence of local agricultural markets in sub-Saharan African cities. This gives the following proposition:

Proposition 1. *Suppose* $0 < \underline{x} < \overline{x} < x_a$. *The city includes three land use and land tenure zones: first, a residential zone with both statutory and non-statutory rights at the proximity of the CBD,* $x \in [0, \underline{x}]$*; second, a fully agricultural zone with customary rights at its far periphery* $x \in [\overline{x}, x_a]$*; and finally, an intermediate zone mixing customary agricultural land and statutory and non-statutory residential land,* $x \in (\underline{x}, \overline{x})$.

The properties of the threshold $\hat{x}(q)$ can be highlighted here. Because higher farm productivity α, larger farm size s and lower farming-good transport cost τ raise farm earnings a, they reduce the incentives of customary sellers to sell their land. As a result, it can be seen from (8) that those parameter changes reduce the threshold $\widehat{x}$, and therefore diminish the extent of the residential area. Similarly, higher wages w and lower commuting cost t raise the urban workers' net income y and therefore their price p^o for customary land. From (8), it comes that those changes push the threshold $\widehat{x}$ away from the CBD and therefore extend the residential area.

However, the properties of the customary risk level on the extent of the residential area are not trivial. Indeed, lower risks both increase the price demanded by customary holders and that offered by buyers. Totally differentiating (8) and using (7), one can show that $\widehat{x}'(q) \gtrless 0$ if and only if

$$\frac{\partial p^o(\widehat{x}, q)}{\partial q} \gtrless a(\widehat{x}) - u \iff v_S(\widehat{x})\Pi'(q) - c\pi'(q) \gtrless a(\widehat{x}) - u. \tag{9}$$

The left hand inequality states that the residential area $[0, \widehat{x}(q)]$ covered by a specific enforcement probability q expands with higher q if this probability raises land value more for buyers than for customary farmers at its border $\widehat{x}(q)$. The right hand inequality breaks down the offered price p^o into its components. It shows that the size of the residential area does not only depend on both statutory and customary land values for buyers and farmers but also on the marginal changes in tenure formalization and compounded enforcement probabilities $\pi'(q)$ and $\Pi'(q)$, as well as on the formalization cost c. Ceteris paribus, the residential area covered by a specific risk level expands with higher compounded enforcement probability if the value of secured land v_S is much larger than the value of customary farm production a at its border $\widehat{x}(q)$, which is likely to be case if the latter is at the vicinity of the CBD. Such an expansion also occurs for a low enough conversion cost c. It finally occurs for plots for which risk reductions marginally bring more security to buyers; that is, where $\Pi'(q)$ is large enough. Note that this inequality depends on tenure formalization and compounded enforcement probabilities as well as on the conversion cost. The inequality holds for a very small conversion cost provided that the compounded enforcement probability is concave. Indeed, when $c \to 0$, we can use expression (8) and check that $\widehat{x}'(q) \leq 0$ if and only if $\Pi(q) \geq q\Pi'(q)$. This condition holds true for a positive and (weakly) concave probability function $\Pi(q)$.

Proposition 2. *Under symmetric information, the residential area* $[0, \widehat{x}(q)]$ *covered by a specific customary enforcement probability* q *expands with* q *if condition (9) holds. It shrinks with higher enforcement probability* q *for a concave compounded enforcement probability* $\Pi(q)$ *and a sufficiently small formalization cost* c*. It expands with* q *for convex compounded enforcement probability* $\Pi(q)$ *with* $\Pi(0) = 0$*.*

Proof. Multiplying inequality (9) by q we get $\widehat{x}'(q) \leq 0$ iff $v_S(\widehat{x})q\Pi'(q) \leq q\left[a(\widehat{x}) - u\right]$. Using (8), we also have $v_S(\widehat{x})\Pi(q) = q\left[a(\widehat{x}) - u\right]$. This gives $\widehat{x}'(q) \leq 0$ iff $v_S(\widehat{x})\left[q\Pi'(q) - \Pi(q)\right] \leq 0$. This holds if Π is a concave function so that $\Pi(q) \geq q\Pi'(q)$. The opposite holds if $\Pi(q) \geq q\Pi'(q)$, that is if Π is a convex function with $\Pi(0) = 0$.

This proposition implies that the monotonicity of $\widehat{x}$ is not guaranteed. In the above discussion, we focused on how plots with a given risk level are transacted across space. We now determine which levels of risk are transacted and which share of transacted plots is formalized at a given distance x. Those properties will be useful for our empirical strategy. □

Probability of land formalization As shown in Figure 1, a share of land remains under customary farming in the distance interval $[\underline{x}, \overline{x}]$. As one moves away from the CBD, less and less land is sold by customary farmers and subject to tenure formalization attempts. This has implication on how the probability of tenure conversion changes with distance to CBD, which will be relevant in our empirical analysis.

To see this, let's assume that $\widehat{x}(.)$ is monotonous and denote $\widehat{q}(x)$ the inverse function of $\widehat{x}(q)$. We consider two cases. On the one hand, when $\widehat{x}$ is an increasing function of q, the threshold $\widehat{q}(x)$ is also an increasing function of distance to CBD, x, so that sales take place for high customary enforcement levels $q \in [\widehat{q}(x), \overline{q}]$. One the one hand, a land plot located at x is formalized with probability $Pr(x \text{ formalized}) = \int_{\widehat{q}(x)}^{\overline{q}} \pi(\mathrm{q})\mathrm{d}G(q)$, which falls with larger x. On the other hand, the probability that this plot is transacted is equal to $\int_{\widehat{q}(x)}^{\overline{q}} \mathrm{d}G(q)$, which also falls with larger x. As a result, the probability that customary land with non-statutory right is formalized at location x conditional of this plot having been purchased,

$$Pr(x \text{ formalized} \mid \text{purchased}) = \frac{\int_{\widehat{q}(x)}^{\overline{q}} \pi(\mathrm{q})\mathrm{d}G(q)}{\int_{\widehat{q}(x)}^{\overline{q}} \mathrm{d}G(q)} \tag{10}$$

has ambiguous properties with respect to x. Nevertheless, in Appendix A, we show that the former effect dominates so that the transition probability is a decreasing function of x. In Appendix A, we show that this transition probability is also a decreasing function when $\widehat{x}(q)$ is a decreasing function. Under symmetric information, whatever the monotone profile of $\widehat{x}(q)$, the probability that customary land with non-statutory right is purchased and formalized at location x is a decreasing function of this distance.

Tenure insecurity and city structure We can now compare city structures under tenure insecurity and full security (benchmark). Using (1), (3), (4) and (8), the following can be shown

(see Appendix A):

Corollary 1. *For any specific tenure risk q, the geographical extent of equilibrium transactions is larger than that of the benchmark case, i.e., $\widehat{x}(q) \leq \tilde{x}$, if and only if*

$$[\Pi(q) - q]\, v_S(\tilde{x}) \leq \pi(q)\, c.$$

Under this condition, the residential area boundary in the model with insecurity $\widehat{x}(q)$ is smaller than in the benchmark model with free and secure property rights $\tilde{x}$. This result is driven by three forces playing in opposite directions. First, fixing $\Pi(q)$, a larger q relaxes the above condition and *decreases* city extent relatively to the full security benchmark. The level of security associated with customary tenure raises farmers' reservation value for the land they occupy, which in turn decreases their incentives to sell their land. Second, fixing q, a smaller compounded enforcement probability $\Pi(q)$ also relaxes the condition, causing the city to *shrink* relatively to the benchmark. Indeed, if $\Pi(q)$ falls, buyers expect a more likely eviction and have lower willingness to pay for customary land. Since resale prices decrease with distance from the CBD, buyers stop purchasing land that is too far away. Finally, when the buyer's expected cost of formalization $\pi(q)\, c$ increases, buyers have lower expected value from formalization attempts, which relaxes the above inequality and *shrinks* city size. This is in line with Sheppard (2010) who finds a negative correlation between informal housing and city size across 120 cities and Djankov et al. (2020) who find that cities extend less under costly protection of property rights. However, under the opposite condition, the urban area may expand in the presence of weak tenure security. This is in line with the common belief among policy makers that informality generates sprawl (Deng and Huang, 2004).

Welfare

We now evaluate the welfare cost of the presence of land tenure risk. The urban welfare surplus under symmetric information consists of the net surplus generated by urban workers over land strips $[0, \hat{x}(q)]$ for each risk level q occurring with probability $G'(q)$ and the net surplus generated to customary farming activity on the rest of land until x_a. Note that, since evicted farmers are replaced by other farmers, customary land is always farmed and yields a value equal to $a(x) - u$. By contrast, land plots of evicted workers are not used. Welfare is given by

$$\begin{aligned} W^S &= \int_{\underline{q}}^{\overline{q}} \int_0^{\hat{x}(q)} \left\{ (w - tx - c - u)\, \pi(q) + [\theta(q)\, (w - tx - u)]\, (1 - \pi(q)) \right\} \mathrm{d}M(x) \mathrm{d}G(q) \\ &\quad + \int_{\underline{q}}^{\overline{q}} \int_{\hat{x}(q)}^{x_a} [a(x) - u]\, \mathrm{d}M(x) \mathrm{d}G(q). \end{aligned}$$

Using the above definitions, this yields

$$W^S = \int_{\underline{q}}^{\overline{q}} \int_0^{\hat{x}(q)} p^o(x,q)\,\mathrm{d}M(x)\mathrm{d}G(q) + \int_{\underline{q}}^{\overline{q}} \int_{\hat{x}(q)}^{x_a} [a(x)-u]\,\mathrm{d}M(x)\mathrm{d}G(q).$$

It is the sum of the land values paid to customary sellers and of the farming production of customary non-sellers. The welfare loss due to tenure risk is then given by

$$W^0 - W^S = \int_{\underline{q}}^{\overline{q}} \int_0^{\hat{x}(q)} [v_S(x) - p^o(x,q)]\,\mathrm{d}M(x)\mathrm{d}G(q) + \int_{\underline{q}}^{\overline{q}} \int_{\hat{x}(q)}^{\widetilde{x}} [v_S(x) - a(x) + u]\,\mathrm{d}M(x)\mathrm{d}G(q)$$

The first term represents the expected loss from buyers' failure to formalize and occupy the land whereas the second term measures the dead-weight loss due to the absence of transactions and subsequent formalization. Indeed, the inner term of the last integral represents the welfare value of the conversion and formalization of a land piece with enforcement level q at a distance x to the CBD. It is positive for the set of risk and distance considered in the expression because customary farmers sell their land only if they receive a price larger than the net gain from customary production (that is, if $p^o(x,q) \geq q\,[a(x)+u]$, which implies $p^o(x,q) \geq a(x)+u$) and therefore $v_S(x) \geq a(x)+u$. Since all terms are positive in the above expression, land tenure risk decreases welfare.

Land tenure risk diminishes urban population and city production. Let us denote L^0 and L^S the urban population in the benchmark model and in the model is symmetric information. Since an urban worker resides on each land plot, the loss of population is easily measured as

$$L^0 - L^S = \int_{\underline{q}}^{\overline{q}} \int_{\hat{x}(q)}^{\widetilde{x}} \mathrm{d}M(x)\mathrm{d}G(q) > 0.$$

Under the normalization that each worker produces a unit of good, urban production falls by the same amount.

We summarize this discussion in the following proposition:

Proposition 3. *Under symmetric information, tenure risk reduces the city's welfare and its population.*

We now study the city structure when buyers are not informed about the customary enforcement levels of land plots.

5 Uninformed buyers of customary land

In this section we study land market allocations when buyers are unable to observe land tenure insecurity in their transactions with customary land holders. Typically, because they do not

belong to the local community, workers are not informed about customary right enforcement q of the local sellers. Therefore, they do not know their own enforcement probability $\pi(q)$ at the time they commit to purchasing a unit of land at the price p from customary farmers. This gives rise to an adverse selection problem where buyers are offered the land with the weakest tenure security.

On the supply side of the land market, a customary land holder chooses his best option between (i) farming his insecure land, which yields a utility level $qa(x) + (1-q)u$, and (ii) selling his land and leaving the city (or becoming an urban worker), which yields a utility level $p+u$. The customary enforcement levels of land plots offered for sale at x are therefore given by the set

$$Q(x,p) = \{q : qa(x) + (1-q)u < p + u\},$$

which expands with the offered price p. Land supply depends negatively on the return on farming net of transport costs $a(x)$, which increases with proximity to the city center. Because $a(x) > u$ on the whole urban area, land supply also depends negatively on customary farmers' tenure enforcement probability q. Only customary farmers with sufficiently low q want to offer their land plots for sale. As those plots also have lower likelihood of tenure formalization, this creates an adverse selection issue between sellers and buyers.

On the demand side of the market, buyers of customary land pay the land price p with certainty but obtain the value $v_S(x) - c$ with probability $\pi(q)$ when they are able formalize the land plot and $v_N(x)$ otherwise. This gives

$$p = \int_{Q(x,p)} \{(v_S(x) - c)\,\pi(q) + v_N(x,q)\,[1 - \pi(q)]\}\,\mathrm{d}G(q).$$

The price therefore balances the expected price of the residential statutory land price net of the formalization cost and that of the non-statutory land price that workers are willing to pay to occupy a land plot. It is easy to see that

$$p = \int_{Q(x,p)} p^o(x,q)\mathrm{d}G(q),$$

which simply is the expected value of the *informed* buyer's price, $p^o(x,q)$.

To formulate the definition of the equilibrium in the customary land market, we first define the buyer's expected gain from a customary land purchase: $V(x,p,Q) \equiv \int_Q p^o(x,q)\mathrm{d}G(q) - p$. In this market, there are two sets of endogenous variables at location x: the land price $p(x)$ and the support of security levels of plots offered for sale, $Q(x,p(x))$. A *competitive land market equilibrium at location* x is then defined as the customary land price $p^*(x)$ and the set of security levels $Q^*(x)$ such that the supply of land is given by $Q^*(x) = Q(x,p^*(x))$ and buyers make no excess gains or losses: $V(x,p^*(x),Q^*(x)) = 0$. As before, for the sake of comparison and exposition, we consider the economic parameters that satisfy $0 < \overline{x} < x_a$. We can then focus

on the land within the city extent $[0, x_a]$ because the customary land beyond x_a is of no interest to buyers.[15]

Customary land holders are willing to sell their unit of land if the offered price p lies above their reservation utility $q\,(a-u)$. The set of customary enforcement levels is therefore given by $Q^*(x,p) = [\underline{q}, p/(a(x)-u)]$ if $p/(a(x)-u) < \overline{q}$ and $[\underline{q}, \overline{q}]$ otherwise. Buyers' expected gain can then be written as

$$\widehat{V}(x,p) \equiv V(x,p,Q^*(x,p)) = \int_{\underline{q}}^{\min\{\overline{q}, p/(a(x)-u)\}} p^o(x,q)\mathrm{d}G(q) - p. \tag{11}$$

The land market equilibrium is found when buyers make zero expected gains, that is $\widehat{V}(x,p) = 0$. This yields the equilibrium price $p^*(x)$.

Let us consider a fixed location at distance x to the CBD. It is easy to see that the function $\widehat{V}(x,p)$ is equal to zero at $p=0$, is negative and decreasing with p for $p/\,(a(x)-u) \in (0, \underline{q})$, and is also decreasing with p for $p/\,(a(x)-u) > \overline{q}$, as shown in Figure 2. For $p/\,(a(x)-u) \in (\underline{q}, \overline{q})$, the function may increase and/or decrease. So, a location x supports an equilibrium if the function $\widehat{V}(x,p)$ is positive for some $p > 0$. This occurs if $\widehat{V}(x,p)$ has an increasing section, reaches a maximum and then falls down. The root of $\widehat{V}(x,p)$ can take several values according to whether p hits $\overline{q}\,(a(x)-u)$. If it does, the price is given by the corner solution

$$p^*(x) = \int_{\underline{q}}^{\overline{q}} p^o(x,q)\mathrm{d}G(q), \tag{12}$$

and otherwise, it solves the interior fixed point

$$p = \int_{\underline{q}}^{p/(a(x)-u)} p^o(x,q)\mathrm{d}G(q) \tag{13}$$

where $p/\,(a(x)-u) \in (\underline{q}, \overline{q})$. For clarity, we denote this interior equilibrium price by $p^{**}(x)$. It can be shown that the equilibrium price is given by $p^*(x)$ if

$$\int_{\underline{q}}^{\overline{q}} p^o(x,q)\mathrm{d}G(q) \geq \overline{q}(a(x)-u) \tag{14}$$

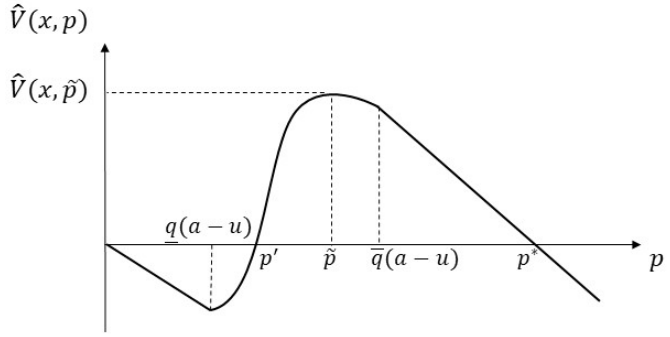
and by $p^{**}(x)$ otherwise.

Figure 2 displays the case for a specific location x. The buyers' expected gain $\widehat{V}(x,p)$ has three roots $p \in \{0, p', p^*\}$ (with $0 < p' < \overline{q}\,(a(x)-u) < p^*$) and is positive on the interval $[p', p^*]$. However, only the highest price p^* is robust to overbidding by buyers. Indeed, if all buyers set a price $p = p^* - \varepsilon$ with small enough $\varepsilon > 0$, any buyer can reap the land market by setting the price at $p^* - \varepsilon/2$ and make a positive profit $\widehat{V}(x, p^* - \varepsilon/2)$. Hence, under asymmetric information,

[15] Indeed, for any $x > x_a$, customary farmers would have lower utility than outside the city: $a(x) - u < 0$. For any $x > \overline{x}$, condition (6) does not hold so that $p^o(x,q) \leq q\,[a(x)-u]$ for all $q \in [\underline{q}, \overline{q}]$. Hence, for $x > x_a > \overline{x}$, $p^o(x,q) < 0$ and $V(x,p,Q) < 0$ for any set Q.

the land market yields the equilibrium price p^* for all transactions with all types of landowners. The same argument holds if the function has an odd number of roots. If the function has an even number of roots, only the highest interior solution p^{**} yields the equilibrium price (see Appendix A). We do not further discuss the characterization of those equilibrium prices. The important take-away is the fact that the land price is unique at each urban distance x from the CBD under asymmetric information. It is the average of the land prices associated with the idiosyncratic risk levels that accompany the use and formalization of customary land.

Figure 2: Buyers' expected gain under asymmetric information



We now discuss the existence of such an equilibrium with land use and tenure conversion. Observe first that a location x supports an equilibrium with $p > 0$ if and only if $\widetilde{V}(x) \equiv \max_p V(x,p,Q(x,p))>0$. This is shown in Figure 2 where the maximum of the function at $\widetilde{p}$ is positive. If the function supports no positive maximum value, it always takes negative values and there exists no equilibrium. As in the previous section, we focus on the realistic situation in which land formalization takes place close to the CBD, say, at distances smaller than x^*. In this situation, it must be that $\widetilde{V}(x) \geq 0$ if and only if $x \in [0, x^*]$. We give two conditions under which this occurs. A first (necessary) condition is that land use and tenure conversion takes place at the CBD. That is, if

$$\widetilde{V}(0)>0. \tag{15}$$

If this condition does not hold, a city may exist with all its land held under customary tenure. The condition naturally holds for sufficiently large $p^o(0,q)$, therefore sufficiently large $v_S(0)$, and hence large enough wages w. A second (sufficient) condition is that $(d/dx)\widetilde{V}(x) < 0$ for all $x \in [0, x_a]$. It is shown that this is satisfied for

$$\frac{y'(x)}{a'(x)} > \max_{q\in[\underline{q},\bar{q}]} \frac{q}{\int_{\underline{q}}^{q} \Pi(q)\mathrm{d}G(q)} \tag{16}$$

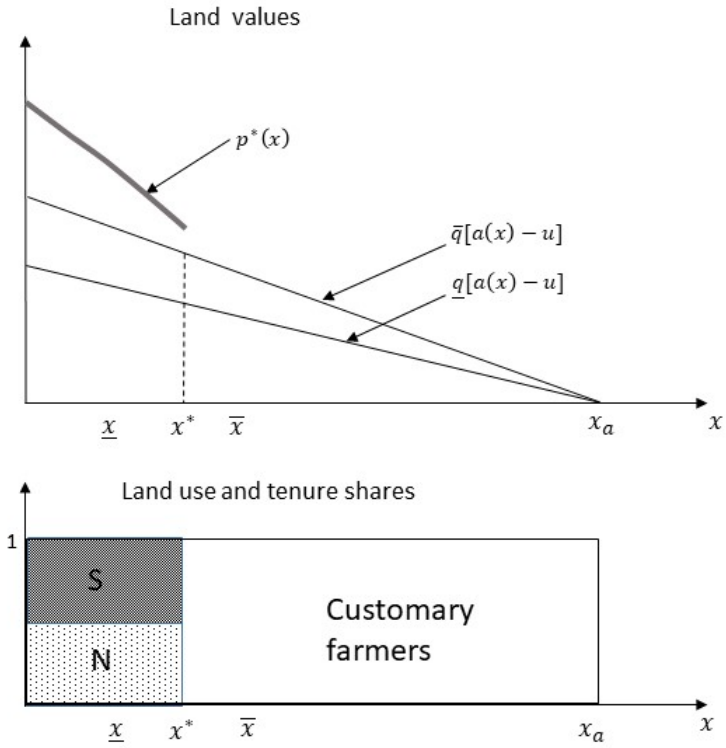
(see Appendix A). That is, commuting cost should be large enough compared to the cost of transporting agricultural goods to CBD. The condition is more constraining than (7) because $\Pi(q) > \int_{\underline{q}}^{q} \Pi(q)\mathrm{d}G(q)$ as $\Pi'(q) > 0$. As a consequence, we assume this condition is met in what follows. To sum up, we have shown that, under conditions (16) and (15), there exists a strictly

positive distance to CBD x^* such that land use and tenure conversion takes place in the interval $x \in [0, x^*]$.

Proposition 4. *Suppose that conditions (15) and (16) hold. Then, there exists a distance to CBD, $x^* > 0$, such that customary land* tenure and use can be converted for $x \leq x^*$, *while they are never converted for $x > x^*$.*

The equilibrium land use and tenure conversion as well as the prices paid to customary land holders are represented on Figure 3. A first difference with the equilibrium with informed buyers lies in the narrower distribution of land prices offered by uninformed buyers. This is because the equilibrium price is equal to the buyers' expected value of informed buyers' equilibrium prices $p^o(x, q)$. This is represented by the thick price curve on the top panel of Figure 3. In this figure, we consider that condition (14) is verified for all urban locations, which implies that the price curve is given by $p^*(x)$ and lies above the reservation values of all customary farmers. As shown in the bottom panel, all plots beneath x^* are then transacted whereas no plot beyond x^* is transacted. This leads to an abrupt end of land conversion at x^*, which constitutes a second difference with the case of informed buyers.

Figure 3: Land transactions and formalization under asymmetric information



Note: The top panel displays the land reservation values of customary farmers and the price paid by urban buyers in each location represented by the gray line. The bottom panel shows land use and tenure status after the buyers' attempt to formalize. S and N stand for "Statutory Residential" and "Non-Statutory Residential" land respectively.

We can also compare the geographical extent of market activity under asymmetric and full information by comparing the borders x^* and $\overline{x}$. Intuitively, customary land buyers have

no incentives to formalize a bunch of land plots under asymmetric information if they have no incentive to formalize them separately under symmetric information. We formalize this intuition in the following proposition:

Proposition 5. *The formalization of land tenure and use takes place within a smaller geographical extent under asymmetric information than under full information:* that is, $x^* < \overline{x}$.

Our result sheds light on Djankov et al.'s (2020) result according to which cities extend less when it is costly to protect property rights. In our case, however, this effect is driven by information asymmetry on tenure risk, a feature absent in the literature.

Probability of land formalization The presence of asymmetric information has implications on how the probability of formalization changes with distance to the CBD. As shown in Figure 2, all land exits the customary system at a distance to the CBD below x^*. A land plot at distance x is formalized with probability $Pr(x \text{ formalized}) = \int_{\underline{q}}^{\overline{q}} \pi(\mathrm{q}) \mathrm{d}G(q)$, which does not depend on this location. Since all land is sold, the probability that customary land with non-statutory right is formalized at location x conditional on having been purchased is given by the same value:

$$Pr(x \text{ formalized} \mid \text{purchased}) = \int_{\underline{q}}^{\overline{q}} \pi(\mathrm{q}) \mathrm{d}G(q).$$

Hence, the probability of land conversion conditional on distance is constant under asymmetric information between customary sellers and buyers.

Welfare Using an argument similar to the one in previous section, the urban welfare surplus under asymmetric information is given by

$$W^A = \int_{\underline{q}}^{\overline{q}} \int_0^{x^*} p^o(x,q) \mathrm{d}M(x) \mathrm{d}G(q) + \int_{\underline{q}}^{\overline{q}} \int_{x^*}^{x_a} \left[a(x) - u\right] \mathrm{d}M(x) \mathrm{d}G(q).$$

Hence, the additional welfare loss or gain due to asymmetric information (in compariston with the case of symmetric information) lies in the structure of the boundary x^*. Indeed, we have

$$W^S - W^A = \int_{\underline{q}}^{\overline{q}} \int_{x^*}^{\hat{x}(q)} \left[p^o\left(x,q\right) - a(x) + u\right] \mathrm{d}M(x) \mathrm{d}G(q).$$

The inside term of the double integral measures the dead-weight loss due to the absence of transactions and subsequent formalization, which is positive as discussed in the previous section. Therefore, the inner integral is positive if and only if $\hat{x}(q) \geq x^*$. This means that asymmetric information yields a welfare loss for tenure risks that entice the informed buyers to purchase land beyond the distance x^*, but a welfare gain otherwise. The ultimate effect depends on the aggregation of those risks and is a priori ambiguous.

Similarly, although asymmetric information shifts the border of the residential area inwards ($x^* < \overline{x}$), it is not clear whether it diminishes the total residential surface, which determines the number of urban workers and therefore city production. This is because only a fraction of land plots is converted under symmetric information. Using a similar argument as in the previous paragraph, the loss of urban workers due to information asymmetry is given by

$$L^S - L^A = \int_{\underline{q}}^{\overline{q}} \int_{x^*}^{\hat{x}(q)} \mathrm{d}M(x)\mathrm{d}G(q).$$

Hence, asymmetric information yields a loss of working population for tenure risks that entice the informed buyers to purchase land beyond the distance x^*, but a gain of working population otherwise. The ultimate effect also depends on the aggregation of those risks and is a priori ambiguous.

To fix ideas, we focus below on an example.

Example Suppose that, since urban workers are migrants to the city, they obtain no infromal right to occupy land without statutory rights. Residential plots without statutory rights are therefore fully insecure for those workers who anticipate that they will be evicted with certainty. Hence, $\theta(q) \to 0$. Suppose further that the risk probability is uniform $G(q) = q/\overline{q}$ for $q \in [0, \overline{q}]$ and the customary land formalization probability of buyers of customary land is linear in the customary right enforcement probability: $\pi(q) = \pi_0 q$ with $(\pi_0 < 1/\overline{q})$. Since urban workers put no value on customary land plots without statutory rights, those land plots are valued at $v_N(x, q) = 0$.

We subsequently consider what happens under symmetric and assymetric information. Under symmetric information, we have the price $p^o(x, q) = [v_S(x) - c]\,\pi_0 q$ and condition (6) becomes $(v_S(x) - c)\,\pi_0 \geq a(x) - u$, which is independent of q. So, there exists a distance to the CBD $\widehat{x}$ that solves

$$(v_S(\widehat{x}) - c)\,\pi_0 = a(\widehat{x}) - u, \tag{17}$$

and divides the city in two areas: an area with statutory and non-statutory residential land for $x \leq \widehat{x}$, and an area with customary agricultural land otherwise. The number of workers is given by $\widehat{x}$. Land tenure risk reduces the urban population by $\widetilde{x} - \widehat{x}$. As shown earlier, welfare falls due to land tenure risk.

Under asymmetric information, the buyer's maximal expected gain $\widetilde{V}(x)$ is reached at the corner for $\widetilde{p}(x) = \overline{q}\,[a(x) - u]$. This is because the price $p^o(x, q)$ rises in q and therefore $\int_{\underline{q}}^{q} p^o(x, q')\mathrm{d}G(q')$ is a convex and increasing function of q under a uniform distribution. The border of the zone where land formalization occurs x^* is given by $\widetilde{V}(x^*) = 0$, which yields

$$(p_S(x^*) - c)\,\pi_0 \frac{\mathrm{E}(q)}{\overline{q}} = a(x^*) - u \tag{18}$$

where $\mathrm{E}(q) = \int_{\underline{q}}^{\overline{q}} q \mathrm{d}G(q)$. Because $\mathrm{E}(q) < \overline{q}$, the LHS of the above condition is smaller than that of (17). So, the solution x^* of (18) is smaller than $\widehat{x}$. As a result, the city is divided in the same types of areas as under symmetric information: a residential area with statutory and non-statutory plots for $x \leq x^*$, and customary agricultural land otherwise. However, the residential area is smaller due to adverse selection. In this example, information asymmetry leads to a land market failure that takes place at locations $x \in (x^*, \overline{x})$. Asymmetric information reduces the border of the residential area and also the number of urban workers by $L^S - L^A = \widehat{x} - x^* > 0$. The welfare loss (see appendix A) is given by $W^S - W^A = \int_{x^*}^{\hat{x}} \left[\mathrm{E}\left[p^o\left(x, q\right)\right] - a(x) + u\right] \mathrm{d}x > 0$. This is summarized in the following corollary:

Corollary 2. *Suppose* fully insecure *plots without statutory rights* $\theta\left(q\right) \to 0$, *a linear tenure formalization probability* $\pi(q)$ *and a uniform distribution of risks. Then, the city hosts fewer workers and generates smaller production and welfare because of asymmetric information.*

6 Secondary land market

In this paper our interest lies in the primary land market where land plots are exchanged and made available to urban workers for the first time. Land can however be resold many times after this first sale. We therefore briefly analyze the secondary land market in the city. This is important as our data analysis will bring forward not only the primary but also the secondary land market. For the sake of comparison and conciseness, we assume that urban workers' land enforcement probability $\theta(q)$ and the probability of formalization $\pi(q)$ remain the same for agents in the secondary market. The secondary market takes place after primary market transactions and before possible evictions. To cause the emergence of a secondary market, we make the assumption that successive buyers make only one conversion attempt on a same land plot. They therefore have an incentive to re-sell their land plots after a tranformation failure.

There are two segments on the secondary land market: one for the land plots with statutory rights and another without statutory rights. In the statutory-right land market, urban workers securely live on their land plots and obtain a unit value $v_S(x)$. They may sell them on at the unit price $p_S(x) = v_S(x)$.

In many cases, buyers cannot obtain a statutory right after the purchase of customary land and therefore live on insecure land. At some point they may also want to resell their plots to new buyers in the secondary market for non-statutory land plots. Resales of same land plots can occur. In the sequel we denote by n the resale instance number that we consider in the analysis ($n \geq 2$). As in the previous section we must distinguish between the case of symmetric and asymmetric information between buyers and sellers.

6.1 Symmetric information in the secondary land market

In the presence of symmetric information, both buyers and sellers of a non-statutory land plot know the land tenure enforcement probability q. The seller obtains a value $v_N(x,q)$ from residing on a plot of non-statutory land. Buyers purchase such non-statutory plots and attempt to formalize them. As they may or may not obtain a statutory right from the formalization procedure, they have expected value $(p_S(x)-c)\,\pi(q)+v_N(x,q)\,(1-\pi(q))$. Because of perfect competition between buyers, this is the price, say $p^n(x,q)$, they offer for a piece of land where n denotes the nth sale in the secondary market. A transaction will occur if and only if $p^n(x,q) \geqslant v_N(x,q)$. After simplification, one can show that a secondary transaction takes place if and only if

$$v_S(x)\,(1-\theta(q))-c \geq 0.$$

The LHS of this inequality expresses a buyer's gain from buying a plot with a non-statutory right. That is, the expected benefit from eliminating future eviction (LHS) minus the conversion cost (RHS). Since $v_S'(x)<0$ and $\theta'(q)>0$, thebenefit is larger for plots located closer to the CBD and bearing higher risks. The binding inequality determines the distance cutoff $\widehat{x}^n(q)$ below which a nth transaction occurs and beyond which no secondary market sale takes place. This cutoff does not depend on successive sales as $\widehat{x}^n(q)=\widehat{x}^2(q)\;\forall n\geq 2$. As soon as risk information is known to buyers, incentives to buy remain the same forever. Furthermore, it can readily be seen that the distance cutoff $\widehat{x}^n(q)$ unambiguously falls with a larger q. In other words, more risky non-statutory plots (lower q) are resold farther away from the CBD. This is because the expected benefit from eliminating eviction is larger for those plots. This property contrasts with that in the primary market where the distance cutoff of first sales is ambiguous and depends on the shape of compounded enforcement probability Π(q) (see Proposition 2). We summarize those results in the following proposition.

Proposition 6. Suppose symmetric information in the secondary land market. The geographical extent of secondary sales of non-statutory land plots is invariant to the resale round. More risky plots (lower q) are resold farther away from the CBD.

We now discuss the land tenure allocation and probability land conversion. The tenure of a land plot depends on whether customary sellers hold private information. We study both cases below.

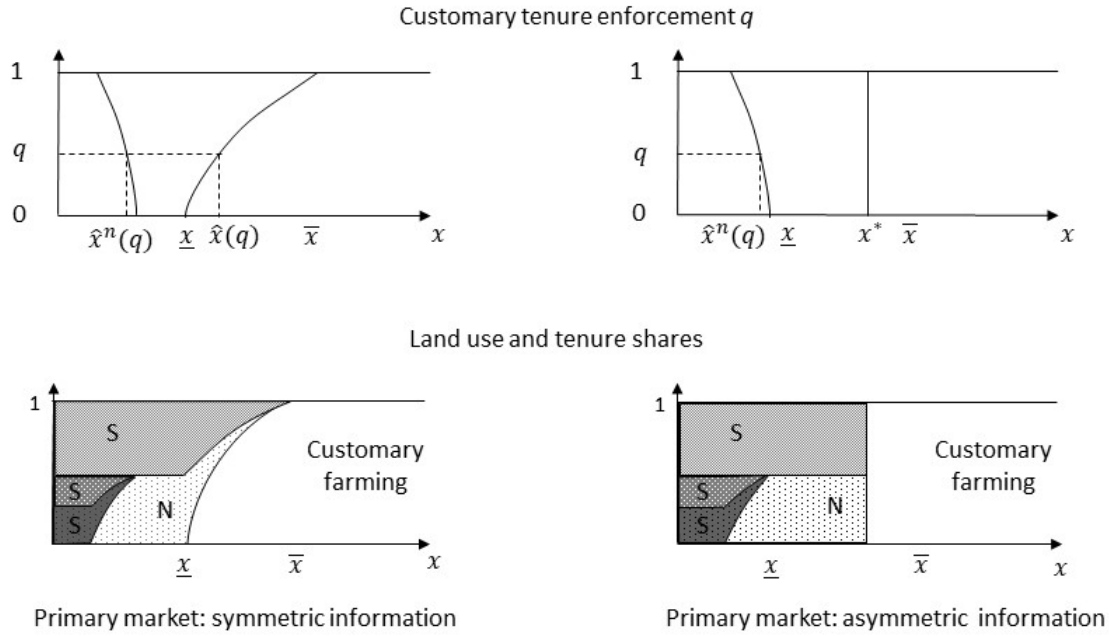
Primary market with symmetric information We first consider that primary market transactions take place under symmetric information. Comparing the geographical thresholds for the primary and secondary market transactions $(\widehat{x}(q),\widehat{x}^n(q))$, we deduce that a plot is never transacted if $x>\widehat{x}(q)$, has only a primary market transaction if $\widehat{x}(q)\geqslant x>\widehat{x}^n(q)$, and has primary and secondary transactions if $x\leq\widehat{x}^n(q)$. The tenure structure of the city therefore depends on how $\widehat{x}^n(q)$ compares to $\widehat{x}(q)$. To simplify the analysis we assume that

$$\theta(q)v_S(x)>q(a(x)-u) \quad \forall q\in[\underline{q},\overline{q}],x<\bar{x}. \tag{19}$$

Assumption (19) guarantees that the value of a land plot for a secondary market seller is higher than that of a customary seller. As a result, $\widehat{x}^n(q) < \widehat{x}(q) \, \forall q$. In other words, secondary market transactions will be located where land prices are larger; that is, closer to the CBD. Then, primary and secondary markets are active on the interval $[0, \widehat{x}^n(q)]$, only the primary market is active on $(\widehat{x}^n(q), \widehat{x}(q)]$, and land is never traded for $x > \widehat{x}(q)$. Whereas the tenure mix does not change in the second zone with only a primary market, the proportion of statutory plots increases with the number of resale rounds n on the first zone which supports both markets (see Appendix A). At the limit when $n \to \infty$, this zone includes only plots with statutory rights. To sum up, as resales happen, the city has an inner zone with an increasing proportion of residential plots with statutory rights and a peri-urban fringe with a constant proportion of plots with non-statutory rights.

This is shown in the left-hand side subfigures of Figure 4. The top figure depicts the schedule $\hat{x}^n(q)$ of the maximal distance from the CBD of a transaction in the nth round of the secondary market. The bottom figure shows the shares of land use and tenure types after buyers' attempts to formalize. The light dark, dark, and strong dark gray areas respectively represent the shares of plots that are formalized after the first sale in the primary market, the second resale in the secondary market, and an infinitely large number of resales in the secondary market. The bottom figure shows that the urban fringe hosts a mix of urban workers holding land with and without statutory rights, and tnon-formalized plots even after a large number of resale rounds in the secondary market.

Figure 4: Land use conversion and formalization in primary and secondary markets



Note: The top panel shows the values of the enforcement probabilities of customary sellers for which there is a transaction. The bottom panel shows the shares of land use and tenure types after buyers' attempts to formalize. The left-hand side figures depict the case with symmetric information in the primary market. The right-hand side figures depict the case with information asymmetry in the primary market. $\hat{x}(q)$ is the maximal distance from the CBD of a transaction in the primary market with enforcement probability q. $\hat{x}^n(q)$ is the maximal distance from the CBD of a transaction in the nth round of the secondary market when the enforcement probability is equal to q. S and N stand for statutory and non-statutory residential land after an attempt to formalize. The light dark, dark, and strong dark gray areas represent the shares of plots converted with statutory rights after the first sale in the primary market, the second resale in the secondary market, and an infinitely large number of resales in the secondary market.

Primary market with asymmetric information. We now consider that primary market transactions take place under asymmetric information. The geographical thresholds for the primary and secondary market transactions are x^* and $\widehat{x}^n(q)$ that cannot be unambiguously ranked. Therefore, there are three possible land tenure structures. First, if $\widehat{x}^n(\overline{q}) \geq x^*$, the city includes primary and secondary markets for x smaller than x^* and no market beyond x^*. Second, if $\widehat{x}^n(\underline{q}) < x^*$, the city includes primary and secondary markets for all $x \in [0, \widehat{x}^n(q)]$, a primary market for $x \in (\widehat{x}^n(q), x^*]$,and no market for x beyond x^*. Finally, if $\widehat{x}^n(\overline{q}) < x^* \leq \widehat{x}^n(\underline{q})$, the city includes primary and secondary markets for $x \in [0, \min\{\widehat{x}^n(q), x^*\}]$, a single primary market for $x \in [\min\{\widehat{x}^n(q), x^*\}, x^*]$, and no market beyond x^*. Here also, the inner zone includes a secondary land market where land tenure is progressively formalized and the proportion of plots with statutory rights increases after successive resale rounds (see Appendix A). This zone becomes fully statutory after an infinite number of resale rounds. The peri-urban fringe of the city hosts a mix of urban workers holding land with and without statutory rights.

This situation is presented in the right-hand side subfigures of Figure 4 where the top figure shows the schedule $\hat{x}^n(q)$ and the bottom one display the shares of land use and tenure types after formalization. Light, normal and strong dark gray areas show the shares of plots converted with statutory rights after first sales, second resales, and later on. The bottom figure shows that the urban fringe hosts a mix of urban workers holding land with and without statutory

rights. There also remains a zone with non-formalized plots even after a large number of resale rounds in the secondary market.

Probability of the formalization of a purchased plot Irrespective of whether there is symmetric or asymmetric information in the primary market, the probability that a non-statutory land plot is converted conditional on being purchased for the nth times is given by

$$Pr(x \text{ converted} \mid \text{purchased}) = \frac{\int_{\underline{q}}^{\widehat{q}^n(x)} \pi(\mathrm{q}) \left(1-\pi(\mathrm{q})\right)^{\mathrm{n}} \mathrm{d}G(q)}{\int_{\underline{q}}^{\widehat{q}^n(x)} \left(1-\pi(\mathrm{q})\right)^{\mathrm{n}} \mathrm{d}G(q)}, \tag{20}$$

where the denominator is the probability that the land plot has not been converted while the numerator is the probability of the land plot is converted after the nth resale.

This conditional probability falls with distance to the CBD. Indeed, differentiating it with respect to x gives

$$\frac{d}{dx} Pr(x \text{ converted} \mid \text{purchased}) = \frac{d\widehat{q}^n}{dx} \left(1-\pi(\widehat{q}^n)\right)^n G'(\widehat{q}^n) \frac{\int_{\underline{q}}^{\widehat{q}^n} \left[\pi(\widehat{\mathrm{q}}^{\mathrm{n}}) - \pi(\mathrm{q})\right] \left(1-\pi(\mathrm{q})\right)^{\mathrm{n}} \mathrm{d}G(q)}{\left(\int_{\underline{q}}^{\widehat{q}^n} \left(1-\pi(\mathrm{q})\right)^{\mathrm{n}} \mathrm{d}G(q)\right)^2} < 0.$$

This is negative because $d\widehat{q}^n/dx < 0$, $G' > 0$ and $\pi(\widehat{q}^n(x) > \pi(q)$ for all $q \in [\underline{q}, \widehat{q}^n(x)]$. Furthermore, because the second term tends to zero when $n \to \infty$, the effect of distance on this conditional probability is less apparent after many resales.

6.2 Asymmetric information in the secondary land market

Under asymmetric information, buyers in the secondary market do not know land risks whereas sellers do. Sellers are former buyers who failed their land tenure formalization attempts; they reside on non-statutory plots and have unit value $v_{NS}(x, q)$. They are willing to sell their plot if they are offered a larger price. Adverse selection is still present here as sellers with higher security levels $\theta(q)$ have higher unobservable reservation values. The enforcement levels of land plots offered for sale at x are therefore given by the set

$$Q(x, p) = \{q : v_N(x, q) < p\}.$$

Buyers contemplate a land purchase in the hope of formalizing it. For each type q at distance x, the expected land value with and without conversion has value $(v_S(x) - c)\,\pi(q) + v_N(x, q)\,[1 - \pi(q)]$, which, as seen in the previous sections, is equal to $p^o(x, q)$. Therefore, at a distance x from CBD and after n rounds of resales, buyers' expected gain is given by

$$\widehat{V}^n(x, p) \equiv \int_{Q(x,p)} p^o(x, q)\, \mathrm{d}H^n(q; x, p) - p \tag{21}$$

where

$$\mathrm{d}H^n(q;x,p) \equiv \frac{[1-\pi(q)]^n\,\mathrm{d}G(q)}{\int_{Q(x,p)}[1-\pi(\xi)]^n\,\mathrm{d}G(\xi)}$$

is the conditional density probability function of finding a non-statutory land plot after n rounds of sales and tenure formalization attempts. As before, the land market equilibrium is found when buyers make zero expected gains; that is, for a price $p = p_N^n(x)$ such that $\widehat{V}^n(x,p) = 0$, which is a fixed point in variable p. Similarly to the previous section, the secondary land market at distance x exists if $\widetilde{V}^n(x) \equiv \max_p \widehat{V}^n(x,p) > 0$ and fails to exist under the opposite condition. Hence, assuming that $\widetilde{V}^n$ is a decreasing function of x, the maximal distance from the CBD for which secondary transactions exist x^{n*} is given by the solution of $\widetilde{V}^n(x) = 0$.

We can easily characterize a remarkable subset of equilibria. Indeed, if

$$\int_{\underline{q}}^{\bar{q}} p^o(x,q)\,\mathrm{d}H^n(q) > v_N(x,\bar{q}), \tag{22}$$

the fixed point gives the unique equilibrium price

$$p^* = \int_{\underline{q}}^{\bar{q}} p^o(x,q)\,\mathrm{d}H^n(q)$$

where $\mathrm{d}H^n(q) = [1-\pi(\mathrm{q})]^{\mathrm{n}}\,\mathrm{dG(q)}/\int_{\underline{q}}^{\bar{q}}[1-\pi(q')]^n\,\mathrm{d}G(q')$. This price is larger than $v_N(x,\bar{q})$ and entices all sellers to sell: $Q(x,p) = [\underline{q},\bar{q}]$. The price inherits the properties of $p^o(x,q)$. In particular, it decreases with larger distance to the CBD. The price is also a function of the number of resales n through the probability distribution function $H^n(q)$. The probability that a plot is formalized conditional on being purchased is given by

$$Pr(x \text{ formalized} \mid \text{purchased}) = \frac{\int_{\underline{q}}^{\bar{q}} \pi(q)\,\mathrm{d}H^n(q)}{\int_{\underline{q}}^{\bar{q}}\mathrm{d}H^n(q)},$$

which is independent of the distance to the CBD.

We do not further characterize the equilibrium because the properties of the integrand of (21) makes it difficult to fully discuss the function $\widehat{V}^n(x,p)$. In addition, it will appear that the setting with asymmetric information is not well supported by the data.

This section provides several takeaways about the secondary market under symmetric and asymmetric information. First, at any specific distance from the CBD, prices of non-statutory plots depend on specific plot risks under symmetric information but do not under asymmetric information. Second, prices in the secondary market fall with distance from the CBD. Third, the probability that a non-statutory plot is formalized after being resold decreases with distance from the CBD under symmetric information while it does not in the case with asymmetric

information. Since those properties are the same as those found for the primary market, they can be used to uncover the presence of asymmetric information in each market.

7 Model predictions

The objective of our empirical analysis is to detect the existence of tenure risk and asymmetric information in a city where land is brought out of the customary regime into land markets with or without statutory rights. To our knowledge, this is the first paper that conducts such an assessment of risk and information asymmetry in urban land markets. The theoretical model leads to several empirical tests of the existence of tenure risk and information asymmetry using data on the price patterns of sales from customary sellers to urban workers.

7.1 Testing for tenure risk

The first test relates to the detection of tenure risk capitalized in land prices. In the version of the model with symmetric information, urban workers buy residential properties with statutory rights at price $p_S(x)$ whereas, by virtue of condition (4), informed buyers purchase customary land at price $p^o(x,q) = v_S(x)\Pi(q) - c\pi(q)$, where $\Pi(q)$ is the compounded probability (5) that a buyer is not evicted after a formalization attempt. Given that $p_S(x) = v_S(x)$ in the market for statutory land, the expected log price of customary land conditional on distance from the city center is given by $\mathrm{E}\left[\log p^o(x,q)\right] = \mathrm{E}\left[\log\left[p_S(x)\Pi(q) - c\pi(q)\right] \mid x < \widehat{x}(q)\right]$, where E is the expectation operator over the distribution of enforcement levels q. In a first-order approximation, we can neglect the formalization cost in the setting of this test, which gives

$$\log p_S(x) - \mathrm{E}\left[\log p^o(x,q)\right] = -\mathrm{E}\left[\log \Pi(q) \mid x < \widehat{x}(q)\right]$$

Since $\Pi(q) \leq 1$, the prediction is that this difference in log prices shall be positive. This test can be performed in the framework of hedonic log-price regression.

The same conclusion applies for the land price gradient with uninformed buyers of customary land: For simplicity, consider that condition (14) is satisfied and the equilibrium price is given by the interior solution (12) $p^*(x) = \int_{\underline{q}}^{\overline{q}} p^o(x,q)\mathrm{d}G(q)$. Then, neglecting again the conversion cost gives

$$\log p_S(x) - \log p^*(x) = -\log \int_{\underline{q}}^{\overline{q}} \Pi(q) dG(q)$$

which is also positive as $\int_{\underline{q}}^{\overline{q}} \Pi(q)G(q) < 1$. Hence, whatever the information structure, in the presence of tenure risks, the log-price should be higher for statutory plots than for customary plots.[16] This property allows us to test for the existence of tenure risk but not for the existence of asymmetric information.

[16]This means that, in price level, the price gradient is steeper for statutory land price.

7.2 Testing for information asymmetry

To test for the presence of asymmetric information, we propose the following three tests.[17] The first test relies on the model prediction of tenure conversion after some elapsed time. Under symmetric information, both the land price $p^o(x,q)$ and the probability of conversion $\pi(q)$ increase with the customary enforcement probability q. This means that, on average, the land price should be higher when buyers have better expectations to formalize the plot. More precisely, transaction prices should be higher for plots that get converted subsequently. This means that we can test whether the expected land price paid for customary land p^o at a date t, conditional on becoming statutory at later time $t+\Delta t$, is higher than the same expected price of the same plot, conditional on maintaining its non-statutory tenure at the later date $t+\Delta t$. That is,

$$\mathrm{E}\left[\log p^o\left(x,q\right) \mid \text{statutory at } t+\Delta t\ \right] > \mathrm{E}\left[\log p^o\left(x,q\right) \mid \text{non-statutory at } t+\Delta t\right]. \tag{23}$$

By contrast, under asymmetric information, the land price $p^*(x)$ is independent of the realization of the formalization probability $\pi(q)$. As a result, the expected land prices p^* conditional on becoming statutory or not at a later time are equal. In the survey data that we will use, the time difference will be obtained from transaction and survey dates. This first test on the presence of private information can be performed in the same framework of the hedonic log-price regression as mentioned above.

The second test relies on the analysis of the transitions from non-statutory to statutory tenure. The land formalization of non-statutory to statutory land differs when buyers are informed or not. As presented in (10), the probability of formalization of a plot purchased at location x, $Pr(x \text{ converted} \mid \text{purchased})$, decreases with distance to the CBD under symmetric information. When buyers can identify risky customary sellers, both the buyers' purchased price $p^o\left(x,q\right)$ and the formalization rate $\pi(q)$ decrease with lower land enforcement probability q. At a given distance to the CBD, plots should have higher prices if buyers have greater expectation to formalize them. As a consequence, transition rates are positively correlated with prices. This is not the case under asymmetric information, where $Pr(x \text{ converted} \mid \text{purchased})$ is neither correlated with the distance to the CBD nor the price. As a result, symmetric information can be detected by the existence of a relationship between the purchased price and land tenure formalization, whereas asymmetric information is expected to imply no such relationship.

Our final test relies on the analysis of variances. Our theoretical model involves different predictions regarding the variances of statutory and non-statutory land prices. In the presence of symmetric information, informed buyers purchase land from customary sellers at a price

[17] The tests of information asymmetry that we provide are specific to our spatial urban setting and available database. Other tests of asymmetric information have been conducted in different settings on the basis of different theoretical models and empirical strategies. For instance, in finance, Chan et al., (2008) test the presence of informed traders using the changes in the trade flows of stock market transactions. In insurance market, Chiappori and Salanié (2014) discuss the presence of asymmetric information using the correlation between insurance coverage and ex-post risk.

$p^o(x,q)$ that varies according to the underlying risk for every given distance x from the CBD. More precisely, the variance of this price conditional on distance to the CBD is equal to

$$\text{var}\left[p^o(x,q)\right] = p_S(x)^2 \text{var}\left[\Pi(q)\right] + c^2 \text{var}\left[\pi(q)\right] > 0.$$

By contrast, under asymmetric information, customary land plots are exchanged at the price $p^*(x)$ that is independent of underlying risks. Therefore, those land prices have zero variance conditional on their distance x to the CBD. In the absence of measurement errors and unobserved characteristics, an indicator of asymmetric information is a zero price variance. However, prices are subject to measurement errors and unobserved characteristics that increase land price heterogeneity in each informational context. Nevertheless, if measurement errors and unobservables are orthogonal to land tenure, $p^*(x)$ and $p_S(x)$ are expected to have the same variance conditional on x in the context of asymmetric information while $p^o(x,q)$ is expected to have a greater variance than $p_S(x)$ conditional on x in the presence of symmetric information. The indicator of the presence of asymmetric information therefore consists in checking the equality of the variances of the prices paid to sellers of non-statutory and statutory land plots, controlling for distance and other characteristics.

8 Empirical analysis

Our empirical analysis focuses on the land market of the Bamako urban area and its rural hinterland, between 2009 and 2012. Bamako is the capital of Mali and is located on the Niger river in the Sudano-Sahelian zone. It is the administrative and economic capital of the country and by far the largest city in the country. The contiguous built-up area extends within a radius of about 15-20 kilometers. It comprises the fully urbanized Bamako District (divided into 6 administrative municipalities) and the urbanized areas of the District's surrounding municipalities as represented on Figure 5). The District of Bamako hosted 1.8 million residents in 2009 and the urbanized surroundings hosted 0.3 million residents for a total of 2.1 million for the whole urban area. This represented almost 15 percent of the total population and more than half of the country's urban population. The population growth of the Bamako urban area is fueled by migration with an annual growth rate of 6.2 percent per year (Mukim et al., 2019). In 2009, the Bamako urban area hosted over 820,000 migrants that were born in another province, representing about 40 percent of its population.[18]

As a capital city, Bamako specializes in administrative and tertiary jobs. It is also broadly monocentric with most administrative jobs located in the center of Bamako, more precisely in the neighborhood of 'Hamdallaye-ACI'. Most private firms locate within or close to the city center, in particular in the neighborhood of the 'Centre Commercial' (Mukim et al., 2019).

[18]Because the peripheral areas of the urban area of Bamako are located in the Koulikoro province, this definition does not include migrants from the Koulikoro province to these peripheral areas.

Migrants mostly come to the Bamako urban area for work and are overwhelmingly employed, with an employment rate of 88.6 percent among male migrants (Mesplé-Somps et al., 2014). Migrants access land throughout the whole urban area as evidenced by the relatively homogeneous spatial distribution of various ethnic groups as defined by their province of birth or spoken language (Mesplé-Somps et al., 2014). There is population mixing and an absence of strong spatial segregation patterns. As migrant workers originate from other provinces, they do not have customary links with native networks that would provide them with a customary access to land. Instead, they must purchase land upon migration to Bamako, which they may obtain with or without a statutory right.

As in all countries in the region, there is a plurality of land tenure situations in Mali, including in the Bamako area. There are four situations: (i) customary possession of the land whereby land is allocated by a village chief to members of its customary group without any monetary exchange; (ii) informal occupation of a land plot without any official property document, but sometimes with an administrative document ("petit papier") that has no legal value but provides some recognition of occupation (e.g., an unregistered sales document or an electricity bill); (iii) a permit to occupy, which is a use-right granted by the authorities against some one-time payment; and (iv) a property title, which is a registered proof of private ownership. The rights provided by the last two categories are statutory. In the sole District of Bamako, there were about 37,000 property titles in 2009, which roughly represented less than 20 percent of the number of households at that time.[19] Tenure security decreases when moving away from the city center. Using declared information in the census, Mukim et al. (2019) reports that 21% of owner occupiers of built plots in the Bamako district have no property rights. This figure stands at 39% in the close suburbs, and 43% in the Greater Bamako area. These figures, however, are for built plots and it is likely that the share of non-statutory plots is larger for unbuilt plots.

The formalization of customary land towards permits to occupy and property titles does not occur without disputes, which have long occupied an important place in Malian affairs. Conflicts over land rights give rise to many evictions and to loss of land plots, harming a large number of people and triggering public demonstrations by "land victims" (RFI, 2014). A case in point is the occupation the Labor Exchange building in Bamako by such victims in 2014. These conflicts are settled by the interested parties themselves or taken to court. The Supreme Court of Mali estimates that 80 percent of court cases involve land tenure issues (République du Mali 2009).

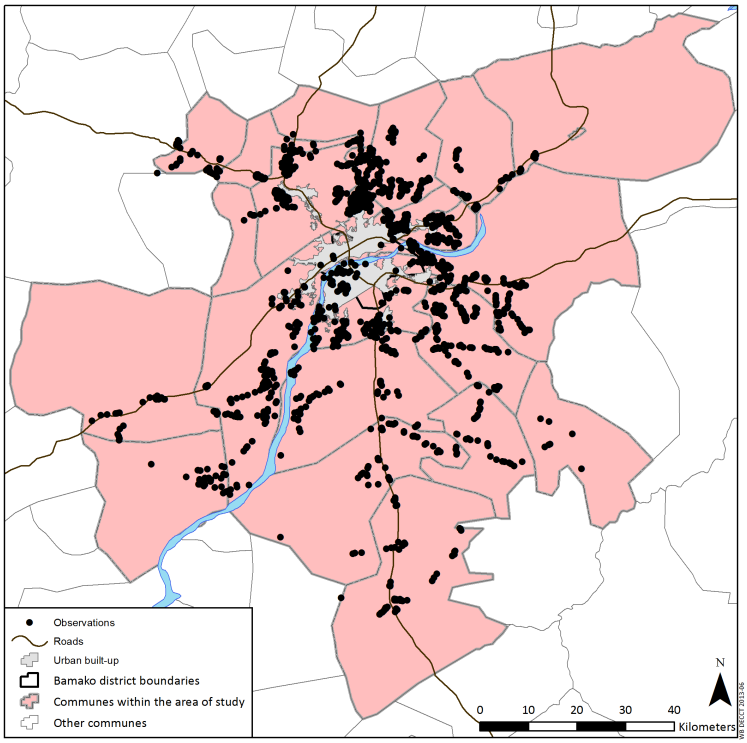
Note that all the above stylized facts are aligned with our monocentric land use model in which urban population and spatial extent reflect the level of migration to the city. Land, originally held within the customary system, is partially converted into residential use while tenure is partially converted to statutory and non-statutory rights.

[19]Due to the incompleteness of registries, dispersal of land information across several administrations, and lack of digitization of records, the number of permits to occupy in the Bamako urban area is not precisely known. Permits to occupy are by all accounts a very common tenure situation and their number is believed to largely exceed the number of property titles (Durand-Lasserve et al., 2015).

8.1 Data

We use information from a unique survey of 1,655 land plots that were transacted as *unbuilt* plots in Bamako between 2009 and 2012 (Durand-Lasserve et al., 2015). Current information was obtained for the year of the survey (in 2012) and retroactive questions were asked regarding the situation of the plot at the time of the transaction (between 2009 and 2012; see survey methodology in Appendix B). The dataset reports characteristics such as price at the time of transaction, tenure both at the time of transaction and at the time of the survey, location (GPS coordinates), intended land use (i.e., residential *vs.* agricultural) at the time of the survey, surface area, municipality, distance to paved main road and river, as well as information on electricity and water access).[20] The sampling for the survey ensures extensive coverage of the Bamako greater area, at regular intervals along main paved roads extending outward from the Bamako city center. To our knowledge, this is the first survey of its kind in the sub-Saharan African context.[21] Figure 5 displays the map of the Bamako urban area and its hinterland, with the main roads, municipality boundaries, built-up area, and the land plots in the sample.

Figure 5: Surveyed land plots in the Bamako urban area and hinterland



Note: The sample consists of plots that were transferred as unbuilt plots in Bamako and its surroundings between 2009 and 2012 (surveyed in 2012). Source: Durand-Lasserve et al. (2015).

[20] Information on each plot was collected by a team of investigators through a variety of local informants (neighbors, informal brokers, customary chiefs, buyers, users, sellers, and elected local officials).

[21] The methodology was partially replicated to collect land maket data in Yaounde, Cameroon (World Bank, 2020).

We drop observations located farther than 40 km from the city center, which imply trip durations over 60 minutes and can be considered to lie outside the influence of Bamako. Observe that the collected data is more extensive than required to test our model's predictions. We further drop observations of land transactions that are not intended for residential or agricultural use, and observations with missing or inconsistent information, which leaves us with a sample of $1,231$ observations (see details in Appendix B). In line with the model, we consider two types of land rights: non-statutory rights, which include both customary land and plots held without formal documentation, and statutory rights, which include land plots with property rights, i.e. permits to occupy and registered titles.

Table 1 presents the summary statistics by use, land tenure and seller type at the time of transaction (taking place between 2009 and 2012) for plots sold for residential use and for plots sold for agricultural use. The first column provides statistics for residential plots that were offered by non-customary sellers and held statutory rights at the transaction time. This category captures the secondary market for statutory land and gives us information on statutory prices $p_S(x)$. The second column describes the characteristics of residential plots that were sold without statutory rights by non-customary sellers. In our theoretical model, this corresponds to the secondary market for non-statutory land sold at price $p_N(x, q)$. The third column presents information about residential plots that were sold by customary holders without statutory rights at price $p^o(x, q)$. This corresponds to the primary market for land plots. The last column is for agricultural plots that were non-statutory at their transaction dates and remained agricultural. This category will be used to provide information on the locations of agricultural plots.

Observe that average land prices fall from the left to the right column. Statutory land is more expensive than non-statutory land, which in turn is cheaper when sold by customary holders. Non-statutory agricultural land is the cheapest. This suggests that tenure status and use are important determinants of land prices. However, it can also be seen that the distance to the CBD is greater moving from the left to the right columns. The same pattern occurs for distance to a main paved road, while access to water (having a well) and electricity is greater in the left column. As those factors are also determinants of the price, they may confound the effect of land tenure on prices. Finally, the table shows non-negligible rates of tenure formalization during the covered period for non-statutory plots sold by customary holders (primary market) and by non-customary holders (secondary market).

Many types of buyers are active on the Bamako land market. Table 2 displays the share of land buyers grouped by economic activity: farmers, merchants and workers, land intermediaries, and civil servants/politicians. The overwhelming majority of buyers are merchants/workers and civil servants/politicians, who are likely to be educated in land matters and/or to be wealthy, having the means to acquire unbuilt land for future residential purposes and having enough skills to undertake the steps of formalization. Land intermediaries are not very active as sellers in the residential land market. In practice, they may mostly offer their service to the buyers rather than purchase land by themselves.

Figure 6 finally presents the shares of tenure and use for transacted land (at the time of

Table 1: Summary statistics

Use	Residential						Agricultural	
Seller type	Non customary		Non customary		Customary			
Tenure	Statutory		Non statutory		Non statutory			
Market segment	Secondary		Secondary		Primary			
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev
Log(P/mˆ2) (CFA/m^2)	8.167	1.467	6.928	1.135	6.275	1.456	4.131	1.261
Distance to CBD (km)	15.199	5.458	19.566	6.509	22.654	6.002	28.225	6.701
Distance to paved road (km)	3.46	3.297	4.979	4.277	3.547	4.683	7.238	6.314
Log(area) (m^2)	6.195	0.850	6.104	0.879	6.344	1.059	9.556	1.295
Water dummy	0.064	0.245	0.022	0.148	0.031	0.174	0.028	0.165
Electricity dummy	0.025	0.155	0.002	0.041	0.005	0.072	0.008	0.089
Tenure formalization	-	-	0.147	0.354	0.082	0.276	-	-
Number of observations	203		584		193		251	

Note: The table presents tenure transitions at the time of transaction (2009-2012). Log is natural logarithm. We dropped 249 transactions either lacking information or locatedmore than 40 km from the CBD. Tenure formalization is a dummy that indicates that the transacted land has been formalized at the time of the survey (2012).

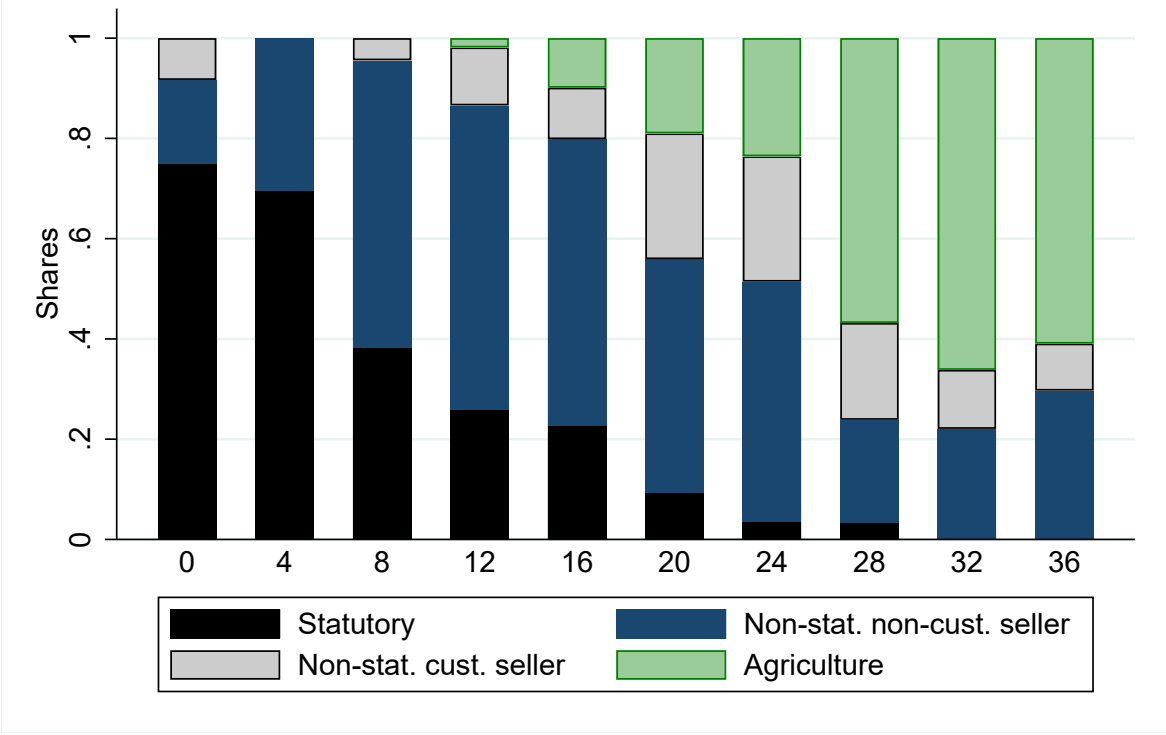
Table 2: Share of land buyers by occupation

	Residential			Agriculture	Total
	Non customary Statutory	Non customary Non statutory	Customary Non statutory		
Farmers	0.99	4.28	5.18	6.77	4.39
Merchants/workers	52.71	43.84	29.02	43.03	42.81
Land intermediaries	0.49	1.37	0.52	0.40	0.89
Civil servants/politicians	30.54	19.18	29.53	37.85	26.48
No profession/unknown	15.27	31.34	35.75	11.95	25.43
Total	100	100	100	100	100

Note: The table reports share of occupations of the buyers of statutory and non-statutory land sold by customary and non customary sellers for residential use. It also reports the occupation share of buyerys of land sold for agricultural use.

transaction) by distance to the city center. The black segments show the share of residential plots transacted with statutory rights. The blue and gray segments show the shares of land plots that had non-statutory rights and were respectively sold by non-customary and customary sellers. The gray segments correspond to the primary land market in our model while the black and blue segments correspond to the secondary market for statutory and non-statutory land respectively. Finally, the green segments show the share of agricultural plots. The figure is in line with our theoretical model in which the share of agricultural plots increases with distance from the city center and the share of plots with statutory rights decreases with distance to the CBD. Observe that sales of land by customary holders occur throughout the city but mostly at the periphery. These patterns are consistent with an active primary land market at the periphery of the city and an active secondary land market in more central locations.

Figure 6: Land tenure and use by distance to the city center (km)



Note: The figure presents the shares of transacted land by tenure and use by distance to the city center at the time of transaction. The black segments show the share of residential plots that have statutory rights. The blue and gray segments show the shares that have non-statutory rights respectively sold by non-customary and customary holders. The green segments show the share of agricultural plots.

8.2 Land prices

To test for the presence of tenure risk and asymmetric information, we report Table 3 below, which shows the results of hedonic regressions of log-price per unit of unbuilt land as a function of distance to the CBD, tenure, and other observable characteristics such as distance to the nearest (paved) main road, area, and the presence of electricity and water on the plot at the time of transaction.[22] Distance to the main road proxies for the accessibility to unobserved amenities (shops, schools, pharmacies, roadside businesses, etc.). Additional proxies for similar unobserved amenities are given by spatial dummies for municipalities or for road catchment areas (which we define as spatial bins along the main roads extending outward from the Bamako city center). Note that Bamako was known at the time to be a peaceful city with no ethnically, cultural or religious conflict, and no spatial segregation along those lines (Mesplé-Somps et al., 2014). As a consequence, controls for neighborhood composition are not needed. All columns include year dummies to control for land price inflation as well as controls for distance to a main road, area of the plot, and the presence of water or electricity. All regressions have robust errors to correct for heteroskedasticity.

[22]We follow the tradition of hedonic pricing that studies the log of land prices and specify income and farming product net of exponential commuting and transport costs. That is, $y(x) = we^{-tx}$ and $a(x) = \alpha s e^{-\tau x}$.

Column (1) isolates the effect of the distance to the CBD and shows a significant negative effect on unbuilt land price. Every additional km away from the CBD reduces per m^2 land prices by 8.1%. Similarly, every additional km away from a main paved road reduces per m^2 land prices by an additional 8.7%. The effects of controls are significantly different from zero and have expected signs: Larger plot areas reduce land prices per m^2, reflecting a well-known feature of single residential plots as well as the high demand for small plots in Bamako. The presence of water and electricity increases land values as they improve future residential use. The regression has good explanatory power (adj $R^2 = 0.531$) as usually found in the hedonic price literature.

Column (2) allows us to test the presence of tenure risk. Towards this aim, it produces the estimates of the impact of tenure status on the price of non-statutory plots offered by customary and non-customary sellers. Those estimates are given by the coefficients on the dummies for non-statutory plots sold by each type of seller. Both dummy coefficients are significantly different from zero. Non-statutory land purchased from a customary seller incurs a discount of 67% (=1-exp(-1.12)) compared to a statutory plot. Non-statutory land purchased from a non-customary seller bears a discount of 57% (=1-exp(-0.85). This is consistent with the existence of tenure risk for non-statutory plots.

Column (3) allows us to assess the existence of asymmetric information. It adds an interaction term to the tenure status of the plot at the time of the transaction, multiplying it by a dummy variable equal to one if the plot is subsequently formalized in the period between the transaction and survey dates and equal to zero otherwise. For customary sellers, the coefficient of this interaction is not significantly different from zero, whereas, for non-customary sellers it is positive and significant. This means our first test for the existence of information asymmetry cannot be rejected for purchases from customary sellers but is rejected for purchases from non-customary sellers. This highlights that the issue of information asymmetry is proper to the primary land market when the plot of customary land is sold on to the market for the first time. As a result, in the following regressions, we keep the interaction term only for plots purchased from non-customary sellers in the secondary market. Column (4) shows that doing so barely affects the regression coefficients reported in Column (3).

Column (5) replaces the municipality dummies by controls for road catchment areas, which further refines spatial controls for unobserved neighborhood amenities. This has no impact on results. Columns (6) reverts to the municipality controls and checks that the bundling of different types of statutory rights has no impact on previous conclusions. This is done by introducing a dummy for 'permits to occupy', which are a common form of statutory rights know to provide a lower tenure protection than 'titles' (see Durand-Lasserve et al. 2015). The significativity of coefficients on non-statutory plot transactions remains unchanged, which shows that our results are robust to accounting for subsegments of the statutory market. Note that a permit to occupy diminishes statutory land values by 53% (=1-exp(-0.76)) compared to statutory plots held with a title. Non-statutory plot sold by non-customary (respectively customary) holders are discounted by 79% (=1-exp(-1.56)) (respectively 83% (=1-exp(-1.78))

Table 3: Land prices and tenure (OLS, log price/m^2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance to CBD (km)	-0.081***	-0.056***	-0.052***	-0.053***	-0.063***	-0.053***	-0.10**
	(0.0055)	(0.0074)	(0.0074)	(0.0074)	(0.0064)	(0.0073)	(0.034)
Non-stat., cust. seller		-1.12***	-1.24***	-1.20***	-1.27***	-1.78***	-1.84***
		(0.11)	(0.12)	(0.12)	(0.11)	(0.15)	(0.21)
Non-stat. cust. seller * formalization			0.32				
			(0.29)				
Non-stat. non-cust. seller		-0.85***	-0.99***	-0.98***	-0.94***	-1.56***	-1.84***
		(0.071)	(0.084)	(0.083)	(0.078)	(0.012)	(0.21)
Non-stat. non-cust. seller * formalization			0.51***	0.51***	0.44***	0.47***	0.46***
			(0.11)	(0.11)	(0.11)	(0.11)	(0.12)
Permit to occupy						-0.76***	-0.73***
						(0.13)	(0.013)
Distance to CBDˆ2 (km^2)							0.00018
							(0.0011)
Non-stat. cust. seller * dist. CBDˆ2							0.00076
							(0.00055)
Non-stat. non-cust. seller * dist. CBDˆ2							0.0011*
							(0.00055)
Distance to main road (km)	-0.087***	-0.070***	-0.068***	-0.068***	-0.078***	-0.069***	-0.069***
	(0.011)	(0.015)	(0.015)	(0.015)	(0.014)	(0.015)	(0.014)
Area (log m^2)	-0.67***	-0.61***	-0.62***	-0.62***	-0.61***	-0.63***	-0.63***
	(0.066)	(0.085)	(0.084)	(0.084)	(0.077)	(0.083)	(0.083)
Water dummy	1.03***	0.43*	0.43*	0.44*	0.50**	0.48**	0.44*
	(0.19)	(0.18)	(0.18)	(0.18)	(0.19)	(0.17)	(0.17)
Electricity dummy	1.06**	0.73**	0.62*	0.61*	0.64*	0.25	0.30
	(0.31)	(0.28)	(0.27)	(0.27)	(0.27)	(0.25)	(0.23)
Municipality dummy	N	Y	Y	Y	N	Y	Y
Catchment area dummy	N	N	N	N	Y	N	N
Year dummy	Y	Y	Y	Y	Y	Y	Y
Observations	980	980	980	980	980	980	980
Adjusted R^2	0.531	0.758	0.764	0.764	0.733	0.773	0.776

Note: The dependent variable is the natural logarithm of price (CFA) per square meter of transacted land plots. 'Non-statutory customary seller' (respectively 'non-statutory non-customary seller') is a dummy variable equal to 1 if the seller was a customary holder (respectively a non-customary holder) offering a non-statutory plot. 'Formalization' designates land that has been converted to a statutory right by the time of the survey. All columns include year dummies to control for price inflation. Columns (2)-(4) and (6)-(7) include municipality dummies to control for unobserved spatial amenities. Column (5) includes a catchment area dummy as an alternative control for unobserved spatial amenities. All columns include controls for distance to the nearest main paved road, the log area of the plot, and dummies for the presence of water and electricity. Column (1) report effects of the distance to the CBD. Column (2) includes dummies for customary and non-customary sellers. Column (3) further breaks down the seller dummies depending on whether the plot was subsequently formalized or not by the time of the survey. This is to test for symmetric information, which is rejected for transaction with customary sellers but not rejected for transaction with non-customary sellers. This justifies the specification in Column (4) which distinguishes only subsequent formalization for transactions with non-customary sellers. Column (5) replaces municipality controls with control for catchment areas (bins of distance from the CBD given by 0-5km,5-10km,10-15km,15-20km and 20-40km, for roads extending north, north-west and south from the city center). Columns (6) adds a control for 'permits to occupy' at the time of the transaction to distinguish between the price of permits from those of titles. Column (7) adds the square of the distance to the CBD as a control and interacts it with each tenure type to check for the concavity of log price patterns with distance for each tenure category. All regressions have robust standard errors. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001

compared to plots sold with a title. Column (7) adds the square of the distance to the CBD and multiplies it with dummies for tenure and seller statuses of transacted plots. This is to check for potential non-linearity of the log price pattern with distance in each tenure and seller category. This has no noticeable effect on results and thus does not invalidate our previous conclusions. In Appendix C, we provide further robustness checks about buyers' and sellers' occupations and residences, survey enumerators and information sources and existence of investments on transacted plots. None of those controls qualitatively alter the above results.

8.3 Land tenure formalization

We now discuss the conversion of land tenure and the presence of asymmetric information. Towards this aim, Table 4 presents a logit regression of the transition to statutory tenure among initially non-statutory plots sold by either customary or non-customary sellers. In the four left hand side columns, we report estimates from tenure transition regressions for plots sold by customary sellers (primary market). In the four right hand columns, we report estimates from tenure transition regressions for plots sold by non-customary sellers (secondary market). The variables of interest are distance to the CBD and the price per m^2 of transacted parcels. All regressions include year dummies to control for the time needed for tenure formalization.[23]

Because the transition probabilities (10-10) in the primary market and (20) in the secondary market differ, we must estimate transition probabilities in the primary and second markets separately. We first discuss tenure transitions on the primary market. Column (1) reports the results for a regression without controls (other than year dummies) and shows that neither the distance to the CBD nor the land price have any significant effect on the probability of tenure formalization. This suggests that information asymmetry cannot be rejected. Column (2) adds controls for distance to the nearest main paved road, plot area, water and electricity access. It confirms that distance to the CBD and the land price have no effect on tenure conversion, which invalidates the hypothesis of symmetric information. Column (3) adds spatial dummy controls for municipalities. It confirms that, within municipalities, neither the distance to the CBD nor the price have any significant effect on tenure transition. Column (4) replaces the spatial dummy controls with road catchment areas, leading to the same result. In the light of the different specifications for this test, we thus cannot reject the hypothesis of asymmetric information in the primary market.

Results for the secondary market are reported in Columns (5) to (8), which replicate Columns (1) to (4) for plots sold by non-customary land holders. As regards the effect of distance to the CBD on tenure transitions, Columns (5) and (6) show that the probability of transition falls with distance to the CBD. Adding controls for municipality in Column (7), the significance of distance to the CBD is weakened as municipalities also capture proximity to the city center. When adding control for road catchment areas in Column (8), the effects becomes insignificant

[23]Buyers having bought a plot in year $t-1$ are indeed less likely to have finalized a tenure formalization than those having bought a plot in year $t-2$, etc.

Table 4: Transition of non-statutory to statutory residential land (logit)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Distance to CBD (km)	-0.028	-0.049	-0.033	0.013	-0.085***	-0.15***	-0.13*	-0.081
	(0.057)	(0.053)	(0.072)	(0.078)	(0.023)	(0.027)	(0.056)	(0.044)
Log(P/mˆ2) (CFA/m^2)	0.13	0.42	1.62	0.36	-0.22*	-0.53***	0.90**	0.72**
	(0.27)	(0.26)	(0.83)	(0.37)	(0.11)	(0.15)	(0.29)	(0.24)
Distance to road (km)		0.052	-0.25	0.020		-0.35***	0.0080	-0.12
		(0.070)	(0.18)	(0.10)		(0.056)	(0.11)	(0.10)
Log(area) (m^2)		0.75**	2.39*	0.67		0.22	1.03***	0.99***
		(0.28)	(1.10)	(0.37)		(0.18)	(0.29)	(0.23)
Water dummy		0.42	-1.86	0.48		-1.40	-0.27	-0.13
		(1.19)	(2.62)	(1.18)		(1.01)	(1.10)	(1.03)
Electricity dummy		0.24	1.19	-2.22		4.90*	3.62	2.06
		(1.92)	(3.50)	(2.13)		(1.93)	(2.45)	(2.01)
Observations	193	193	193	193	584	584	584	584

Note: Logit regression. Dependent variable is a dummy for a transaction of non statutory land at the transaction time that is converted into statutory land at survey time. Year dummies, which are always included, control for time differences in plot formalization. Log are natural logarithms. Columns (1)-(4) reports transactions with customary sellers of non-statutory plots (primary market). Columns (5)-(8) reports transactions without customary sellers (secondary market). Columns (2) and (6) include control for distance to paved road, plot area, electricity and water connection. Columns (3) and (7) add neighborhood dummies for municipalities. Columns (4) and (8) use dummies for road catchment areas, which include 5km segments of the north, north-west and south roads (bins of distance from CBD given by 0-5km,5-10km,10-15km,15-20km and 20-40km) and refine the control for unobserved neighborhood amenities. Standard errors in parentheses. Logit is computed with penalized maximum likelihood estimation. * p<0.05, ** p<0.01, *** p<0.001

as catchment areas are better proxies than municipalities for distance to the city center. This is consistent with our model in symmetric information. As regards the impact of land prices on tenure conversion, Columns (5)-(8) shows significative results in opposite directions. However, controlling for amenities in municipalities (Column 7) or catchment areas (Column 8), we see that the likelihood of subsequent tenure transitions is positively and significantly correlated with the prices of land transactions. This is consistent with the presence of symmetric information, where market values capture risk and the ease of formalization.

Taken together, the above results indicate the presence of asymmetric information in the primary market and symmetric information in the secondary market. This is consistent with the absence of information sharing on land risks outside customary communities when land is first put into circulation (primary market) but with buyers accessing information on risks after plots have been subsequently transacted (secondary market).

8.4 Variances

Our last test relies on the comparison of the variances of land prices: Ceteris paribus, a discrepancy in the price variance of non-statutory and statutory plots rejects the null hypothesis of asymmetric information. Furthermore, a greater price variance of non-statutory plots suggests

evidence of the alternative hypothesis of symmetric information. In practice, we implement this test by comparing the variances of the residuals in hedonic regressions of plot prices controlling for distance to the CBD and all major observables. In Panel A of Table 5, we report the standard deviations of the residuals of separate hedonic regressions for the samples of non-statutory plots sold by customary landholders (Columns (1)-(3)) and of non-statutory plots sold by non-customary landholders (Columns (4)-(6)). In Panel B, we report the same information for the sample of statutory plots (Columns (1)-(3) repeated in Columns (4)-(6)). In the last row, we show the p-values for the test of equal variance of non-statutory and statutory plots (H0) against a greater variance of non-statutory plots (H1).

Table 5: Comparison of variances of residuals in hedonic regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Non-statutory land						
	Customary sellers			Non-customary sellers		
σ_N	.775	.558	.584	.791	.582	.657
Nb. obs.	189			579		
Panel B. Statutory land						
σ_S	.749	.596	.583	.749	.596	.583
Nb. obs.	194			194		
FE controls						
Municipality FE	N	Y	N	N	Y	N
Road catchment FE	N	N	Y	N	N	Y
Test $H_0 : \sigma_N^2/\sigma_S^2=1$						
$H_1 : \sigma_N^2/\sigma_S^2>1$						
P-value	0.31	0.81	0.49	0.18	0.66	0.03

Note: The table reports the standard deviations of the residuals from three sets of regression of log prices on distance to the CBD, the square of distance to the CBD, distance to the main paved road, the log of the plot area, dummies for access to water and electricity and year dummies (Columns (1) and (4)). Logs are natural logarithms. Column (2) and (5) add controls for municipalities. Column (3) and (6) add controls for road catchment areas, which include 5km segments of the north, north-west and south roads (bins of distance from CBD given by 0-5km,5-10km,10-15km,15-20km and 20-40km). The first set of regressions is run on the sample of non-statutory plots sold by customary sellers (Panel A, Columns (1)-(3)). The second set of regressions is run on the sample of non-statutory plots sold by non-customary sellers (Panel A, Columns (4)-(6)). The third set of regressions is run on the sample of transacted statutory plots (Panel B, Columns (1)-(3) repeated in Columns (4)-(6)). To add controls on observables, this set of regressions also includes a dummy for land title (as opposed to a permit to occupy) and its interaction with distance to the CBD. The last row of the table shows the p-values for the test of equal variance of non-statutory and statutory plots (H0) against a greater variance of non-statutory plots (H1).

Columns (1) to (3) report the variance information for non-statutory land sold by customary landholders and for statutory land. Column (1) presents the benchmark case without neighborhood controls. The standard deviation for non-statutory land sold by customary sellers is slightly larger than that for statutory land. However, the p-value indicates that the equality of variances (H0) cannot be rejected, which favors the hypothesis of asymmetric information in the primary market. Column (2) adds controls for municipalities and reports a standard deviation lower for non-statutory plots sold by customary sellers, which again supports the

case for asymmetric information (H0 cannot be rejected and H1 is rejected). Similarly, Column (3) includes controls for road catchment areas and does not allow to reject the equal variance hypothesis, arguing again in favor of asymmetric information in the primary market.

Similarly, Columns (4) to (6) report the variance information for non-statutory land sold by non-customary sellers and for statutory land. It can be noted that variances for non-statutory plots are higher in those columns compared to the previous columns. As p-values are lower, test results are less favorable to the presence of asymmetric information in this market segment. Although Column (4) presents a higher variance for non-statutory land, its high p-value does not permit to reject the presence of asymmetric information (H0). As in Column (2), Column (5) also does not give support in favor of the alternative hypothesis of symmetric information (H0 cannot be rejected and H1 is rejected). However, the very low p-value in Column (6), when alternative geographic controls are introduced in the regression, is strongly indicative of absence of asymmetric information, allowing us to reject its presence at more than the 5% significance level. As a consequence, the last three columns provide mixed evidence in favor of the presence of asymmetric information in the secondary market for non-statutory land.

To sum up, our data analysis is consistent with the presence of risk in Bamako land markets. All three tests presented in this section unambiguously point towards information asymmetry in the primary market where customary sellers exchange their non-statutory plots with urban buyers. As regards the the secondary market, the first two tests point towards symmetric information and the third test is inconclusive. Our empirical study therefore gives strong support about the view that information asymmetry about tenure risk is an important facet of primary land markets in a context where the city grows on land governed under a customary regime. By contrast, although tenure risks remain in the secondary market of non-statutory plots, we find evidence that buyers have better information on risks in the secondary market. This said, information asymmetry does not seem to be completely alleviated after the first tenure formalization attempts.

9 Conclusion

As cities in Sub-Saharan Africa grow and expand spatially, peri-urban land transitions from agricultural to residential purposes. At the same time, as land is being sold to private parties for residential development, its tenure is being converted from undocumented customary arrangements to other tenure situations, both formal (statutory) and, to a large extent, informal (non-statutory). Although such land use and land tenure transformations are currently happening at a massive and unprecedented scale and predicted to continue over the next decades, the phenomenon remains largely understudied by economists. Yet, in contexts where customary land rights are only weakly recognized by authorities, and where the legal transition towards private property rights is not clearly organized, the process of urban expansion can be problematic. There may indeed be large social costs due to the numerous conflicts arising from

contested land transactions. The partial failure to establish statutory property rights on newly developed land also involves economic inefficiencies as holding and transacting land outside the formal property rights system remains risky.

To shed light on these important issues, we presented an urban economics model with land-tenure conversion from customary to statutory property rights. A key feature of the model is that land tenure is risky and buyers who purchase land from customary holders have the capacity to formalize tenure and reduce insecurity. Information on tenure insecurity and on the ease of formalization may be symmetric or asymmetric across customary land sellers and buyers. Under symmetric information, buyers perfectly evaluate the idiosyncratic formalization probability of each land plot. As a result, we show that the share of customary land smoothly increases with distance from the city center. We also show that the presence of tenure reduces the city's population and welfare. Under asymmetric information, buyers are unable to evaluate these risks. We show that this can further reduce the city's population and welfare. We then check the predictions about tenure conversions using a georeferenced survey of land plots in Bamako, Mali and its peri-urban area. The empirical analysis confirms the main features of the model and suggests the existence of asymmetric information in the primary land market with customary sellers. By contrast, it does not find evidence of asymmetric information in the secondary market where sellers are not customary farmers and hold land plots that have already been put onto the market.

To our knowledge, our paper is the first to study the conversion of land use and land tenure in the light of an urban theoretical framework. Although we provide empirical tests of the model using the limited available data for one particular city, there is a clear need for additional empirical studies to further describe, collect relevant data on, and analyze the ongoing process of urban expansion in Sub-Saharan African cities. Such studies will be necessary to understand in more detail the barriers associated with land use transactions and land tenure formalization, and, in line with our model, the specific informational barriers and information asymmetries that can affect the process. In this respect, improving information on risks and tenure conversion processes in addition to reducing the cost of fomalization would help improve the efficiency of the process. Equity issues regarding asymmetric bargaining power in land transactions, dispossession of customary holders through distressed sales, abuse of power by village chiefs selling co-villagers' land, and the potentially poverty-enhancing aspect of land use conversion should also be studied in the future. These are important aspects that policies will need to take into account to accompany the massive process of land use and tenure conversion whilch will continue to occur over the coming decades in sub-Saharan Africa,

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Appendix A: Theory

Symmetric information

Probability of land formalization

Let $\widehat{q}(x)$ be the inverse function of $\widehat{x}(q)$. We consider two cases. In the first case, when $\widehat{x}$ is an increasing function of q, the threshold $\widehat{q}(x)$ is also an increasing function of distance to CBD, x, so that sales take place for high customary enforcement levels $q \in [\widehat{q}(x), \overline{q}]$. A land plot located at x is formalized with probability

$$Pr(x \text{ formalized}) = \int_{\widehat{q}(x)}^{\overline{q}} \pi(\mathrm{q}) \mathrm{d}G(q),$$

which falls with larger x. Furthermore, the probability that customary land with non-statutory right is purchased and formalized with statutory right at location x is given by

$$Pr(x \text{ formalized} \mid \text{purchased}) = \frac{\int_{\widehat{q}(x)}^{\overline{q}} \pi(\mathrm{q}) \mathrm{d}G(q)}{\int_{\widehat{q}(x)}^{\overline{q}} \mathrm{d}G(q)}.$$

One can calculate that

$$\frac{d}{dx} \log Pr(x \text{ formalized} \mid \text{purchased}) = -\widehat{q}' G' \frac{\int_{\widehat{q}}^{\overline{q}} (\pi(\mathrm{q}) - \pi(\hat{\mathrm{q}}))\, \mathrm{d}G(q) * \int_{\widehat{q}}^{\overline{q}} \mathrm{d}G(q)}{\int_{\widehat{q}}^{\overline{q}} \pi(\mathrm{q}) \mathrm{d}G(q)}.$$

This is negative because $\widehat{q}' > 0$ and $\pi(q) \geq \pi(\hat{q})$ in the first integral as π is an increasing function of q. Hence, the latter probability decreases with x.

In the second case, when $\widehat{x}(q)$ is a decreasing function, the threshold $\widehat{q}(x)$ is also a decreasing function and sales take place for low customary enforcement levels $q \in [\underline{q}, \widehat{q}(x)]$. The probability of land conversion conditional on distance to CBD, given by

$$Pr(x \text{ formalized}) = \int_{\underline{q}}^{\widehat{q}(x)} \pi(\mathrm{q}) \mathrm{d}G(q),$$

also falls in distance x. Similarly, the probability that customary land with non-statutory right is purchased and formalized at location x,

$$Pr(x \text{ formalized} \mid \text{purchased}) = \frac{\int_{\underline{q}}^{\widehat{q}(x)} \pi(\mathrm{q}) \mathrm{d}G(q)}{\int_{\underline{q}}^{\widehat{q}(x)} \mathrm{d}G(q)}.$$

is also a decreasing function of x. One indeed has that

$$\frac{d}{dx} \log Pr(\text{x converted} \mid \text{purchased}) = \widehat{q}' G' \frac{\int_{\underline{q}}^{\widehat{q}} (\pi(\hat{\mathrm{q}}) - \pi(\mathrm{q}))\, \mathrm{d}G(q) * \int_{\underline{q}}^{\widehat{q}} \mathrm{d}G(q)}{\int_{\underline{q}}^{\widehat{q}} \pi(\mathrm{q}) \mathrm{d}G(q)},$$

which is negative because $\widehat{q}' < 0$ and $\pi(\hat{q}) \geq \pi(q)$ in the first integral as $\pi' > 0$. To sum up, under symmetric information, the probability that customary land with non-statutory right is purchased and converted with statutory right at location x is a decreasing function of this distance.

Proof of corollary 1:

We show that, for any specific tenure risk q, the geographical extent of equilibrium transactions is larger than that of the benchmark case, $\widehat{x}(q) \leq \tilde{x}$, if and only if

$$[\Pi(q) - q]\, v_S(\tilde{x}) \leq \pi(q)\, c. \tag{24}$$

Fix q and dispense with reference q for the sake of conciseness. Using (1), (3), (4) and (8), we get

$$\begin{aligned} qv_S(\tilde{x}) \quad &= \quad q(a(\tilde{x}) - u), \\ \Pi v_S(\hat{x}) \quad -\pi c = \quad &q(a(\hat{x}) - u). \end{aligned}$$

Write $G(x) = \Pi v_S(x) - \pi c - q(a(x) - u)$. Then, in the equilibrium we have $G(\hat{x}) = 0$ by construction and $G' < 0$ to satisfy a spatial equilibrium with land transactions on the interval $[0, \hat{x}]$. It readily comes that $\widehat{x} \leq \tilde{x}$ iff $G(\hat{x}) = 0 \geq G(\tilde{x})$. We then successively get $G(\tilde{x}) = \Pi v_S(\tilde{x}) - \pi c - q(a(\tilde{x}) - u) = \Pi v_S(\tilde{x}) - \pi c - q v_S(\tilde{x}) = (\Pi - q)\, v_S(\tilde{x}) - \pi c \leq 0$, which gives result (24).

Asymmetric information

Figure 7 represents buyers' expected profit in a given location x under asymmetric information when the equilibrium price $p^{**}(x)$ maps in the interior of the interval $(\underline{q}(a(x) - u), \overline{q}(a(x) - u))$ as given by eq. (13). Figure 8 represents the land transaction and formalization equilibrium incorporating both corner and interior price solutions given by $p^*(x)$ (eq. 12) and $p^{**}(x)$ (eq. 13).

Figure 7: Buyers' expected gain under asymmetric information (interior p^{**})

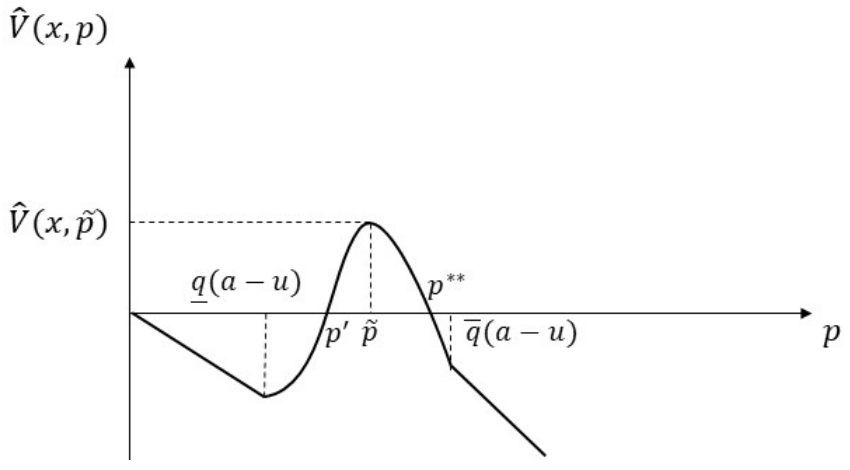
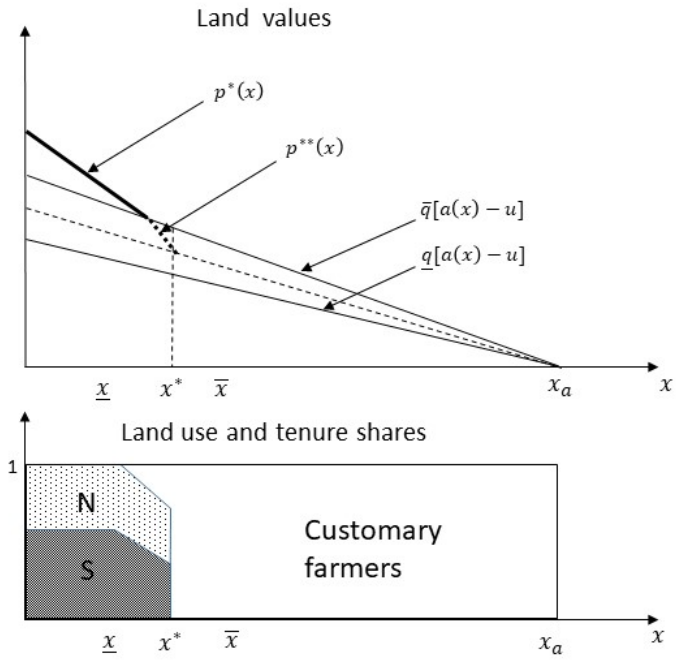


Figure 8: Land transactions and formalization under asymmetric information (with corner p^* and interior p^{**})



Note: The top panel displays the land values of customary farmers and the price paid by urban buyers in each location represented by the gray line. The bottom panel shows land use and tenure status after the buyers' attempt to formalization. S and N stand for statutory and non-statutory residential land respectively.

Proof of Proposition 3. We need to prove that condition (16) implies $(d/dx)\widetilde{V}(x) < 0$ for all $x \in [0, x_a]$. First suppose that the equilibrium price is the corner solution (12). Then,

$$\begin{aligned}
\frac{d}{dx}\widetilde{V}(x) &= \frac{d}{dx}\left\{\int_{\underline{q}}^{\overline{q}} p^o(x,q)\mathrm{d}G(q) - \overline{q}\left[a(x)-u\right]\right\} \\
&= \frac{dp_S}{dx}\int_{\underline{q}}^{\overline{q}} \Pi(q)\mathrm{d}G(q) - a'(x)\overline{q} \\
&= -t\int_{\underline{q}}^{\widetilde{q}(x)} \Pi(q)\mathrm{d}G(q) + \tau\alpha s\overline{q}.
\end{aligned}$$

So,

$$\frac{d}{dx}\widetilde{V}(x) < 0 \iff t > \tau\alpha s\frac{\overline{q}}{\int_{\underline{q}}^{\overline{q}}\Pi(q)\mathrm{d}G(q)}.$$

This is implied by condition (16).

Second suppose that the equilibrium price is the highest interior solution (13). Let $\widetilde{p}(x) \equiv \arg\max_p V(x,p,Q(x,p))\geq 0$, which solves the first order condition $p^o(x,\widetilde{q}(x))g(\widetilde{q}(x)) = a(x)-u$ where $\widetilde{q}(x) \equiv \widetilde{p}(x)/[a(x)-u] \in [0,1]$. Using this property and definition we successively have

$$\begin{aligned}\frac{d}{dx}\widetilde{V}(x) &= \frac{d}{dx}\left\{\int_{\underline{q}}^{\widetilde{p}(x)/(a(x)-u)} p^o(x,q)\mathrm{d}G(q) - \widetilde{p}(x)\right\} \\ &= \frac{dp_S}{dx}\int_{\underline{q}}^{\widetilde{q}(x)} \Pi(q)\mathrm{d}G(q) - \frac{a'(x)}{(a(x)-u)^2}\widetilde{p}(x)p^o(x,\widetilde{q}(x))g(\widetilde{q}(x)) \\ &= -t\int_{\underline{q}}^{\widetilde{q}(x)} \Pi(q)\mathrm{d}G(q) + \tau\alpha s\widetilde{q}(x).\end{aligned}$$

So,

$$\frac{d}{dx}\widetilde{V}(x) < 0 \quad \Longleftrightarrow \quad t > \tau\alpha s\frac{\widetilde{q}(x)}{\int_{\underline{q}}^{\widetilde{q}(x)} \Pi(q)\mathrm{d}G(q)}.$$

This is also implied by condition (16).

Proof of Proposition 4.

We compare the geographical extent of market activity under asymmetric and full information by comparing the borders x^* and $\overline{x}$. Note that there is no land transaction for $x \geq \overline{x}$ under symmetric information because $p^o(x,q) - q\left[a(x)-u\right] \leq 0$ by (6). Under asymmetric information, land transactions do not take place if $\widetilde{V}(x) < 0$ for $x \geq \overline{x}$. To see that this is true, let us denote the maximizing price by $\widetilde{p}(x)$ and, for clarity, let us define $\widetilde{q}(x) \equiv \widetilde{p}(x)/[a(x)-u] \in [0,1]$ so that $\widetilde{V}(x) = \int_{\underline{q}}^{\widetilde{q}(x)} p^o(x,q)\mathrm{d}G(q) - \widetilde{q}(x)\left(a\left(x\right)-u\right)$. This can be rewritten as

$$\widetilde{V}(x) = \int_{\underline{q}}^{\widetilde{q}(x)} \left[p^o(x,q) - q\left(a\left(x\right)-u\right)\right]\mathrm{d}G(q) - \left(a\left(x\right)-u\right)\left[\widetilde{q}(x) - \int_{\underline{q}}^{\widetilde{q}(x)} q\mathrm{d}G(q)\right],$$

which is negative because the first integral term is negative for any $x \geq \overline{x}$ by (6) and the second term is negative as $\widetilde{q}(x) \geq \int_{\underline{q}}^{\widetilde{q}(x)} q\mathrm{d}G(q)$. Hence, this shows that $x^* < \overline{x}$. Intuitively, customary land buyers have no incentives to formalize a bunch of land plots under asymmetric information if they have no incentive to formalize them separately under symmetric information. To sum up, the conversion of land tenure and use takes place within a smaller geographical extent under asymmetric information than under full information: that is, $x^* < \overline{x}$.

Secondary land market

Primary market with symmetric information We first consider that primary market transactions take place under symmetric information. Assuming

$$\theta(q)v_S(x) > q(a(x)-u) \quad \forall q \in [\underline{q},\overline{q}], x < \bar{x}, \tag{25}$$

the primary and secondary markets are both active for land on the interval $[0,\widehat{x}^n(q)]$, only the

primary market is active for land on $(\widehat{x}^n(q), \widehat{x}(q)]$, and there is never any market activity for land with $x > \widehat{x}^n(q)$. Let us consider $\widehat{q}(x)$ and $\widehat{q}^n(x)$ the inverse function of $\widehat{x}(q)$ and $\widehat{x}^n(q)$. Because $\widehat{x}^n(q)$ is a decreasing function, $\widehat{q}^n(x)$ is also a decreasing function. Hence, first and secondary market activity take place for all enforcement probabilities $q \in [\underline{q}, \widehat{q}^n(x)]$. Land active only in the primary market has tenure probabilities $q \in [\widehat{q}^n(x), \widehat{q}(x)]$. As a result, the probability that a plot is formalized conditional on its location x is given by

$$Pr(x \text{ formalized}) = \int_{\underline{q}}^{\widehat{q}^n(x)} [1 - (1 - \pi(\mathrm{q}))^{\mathrm{n}}] \, \mathrm{d}G(q) + \int_{\widehat{q}^n(x)}^{\hat{q}(x)} [1 - \pi(\mathrm{q})] \, \mathrm{d}G(q)$$

This expression collapses to the same result as that obtained for the primary market when the secondary market has not yet emerged, i.e. when $n = 1$. Note firstly that this probability increases with successive attempts as the integrand in the first term increases with larger n. After infinitely many resales ($n \to \infty$), secondary market land with enforcement probabilities $q \in [\underline{q}, \widehat{q}^n(x)]$ is fully converted to statutory rights so that the first term is equal to $G(\widehat{q}^n(x))$. When $\widehat{q}^n(x) \geq 1$, this is equal to one so that all land at distance to CBD below $\widehat{x}^n(q)$ is converted. Otherwise, there is a fringe of low risk plots ($q \in [\widehat{q}^n(x), \widehat{q}(x)]$) that is not formalized (second term). To sum up, after many resales, the city has an inner zone with statutory rights and a peri-urban zone with non-statutory rights.

Primary market with asymmetric information. As explained in the text, there are three possible land tenure structures. First, if $\widehat{x}^n(\overline{q}) \geq x^*$, the city includes primary and secondary markets for x smaller than x^* and no market beyond x^*. Second, if $\widehat{x}^n(\underline{q}) < x^*$, the city includes primary and secondary markets for all $x \in [0, \widehat{x}^n(q)]$, a primary market for $x \in (\widehat{x}^n(q), x^*]$,and no market for x beyond x^*. Finally, if $\widehat{x}^n(\overline{q}) < x^* \leq \widehat{x}^n(\underline{q})$, the city includes primary and secondary markets for $x \in [0, \min\{\widehat{x}^n(q), x^*\}]$, a single primary market for $x \in [\min\{\widehat{x}^n(q), x^*\}, x^*]$, and no market beyond x^*.

Let us consider $\widehat{q}^n(x)$ the inverse function of $\widehat{x}^n(q)$. Because $\widehat{x}^n(q)$ is a decreasing function, $\widehat{q}^n(x)$ is also a decreasing function. Let $\widehat{q}^* = \widehat{q}^n(x^*)$. Then, primary and secondary market activity take place for all enforcement probabilities $q \in [\underline{q}, \min\{\widehat{q}^n(x), \widehat{q}^*\}]$. Land transacted only in the primary market has tenure probabilities $q \in [\widehat{q}^n(x), \widehat{q}^*]$. As a result, the probability that a plot is converted conditional on its location $x \leq x^*$ is given by

$$Pr(x \text{ formalized}) = \int_{\underline{q}}^{\widehat{q}^n(x)} [1 - (1 - \pi(\mathrm{q}))^{\mathrm{n}}] \, \mathrm{d}G(q) + \int_{\widehat{q}^n(x)}^{\overline{q}} [1 - \pi(\mathrm{q})] \, \mathrm{d}G(q).$$

As $n \to \infty$, the first term tends to $G(\widehat{q}^n(x))$. So, there exists an urban fringe where urban workers prefer not to resell their non-statutory land plots.

Appendix B: Survey methodology and data

The survey was funded by the World Bank's Multi-Donor Trust Fund for Sustainable Cities and implemented by the World Bank (Principal Investigator: Harris Selod).

The survey covers the urban and peri-urban areas of Bamako and its rural hinterland. The urban area includes the six municipalities I, II, III, IV, V and VI of the Bamako District. The peri-urban area includes the urbanized or urbanizing parts of eight adjacent municipalities (Baguineda, Dogodouman, Dialakorodji, Moribabougou, Mandé, N'gabacoro-droit, Kalabankoro and Sangarébougou). The rural hinterland corresponds to the zones that are not yet urbanized but are within the Bamako land market in which Bamako residents are active.

The survey design aimed to collect a sufficient number of observations on land transactions to characterize land uses and tenure situations in the Bamako urban area and its surroundings. After implementation, data was collected for 1,655 observations that uniformly covered the studied area. This allowed a margin of error of 5% of the population standard deviation at a bilateral confidence level of 5%.

The sampling approach followed from the absence of a sample frame and the lack of information required to define spatial strata for a survey of land plots and transactions representative of Bamako area's land market. Indeed, there was no record of the past transactions of non-statutory land plots, no exhaustive and accurate records of past transaction of statutory land plots, and finally no database about commuting patterns in the surroundings of Bamako. The retained approach aims at a wide coverage of the area taking into account all possible tenure situations.

The enumerators were chosen among geographer professionals, members of the *Association des Jeunes Géographes du Mali*. The data collection standards were applied by the World Bank (full training of enumerators, piloting of questionnaire, data collection monitoring and quality control). Data was collected between February and April 2012.

The enumerators were instructed to drive along the five main radial roads ("goudron") and the river banks starting from the CBD and stopping at intervals of approximately 3 kms. At each stop, they were asked to inquire about land plots that were transacted as unbuilt plots since 2009 in the same geographical zone. They were asked to cover the plots at various distances from the main road in the inland area. To identify the relevant transactions, they were required to discuss with local residents, customary authorities (village chiefs), civil society organizations, civil servants, construction workers, etc. Information of each transaction was cross-checked from various sources.

Collected information includes the GPS coordinates of the parcel, price, tenure at both the time of the transaction and the time of the survey, intended land use (i.e., residential *vs.* agricultural), plot size, infrastructure and services, municipality, and distance to paved main road and river.

In this text we report as land with statutory rights plots with registered titles (*"titres fonciers"*)

and permits to occupy (*"concessions urbaines à usage d'habitation"*). We report as land with no statutory rights plots with administrative documents (*"petits papiers"*) and absence of any documentation. For more details on these tenure situations, see the book by Durand-Lasserve et al. (2015). All prices are nominal and reported in CFA francs (with CFA 1,000 approximately equal to EUR 1.5).

The distance to the CBD is defined as the straight line distance (kilometer) to the "Cité Administrative" of Bamako.

We drop 175 observations that have no reported price and 162 observations located farther than 40 km from the city center because they imply trips with more than 60 minutes and can be considered to lie outside the Bamako catchment area. We further drop 56 observations of land transactions without residential or agricultural use, 2 zero price observations and 1 observation without distance to paved road, which leaves $1,259$ observations. We finally drop 24 inconsistent observations with statutory land plots sold by customary owners. (Results do not change if we include those transactions in the set of residential statutory plots offered by non-customary sellers.) This leaves 1231 observations.

Appendix C: Robustness checks

As a first set of robustness checks, we replicate the regression analysis presented in Table 3 with the introduction of additional controls. Results are presented in Table 7. Column (1) is the same as Column (4) in Table 3 and is used as a benchmark. We first control for potential differences in bargaining powers of buyers and sellers. Column (2) includes dummies for buyers' occupational groups (see Table 2). Column (3) includes dummies for a finer typology of buyers' occupations as reported in the survey. Column (4) includes the residential location of the buyer. Column (5) includes the occupational group of sellers (same as in Table 2). We then control potential biases associated with the survey process. Column (6) has a control dummy for each survey enumerator. Column (7) includes a dummy indicating the status of the main person providing the information on the transaction. Finally, we control for the unobserved characteristics that facilitate future investments and make the land tenure formalization more valuable. For this, Column (8) adds a dummy indicating whether an investment on the plot was made after the sale. Column (9) adds a dummy indicating whether a well was bored after the sale. Column (10) adds a dummy indicating whether the plot was connected to the electrical grid after the sale. For all regressions, the estimated coefficients on our variables of interest remain almost identical to those estimated in the benchmark regression.

Table 7: Land prices and tenure (OLS, log price/m2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Distance to CBD (km)	-0.053***	-0.052***	-0.052***	-0.051***	-0.052***	-0.049***	-0.053***	-0.053***	-0.053***	-0.053***
	(0.0074)	(0.0074)	(0.0073)	(0.0073)	(0.0074)	(0.0075)	(0.0074)	(0.0074)	(0.0074)	(0.0074)
Non-staturoty plot., customary seller	-1.20***	-1.19***	-1.18***	-1.14***	-1.16***	-1.19***	-1.17***	-1.20***	-1.19***	-1.20***
	(0.12)	(0.12)	(0.11)	(0.12)	(0.13)	(0.13)	(0.12)	(0.12)	(0.12)	(0.12)
Non-statutory plot, non-customary seller	-0.98***	-0.98***	-0.96***	-0.93***	-0.97***	-0.95***	-0.98***	-0.98***	-0.97***	-0.99***
	(0.083)	(0.082)	(0.080)	(0.084)	(0.086)	(0.089)	(0.084)	(0.083)	(0.083)	(0.082)
Non-stat., non-cust. seller * conversion	0.51***	0.53***	0.50***	0.50***	0.50***	0.51***	0.51***	0.51***	0.49***	0.51***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)
Distance to main road (km)	-0.068***	-0.068***	-0.069***	-0.067***	-0.064***	-0.069***	-0.066***	-0.069***	-0.068***	-0.068***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)	(0.015)	(0.015)	(0.015)	(0.015)
Area (log m^2)	-0.62***	-0.62***	-0.63***	-0.62***	-0.62***	-0.61***	-0.61***	-0.61***	-0.61***	-0.62***
	(0.084)	(0.084)	(0.083)	(0.084)	(0.084)	(0.084)	(0.082)	(0.084)	(0.087)	(0.086)
Water dummy	0.44*	0.46*	0.48**	0.43*	0.38*	0.33	0.44*	0.44*	0.40*	0.44*
	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.19)	(0.17)	(0.18)	(0.18)	(0.19)
Electricity dummy	0.61*	0.61*	0.68**	0.69**	0.61*	0.46	0.70**	0.61*	0.46*	0.65
	(0.27)	(0.27)	(0.24)	(0.26)	(0.25)	(0.26)	(0.24)	(0.27)	(0.22)	(0.41)
Observations	980	980	980	980	980	980	978	980	980	980
Adjusted R^2	0.764	0.765	0.768	0.767	0.766	0.766	0.763	0.764	0.765	0.763

Note: Natural logarithms. Column (1) is the baseline OLS regression including controls for year and municipality fixed effects. Column (2) includes dummies for buyers' occupational groups (see Table 2). Column (3) includes dummies for a finer typology of buyers' occupations as reported in the survey (farmer, merchant, private employee, liberal profession, intermediary, agent of state or municipality, police/military, elected or responsible person at state and municipal level, other, unknown). Column (4) includes the residential location of the buyer (same plot, same Bamako municipality, other Bamako municipality, other Malian city, outside Mali, unknown). Column (5) includes the occupational group of sellers (same as in Table 2). Column (6) has a control dummy for each survey enumerator. Column (7) includes a dummy indicating the status of the main person providing the information on the transaction (buyer, occupier or seller of the plot, village inhabitant or chief, intermediary). Column (8) adds a dummy indicating whether an investment on the plot was made after the sale. Column (9) adds a dummy indicating whether a well has was bored after the sale. Column (10) adds a dummy indicating whether the plot was connected to the electrical grid after the sale. All regressions have robust standard errors. All regressions have robust standard errors. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001

In a second robustness check (Table 8), we replicate the regression analysis presented in Table 3 with the *price level* as the dependent variable. As prices differences are larger in the data sets, the regression of the price level has less explanatory power compared to that of the logarithm of the price. The results are nevertheless qualitatively similar to those found in Table 3. The main difference is that coefficients should be interpreted as effects on price levels. Column (2) shows significant coefficients on the dummies for non-statutory plots sold by each type of seller (irrespective of their subsequent formalization). Column (3) informs us on the existence of asymmetric information. For customary sellers, the coefficient of the interaction between tenure and subsequent conversion is not significantly different from zero, whereas, for non-customary sellers it is positive and significant. This suggests the existence of information asymmetry cannot be rejected for purchases from customary sellers but is rejected for purchases from non-customary sellers. Other columns permit similar robustness conclusion as for Table 3.

Finally, in Table 9, we present an analysis bias-adjusted coefficient as discussed in Oster (2019). It showns that the coefficients on tenure and conversion are particularily stable with respect to the assumption on unexplained variations and correlations with treatment variables. Such a stability of the effect of tenure for both customary and non-customary seller and the large effect of formalization for non-customary sellers confirms the existence of tenure risk and the presence of symmetric information in the secondary market where non-customary sellers transact non-statutory plots.

Table 8: Land prices and tenure (OLS, priceCFA/m^2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance to CBD (km)	-473.2***	-169.5***	-158.4***	-159.2***	-373.0***	-161.3***	-997.7***
	(64.6)	(41.6)	(42.7)	(42.4)	(57.7)	(40.6)	(291.3)
Non-stat., cust. seller		-3959.7***	-4293.4***	-4242.1***	-4033.2***	-12169.0***	-16070.4***
		(594.4)	(614.6)	(618.0)	(703.8)	(1783.2)	(2092.0)
Non-stat. cust. seller * conversion			459.6				
			(1282.7)				
Non-stat. non-cust. seller		-3659.7***	-4134.2***	-4124.5***	-4399.6***	-12043.6***	-15706.3***
		(504.4)	(522.3)	(520.5)	(669.1)	(1778.2)	(2104.0)
Non-stat. non-cust. seller * conversion			1810.0*	1800.5*	1484.8	1252.0	1017.0
			(841.1)	(839.8)	(846.5)	(803.1)	(814.3)
Permit to occupy						-10384.8***	-9939.9***
						(2031.0)	(1945.8)
Distance to CBDˆ2 (km^2)							3.85
							(6.51)
Non-stat. cust. seller * dist. CBDˆ2							15.6***
							(4.02)
Non-stat. non-cust. seller * dist. CBDˆ2							15.3***
							(4.10)
Distance to main road (km)	-357.1***	-120.0**	-112.3**	-112.6**	-142.6**	-127.9**	-136.3**
	(62.4)	(44.3)	(42.3)	(42.5)	(52.1)	(43.3)	(42.2)
Area (log m^2)	-561.9	-334.0	-424.2	-413.3	-487.8	-726.4	-1094.5
	(794.0)	(721.0)	(743.0)	(735.5)	(688.2)	(696.2)	(618.9)
Water dummy	9263.0*	6362.7	6377.6	6390.3	5835.6	6934.8*	6628.2*
	(4230.4)	(3387.0)	(3400.0)	(3390.3)	(3064.7)	(3270.1)	(3146.7)
Electricity dummy	13569.1	12708.6	12290.7	12278.0	14939.0	7362.6	8088.0
	(9991.6)	(10629.2)	(10677.7)	(10671.1)	(9618.8)	(9906.2)	(9205.2)
Municipality dummy	N	Y	Y	Y	N	Y	Y
Catchment area dummy	N	N	N	N	Y	N	N
Year dummy	Y	Y	Y	Y	Y	Y	Y
Observations	980	980	980	980	980	980	980
Adjusted R^2	0.288	0.593	0.594	0.594	0.475	0.640	0.664

Note: The dependent variable is the price (CFA) per square meter of transacted land plots. 'Non-statutory customary seller' (respectively 'non-statutory non-customary seller') is a dummy variable equal to 1 if the seller was a customary holder (respectively a non-customary holder) offering a non-statutory plot. 'Formalization' designates land that has been formalized to a statutory right by the time of the survey. All columns include year dummies to control for price inflation. Columns (2)-(4) and (6)-(7) include municipality dummies to control for unobserved spatial amenities. Column (5) includes a catchment area dummy as an alternative control for unobserved spatial amenities. All columns include controls for distance to the nearest main paved road, the log area of the plot, and dummies for the presence of water and electricity. Column (1) report effects of the distance to the CBD. Column (2) includes dummies for customary and non-customary sellers. Column (3) further breaks down the seller dummies depending on whether the plot was subsequently converted or not by the time of the survey. This justifies the specification in Column (4) which distinguishes only subsequent formalizations of transactions with non-customary sellers. Column (5) replaces municipality controls with control for catchment areas (bins of distance from the CBD given by 0-5km,5-10km,10-15km,15-20km and 20-40km, for roads extending north, north-west and south from the city center). Columns (6) adds a control for 'permits to occupy' at the time of the transaction to distinguish between the price of permits from those of titles. Column (7) adds the square of the distance to the CBD as a control and interacts it with each tenure type to check for the concavity of log price patterns with distance for each tenure category. All regressions have robust standard errors. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 9: Oster bias-adjusted coefficient analysis

	Uncontrolled regression		Controlled regression		Coefficient value				
	Coefficient value	R2	Coefficient value	R2	delta:	0.9	0.9	1	1
					R2 max:	0.9	1	0.9	1
	(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)
Distance to CBD (km)	-0.089	0.342	-0.052	0.781		-0.022	0.025	-0.017	0.047
Non-stat., cust. seller	-1.241	0.342	-1.810	0.781		-2.521	-4.262	-2.679	-5.525
Non-stat. cust. seller * formalization	0.145	0.301	0.130	0.781		0.346	0.385	0.350	0.396
Non-stat. non-cust. seller	-0.801	0.342	-1.567	0.781		-2.842	-5.054	-3.187	-6.912
Non-stat. non-cust. seller * formalization	-0.339	0.342	0.473	0.781		0.842	1.247	0.892	1.370

Note: This table presents a bias-adjusted estimation as in discussed in Oster (2019). The base regression is taken from Table 3 with five treatement variables displayed in each above row and with controls used in Table 3. Columns (1) to (2) provide the estimated coefficient and the coefficient of determination R2 of each regression model without controls. Columns (3) to (4) presents the same for the estimation with all observable variables. Columns (5) to (8) provide the re-estimated coefficients under the first assumption that unobserved variables correlate as much with the treatment variable as the observed ones (delta=1) or less than those (delta=0.9) and the second assumption that omitted variables represent 90% and 100% of unexplained variations (R2 max = 0.9 and 1). It is shown that all re-estimated coefficients on tenure and formalization keep the same sign whatever the assumption on unexplained variations and correlations with treatment variables. Such a stability of the effect of tenure for both customary and non-customary seller and the large effect of formalization for non-customary sellers confirms the existence of tenure risk and the presence of symmetric information in the secondary market where non-customary sellers transact non-statutory plots. The coefficient on distance is however less stable as it changes its sign under the assumption that omitted variable explains all the regression variation (R2 max=1). Such an assumption may be too strong as it forbids any kind of measurement errors or slight functional specification errors in commuting costs.