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Customary Land Conversion and the Formation of the African City

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Abstract

As cities grow and spatially expand, agricultural land is converted into residential land. In many developing countries, especially in Sub-Saharan Africa, this process is accompanied by a change in land tenure, whereby plots held under traditional customary arrangements are sold to new urban residents, possibly with formal property rights. This paper studies joint land-use and land-tenure conversion in an urban economics model in which intermediaries purchase agricultural land from customary owners and attempt to transform it into residential plots with statutory property rights. The spatial equilibrium includes a mix of land uses and rights where statutory and non-statutory residential plots coexist with customary land that is mainly used for agriculture. Because customary ownership is subject to uncertainty (because of tenure insecurity), the conversion process includes a potential information asymmetry between customary owners and intermediaries. The analysis shows that a market failure may emerge whereby some customary owners prefer to continue farming their land rather than participate in the urban residential land market, which results in a city that is too small. Empirical analysis using Malian data validates the key features of the model captured by land price gradients, as well as the ranking and the variance of land prices, and is suggestive of the presence of information asymmetry.

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1 Introduction

Cities are growing at an unprecedented pace in countries in Sub-Saharan and Asia and the trend is expected to continue over the first half of the twenty-first century. In Sub-Saharan Africa alone, the urban population is projected to increase by an additional 800 million residents by 2050, an almost threefold increase in just over three decades (United Nations, 2018). With such a large urban population growth fueling demand for land, cities in Sub-Saharan Africa will also continue to expand spatially in very significant proportions (Angel, 2012). As countries in the region are largely rural, urban expansion will continue to involve a massive process of land use conversion whereby agricultural land in peri-urban areas is transformed into urban residential land (Locke and Henley, 2016, Camara, 2017). With land plots in peri-urban areas still overwhelmingly governed by a customary system of land allocation (Durand-Lasserve et al., 2015, World Bank, 2020),[1] this has two major implications. First, because land for housing is developed in a decentralized fashion, peri-urban land is being purchased from customary owners by private intermediaries and sold to urban residents (Mends and De Meijer, 2006, Naab et al. 2013, Durand-Lasserve et al. 2015). As land exits the customary system, it becomes tradable individual property, a phenomenon described in the anthropological literature as a "commodification of land" or the "emergence of land markets" (Wehrmann, 2005). Second, the process of land-tenure individualization that accompanies urban expansion simultaneously involves a conversion of land tenure from customary rights to either formal statutory rights (i.e., the establishment and registration of titled deeds, or the granting of use rights by public authorities) or, in many other instances, to the absence of any statutory right, fueling the informal land market (Durand-Lasserve et al. 2015, Camara 2017). It is notable that the conversion of customary tenure to a statutory right is neither an instantaneous nor a riskless process. For instance, a land plot may be sold by an illegitimate owner, or multiple claimants may sell the same land plot to different buyers simultaneously. In fact, 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). This is why buyers of peri-urban customary land who can afford to pay formalization fees may choose to convert their tenure to a statutory property right and therefore remove–or significantly reduce–the risk of subsequently losing their plot (Barry and Danso, 2014). However, because of tenure insecurity and barriers to formalization, the process of land-use conversion that accompanies urban expansion is likely to occur in inefficient ways. Understanding how the land use conversion process happens on the ground and what

[1] Customary land systems refer to traditional norms and institutions that 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 10 cola nuts). Because no money is involved in the exchange, there are no land markets. Even though land is "owned" by the allottee and can be inherited by his children, it cannot be sold and it is only held under the social understanding that the ultimate owner of the land is the community (Paaga, 2013). In theory, land can be taken back in the future by customary authorities and reallocated to other users.

the associated inefficiencies are is a prerequisite to inform any policy that will aim to accompany population growth and urban expansion in Sub-Saharan Africa. This is the purpose of this paper.

To our knowledge, our paper is the first to provide a joint theory of customary land sales and land tenure conversion. Using a monocentric-city 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 our framework, all the land is initially in the hands of customary owners who practice agriculture. Intermediaries (labeled "brokers") purchase land from customary owners and attempt to formalize tenure as a means to reduce tenure insecurity before reselling plots to incoming urban workers. These brokers actually encompass a variety of stakeholders who transform land and tenure, including informal brokers (known as "coxers"), real estate agents, developers and private individuals.[2] It is assumed that only brokers but not customary owners can convert tenure. This is because customary owners, who usually are agricultural laypersons, usually do not have the capacity to navigate the administration. The tenure formalization attempts of brokers, 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. Furthermore, land plots are heterogeneous in the probability of land tenure formalization, an assumption which reflects the variety of situations that can lead to a conflict (such as disputed inheritance among family members, or local disputes regarding the allocation of the plot by village customary authorities, etc.). Although brokers cannot avoid the risk of a formalization failure, they may be able to assess it to some extent. We first analyze the case where brokers can obtain complete information on this risk. Then, their business is simply to acquire land from a customary owner and to attempt to establish statutory rights on the plot. If successful, they have to pay a conversion fee (which may cover various expenses ranging from land surveying fees to registration in the cadaster). We then contrast this with the case where brokers 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 different stakes in the ownership of a land plot. We show that brokers then face an additional problem of adverse selection as customary owners may choose to offer the riskiest plots for sale. The information asymmetry causes a land market failure, as transactions fail to take place at some specific distance from the city center.

The paper also provides a framework for an empirical analysis of land tenure conversions in Sub-Saharan African cities. It exploits a unique survey of land plots in Bamako, Mali, that were transacted between 2009 and 2012 and unbuilt at the time of

[2]In Mali, coxers are land brokers who facilitate transactions between customary owners and buyers. According to Durand-Lasserve et al. (2015), they maintain a network of informers in peri-urban villages to identify land that can be transacted. They negotiate with village authorities on behalf of buyers and are therefore key players in the conversion of customary agricultural land into residential land. They know how to circumvent regular procedures and deal with the administration to make sales and land tenure conversion effective. They can be found alongside roads, near plots for sale.

the transaction (Durand-Lasserve et al. 2015). The empirical analysis provides several pieces of evidence corroborating the main predictions of the theoretical model with informed brokers. In particular, it is shown that formalization from non-statutory to statutory rights decays with distance from city center. Furthermore, as predicted by the model, the land price gradient (i.e., the price change with respect to distance from the city center) is smaller for non-statutory land plots that were upgraded to statutory rights after their purchase than for the plots that were already held under statutory rights when purchased. It is also shown that the variance in the price of non-statutory land plots is higher than that of statutory land plots, reflecting that there are greater variations in risk for the former than for the latter. Finally, although the analysis is suggestive of the presence of information asymmetry, it does not provide a strong support towards price patterns that would be consistent with a strong adverse selection issue generated by the brokers' lack of information about the risk of non-statutory land tenure.

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 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 contexts of an inelastic urban land supply.[3] Our paper nevertheless does not address the issue of the violation of existing property right as highlighted in squatting models. Instead, we study the transformation of a type of informal right to other types of informal and formal rights. A handful of models have recently embedded tenure transformation 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 the 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 dynamic stochastic model with internal migration. After calibrating their model, they simulate the long-term trajectory of formal and informal land uses in a city and study the persistence of in-

[3]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.

formal urban land use in developing country contexts. 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 submarket 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, simulate and calibrate it for the city of Cape Town, South Africa. Other recent contributions have also studied 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, 2017, Henderson et al., 2018, Cavalcanti et al., 2019).

As in this recent literature, our paper studies the coexistence of formal and informal land uses within the same urban economy. Our paper, however, innovates in two important ways: First, it explicitly models customary land rights as part of the urban land system. Customary land use is omnipresent in West African cities and coexists alongside formal and informal land uses, a situation known as "legal pluralism". This is absent from the previous theoretical urban economics literature. Second, the 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, they are characterized by imprecision and local interpretation, which gives customary sellers strong private information about the transferability of their land plots' ownership. To our knowledge, the only other paper studying information asymmetry is that of Lanjouw and Levy (2002) in a non-spatial framework. 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.

Section 2 presents the general architecture of the model and sections 3 and 4 develop two versions of the model depending on whether brokers are informed or not of the levels of tenure insecurity of the customary plots they purchase. Section 5 describes the model predictions. Secion 6 contains the empirical analysis inspired by the model. The last section concludes.

2 Model

We consider an open city with a central business district (CBD) at $x = 0$ and perfectly mobile and risk neutral individuals. Individuals who live in the city may reside at various locations x from the CBD and 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 right holdings. In the first category, individuals reside and work outside the city, hold no customary land right in the 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. In conformity with reality, customary farmers are endowed with a "customary land right", which allows them not to pay any land rent. Their land plots include 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 an iceberg transport cost $\tau \in (0, 1)$ per unit of distance and farming good for carrying to and trading their production at the CBD. After exchanging their production, they can consume the homogeneous good in quantity

$$z = a(x) \equiv \alpha s(1 - \tau x),$$

where the RHS is their net income from selling their farming production from their location x. Customary farmers exist only for $x < 1/\tau$. As customary land holders, farmers hold their land plots under a customary tenure right that provides a "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). 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 land is appropriated by another customary farmer at the same location. The evicted farmer leaves the city (or becomes an urban worker, see below). Given this uncertainty, the customary farmers' expected utility 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 get 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 (which is indifferent between living in the city and the rural area) lives at distance x_a from the CBD, with

$$x_a \equiv \frac{1}{\tau}\left(1 - \frac{u}{\alpha s}\right)$$

and where $a(x_a) = u$.

The two other categories of individuals include "urban workers" who reside in the city and work at the CBD. Urban workers have identical work productivity and therefore identical wages w while they incur the same commuting cost t 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 certified land plots with fully-secure statutory rights so that they do not face any risk of eviction. If located in x, they pay the land price $p_S(x)$ for their unit residential plot. Their budget constraint is given by $w = z + tx + p_S(x)$ so that they obtain a consumption level $z = w - tx - p_S(x)$. Urban workers are perfectly mobile and free to migrate in and out of the city. The free mobility condition $u = z$ gives the statutory residential land price

$$p_S(x) = w - u - tx.$$

By contrast, urban workers holding no statutory right live on land plots with insecure tenure. They pay a price $p_{NS}(x)$ for their unit residential land with no statutory right in location x. Because their land ownership is not documented, they face the same threats of eviction that a customary farmer would face for that same plot. 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 and consume $z = w - tx - p_{NS}(x)$ where x is their residential location. With probability $1 - \theta(q)$, they are evicted, lose their land, leave the city and get a utility u so that their net utility becomes $u - p_{NS}(x)$.[4] The expected utility of a worker with no statutory right is thus given by $\theta(q)(w - tx - p_{NS}(x)) + (1 - \theta(q))(u - p_{NS}(x))$. Because, workers are free to migrate before purchasing their land, at the equilibrium, this expected utility must be equal to the outside utility level u. This gives the following price of non-statutory residential land for workers:

$$p_{NS}(x, q) = \theta(q)(w - u - tx) = \theta(q)\, p_S(x) < p_S(x).$$

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

Brokers. Land transformation from customary to statutory rights is managed by a group of perfectly competitive risk-neutral land brokers, who acquire customary land plots, attempt to establish statutory rights and resell those plots to urban workers. In our model, brokers account for the function of transforming land use and land tenure. Therefore, we assume that they cannot be evicted between their purchase and the resale of a plot but instead that they face potential conflicts over land that affect their likelihood of successfully establishing statutory property rights. More formally, a land broker offers a price $p(x)$ to acquire a unit of customary land and holds it under the tenure transformation probability $\pi(q) \in [0,1]$. This probability rises with q ($\pi' > 0$) because conflicts about land ownership carry over after land purchases. The

[4] Our framework does not require specifying what happens once the worker is evicted. The plot could be appropriated by an urban worker or resold to an urban workers at the price $p_{NS}(x)$.

probability $\pi(q)$ is also higher than the farmer's customary right enforcement probability q ($\pi(q) > q$) because the sale is generally documented and brokers use their higher social status and larger social network to prevent conflicts from materializing and threatening the certification of the land. With probability $\pi(q)$, the broker's ownership of the plot is not contested, allowing her to pay the certification cost c and obtain a statutory property right from the land administration. This property right is fully secure (there is no more risk of eviction) and transferable. In this case, the broker formally re-sells the land for a value $p_S(x)$ to urban workers and transfers the statutory property rights to them. With probability $1 - \pi(q)$, however, the broker does not succeed in certifying the land plot and thus does not incur any certification cost but resells the plot as a non-statutory residential plot at a price $p_{NS}(x, q)$.

Benchmark case. Before proceeding with the rest of the analysis, it is interesting to briefly discuss the benchmark case of free and secure property rights. The uncertainty in land property rights can be eliminated through the setting up and enforcement of a registration system (land registry or cadaster) that extinguishes competing claims and unequivocally assigns statutory property rights on each land plot. Furthermore, if the registry is costless and free to access, we can impose $q = \pi(q) = \theta(q) = 1$ and $c = 0$. This implies that all land plots have statutory rights and brokers are not needed. A farmer gets a utility $a(x)$ from her farm production and $p_S(x) + u$ 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

$$p_S(x) + u \geq a(x) \iff w - tx \geq \alpha s(1 - \tau x).$$

To fit reality, we assume that urban residences lie close to the CBD, which requires that the LHS falls more rapidly than the RHS. That is,

$$t > \alpha s \tau. \tag{1}$$

Under the above assumption, commuting costs should be higher than the costs of transporting farming goods to the CBD (corrected for farm size and farm productivity). The above condition then determines the following unique frontier between the urban workers' residential area and the urban farming area:

$$\widetilde{x} = \frac{w - \alpha s}{t - \tau \alpha s} > 0.$$

In our 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 rights. Intuitively, the residential frontier $\widetilde{x}$ expands with higher urban wages, lower commuting cost and higher unit transportation cost of farming goods.

3 Informed brokers

In this section, we study the city structure when brokers are perfectly informed about customary enforcement risks. We first determine the price that brokers pay for land

plots conditional on the level of customary right enforcement. Brokers get the revenue $p_S(x)$ or $p_{NS}(x)$, incur the certification cost c and pay the land price p. Under symmetric information, brokers know the customary enforcement level q of a given plot and have expected profit

$$V(x,p,q) = (p_S(x) - c)\,\pi(q) + p_{NS}(x,q)\,(1-\pi(q)) - p.$$

Because of land brokers' competition, customary land owners with enforcement right q are able to sell their land at a price p^o that makes brokers indifferent between making and not making a transaction (given by the zero-profit condition $V(x,p^o,q)=0$). That is,

$$p^o(x,q) = p_S(x)\Pi(q) - c\pi(q) \tag{2}$$

where

$$\Pi(q) \equiv \pi(q) + \theta\,(q)\,(1-\pi(q)) \leq 1 \tag{3}$$

is the broker's *compounded* probability of land tenure transformation and non-eviction. This is also the *ex-ante* probability that a future buyer will not be evicted (accounting for the likelihood of tenure transformation by the broker).[5] This probability rises with q (since $\Pi' = (1-\theta)\,\pi' + \theta'\,(1-\pi) > 0$).

We then focus on customary farmers' decision to transact under $p^o(x,q)$. On the one hand, customary land holders get a utility $p^o(x,q)+u$ when they sell their land and leave the city (or become urban workers). On the other hand, customary farmers get the utility $qa(x)+(1-q)u$ $(\geq u)$ when they farm their customary land with tenure insecurity. This means that they must at least obtain the utility level $u + q\,[a(x)-u]$ to transact. The transaction takes place if and only if

$$p^o(x,q) \geq q\,[a(x)-u]\,. \tag{4}$$

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 (4) falls more rapidly with x than its RHS, which is equivalent to imposing that

$$t \geq \tau\alpha s \max_{q\in[\underline{q},\overline{q}]} \frac{q}{\Pi(q)}. \tag{5}$$

This requires that commuting costs are high enough compared to the cost of moving farming goods to the city marketplace. Then, there exists a unique location $\widehat{x}(q)$ such that brokers and customary farmers with enforcement level q make a transaction for all locations $x \leq \widehat{x}(q)$ and none otherwise. We compute

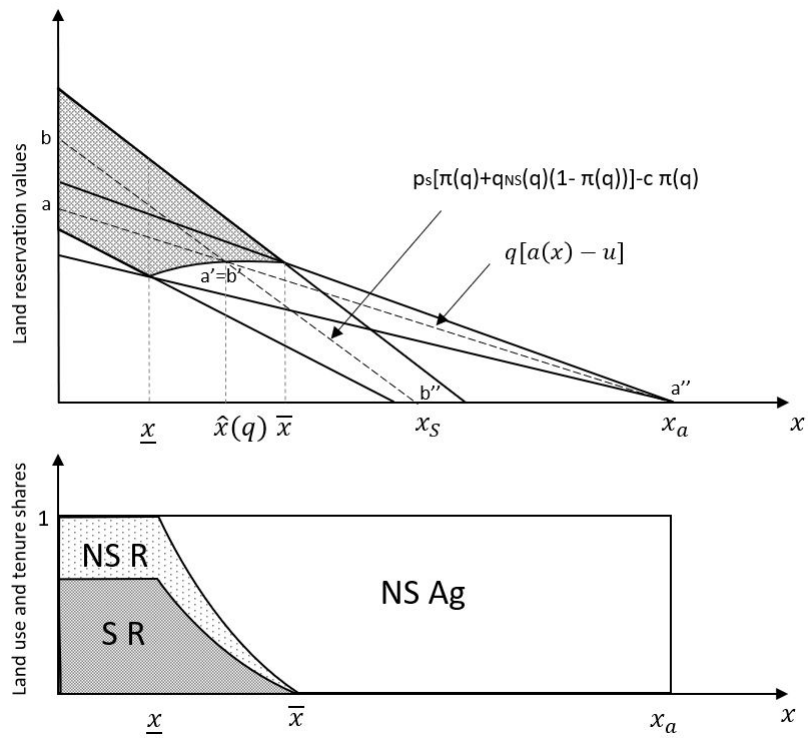
$$\widehat{x}(q) = \frac{(w-u)\,\Pi(q) - c\pi(q) - q\,(\alpha s - u)}{t\Pi(q) - \tau\alpha s q}. \tag{6}$$

[5]Indeed, $\pi(q)$ is the probability that the the broker manages to certify the plot (and sells it under a non-evictable statutory right), while $\theta\,(q)\,(1-\pi(q))$ is the probability that the plot could not be certified by the broker and that the buyer of the plot–who holds a non-statutory right–is not evicted.

This is a continuous function of q that accepts minimum and maximum values $(\underline{x}, \overline{x})$. Then, all the land remains under customary rights and is used for farming at $x \geq \overline{x}$. For $x \leq \underline{x}$, all the land is purchased by brokers: the fraction $\pi(q)$ of land with enforcement q gets certified and sold as worker residences with statutory rights, and the fraction $1 - \pi(q)$ is sold as residences with non-statutory rights. On the interval $(\underline{x}, \overline{x}]$, three types of land use and tenure exist: customary farm land and worker residences with and without statutory rights.

This is shown in the top panel of Figure 1. To understand the figure, fix the probability of keeping the land to a specific value q . Then, the dashed ray aa'' represents the reservation values of customary farmers with probability q while the dashed line bb'' corresponds to the reservation values of brokers with tenure transformation probability $\pi(q)$. The two lines intersect at $a' = b'$. Because of perfect competition, brokers' transaction prices lie on the line segment bb' when customary farmers sell their land. There is no transaction on the segment $b'b''$ because customary farmers prefer holding on to their land. The same argument applies for land with higher risk security levels q, in which cases the ray aa'' and line bb'' move up. The upper and lower continuous lines represent the loci of aa'' and bb'' for $q = \overline{q}$ and $q = \underline{q}$. Then, the gray zone represents the prices and locations where brokers acquire customary land. The bottom panel of Figure 1 depicts the shares of land use and tenure. For $x < \overline{x}$, transactions lead to a mix of statutory and non-statutory rights in proportion with brokers' probability $\pi(q)$ to establish statutory rights.

Figure 1: Land transactions and formalization under full information



Note: The top panel displays the land reservation values of customary farmers and brokers. The shaded area represents the set of values for the realized transactions between customary farmers and brokers in each location. The bottom panel shows land use and tenure status after the brokers' attempt to formalization. SR, NSR and NSAg stand for "Statutory Residential", "Non-Statutory Residential" and "Non-Statutory Agricultural" land.

Finally, to shorten and make our discussion more realistic, we assume that $\overline{x} < x_a$. 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* $x \in [\bar{x}, x_a]$*; and finally, an intermediate zone mixing customary agricultural lands and statutory and non-statutory residential land,* $x \in (\underline{x}, \overline{x})$.

It can readily be seen that $\widehat{x}$ rises with larger w and τ and with smaller t. Hence, larger earnings w and smaller commuting costs t raise the urban workers' net income and their willingness to pay for residential plots. This gives more incentives to brokers to try to acquire statutory rights in the urban core. Larger unit transport costs for farming

goods τ also diminish the customary farmers' earnings and raise their incentives to sell their land to brokers. Similarly one can show that $\mathrm{d}\widehat{x}/\mathrm{d}(\alpha s) < 0$ so that a smaller farm production raises the customary farmers' incentives to sell their land, which pushes outwards the boundary of the residential area with statutory rights.[6]

Tenure insecurity and city structure. Comparing our results from this section with those of the benchmark model presented at the end of the previous section, we can now briefly compare land market allocations with and without tenure insecurity. One can show that $\widehat{x}(q) < \widetilde{x}$ if and only if

$$\left[\frac{\Pi(q)}{q} - 1\right]\left(\frac{x_a - x_S}{\frac{1}{s\alpha\tau} - \frac{1}{t}}\right) < \frac{\pi(q)}{q}c$$

where x_S is the location where the price $p_S(x)$ is equal to 0 (see $x_S < x_a$ in Figure 1). By virtue of (1), the ratio in the LHS of this condition is positive. In conformity with reality, let us consider that the compounded probability $\Pi(q)$ is larger than the customary farmer's enforcement probability q so that both sides of the condition are positive. Then, if the certification cost is high enough, the condition holds true so that the tenure risk reduces the city extent at any enforcement probability q. This is because too a high certification cost reduces the brokers' incentives to transform the land. The opposite may however occur. For instance, the above condition does not hold if the certification cost tends to zero. In this case, by formalizing land plots, brokers increase the land value so much that customary farmers prefer to sell their insecure land plots, even though they would have held on to the same plots under fully-secured rights in the benchmark model. Hence, *the city's geographical extent may paradoxically be larger with tenure insecurity than without it.*

Other comparative statics. Comparative statics are difficult to obtain for other parameters. In general, the impact of the enforcement probability q on $\widehat{x}$ is neither linear nor monotone. To illustrate this impact, we explore the following example where $\pi(q) = \pi_0 q$, $\theta(q) = \theta_0 q$, $q \in [0, \overline{q}]$, $\pi_0 < 1/\overline{q}$, $\theta_0 \in [1, \pi_0]$. The parameter π_0 measures the ease of tenure transformation, i.e. the capacity of brokers to avoid potential conflicts and successfully navigate the formalization procedure. The higher this parameter is, the better the brokers are able to ensure the land-tenure transformation from customary to statutory rights. The parameter θ_0 measures the price discount brokers must accept when they resell non-statutory land to residents (as compared to land with a statutory right). Calculations lead to

$$\widehat{x}(q) = \frac{(w-u) - \frac{c\pi_0 + (\alpha s - u)}{\pi_0 + \theta_0(1-\pi_0 q)}}{t - \alpha\tau s \frac{1}{\pi_0 + \theta_0(1-\pi_0 q)}},$$

[6]Indeed, one can show that $\mathrm{d}\widehat{x}/\mathrm{d}(\alpha s) = \tau q\left[\widehat{x}(q) - 1/\tau\right] / \left[t\Pi(q) - \tau\alpha s q\right]$, which is positive by (5), $\widehat{x}(q) < \overline{x}$ and $\overline{x} < x_a < 1/\tau$.

which is a monotone function of q. It increases in q if and only if

$$t\left(\alpha s+\pi_0 c-u\right)<\alpha s\tau\left(w-u\right). \tag{7}$$

That is, for low enough ease of tenure transformation parameter π_0, when the schedule of customary land sales $\widehat{x}(q)$ is monotonically increasing (as in the top panel of figure 1), brokers prefer to buy the more secure land plots; in other words, the plots with higher customary security q are transacted more and up to a larger geographical extent. To see this, note that the location $\overline{x}$ has transactions with the highest customary security level $\overline{q}$ and therefore the highest probability of transformation $\pi(\overline{q})$. Conversely, the inner location $\underline{x}$ has transactions with the least secure land $\underline{q}$ and the lowest probability of transformation $\pi(\underline{q})$. According to Condition (7), brokers prefer to buy more secure land plots for a low enough ease of tenure transformation parameter π_0. Interestingly, the opposite argument obtains for a high enough ease of tenure transformation parameter π_0 and therefore for decreasing schedules $\widehat{x}(q)$. In this case, brokers attract customary owners with the lower tenure security q and transform their plots to statutory residential plots with a high probability of success. These contrasting results reflect the trade-off for the brokers between buying cheaper insecure plots and the difficulty at which they can formalize those plots. In what follows, we do not make any assumption regarding whether $\widehat{x}$ is an increasing or decreasing function of q.

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

4 Uninformed brokers

In this section we study land market allocations when brokers are unable to observe land tenure insecurity in their transactions with customary land holders. Typically, brokers are not informed about the seller's customary right enforcement q and, therefore, do not know their own enforcement probability $\pi(q)$ at the time they commit to purchasing a unit of customary land at price p. This gives rise to an adverse selection problem where brokers are offered the land with the weakest tenure security.

On the supply side of the land market, a customary land holder chooses her best option between (1) farming her insecure land, which yields a utility level $qa(x)+(1-q)u$, and (2) selling her 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 transformation, this creates an adverse selection issue between sellers and brokers. In this paper, the seller's value stems from the sales of her farming production in the city center $a(x)$. The idea would readily extend to any other value created by city center proximity for customary owners such as access to shopping, public administration, informal work, etc.

On the demand side of the market, brokers pay the land price with certainty but obtain a revenue $p_S(x) - c$ with probability $\pi(q)$ when they are able certify the land rights and $p_{NS}(x)$ otherwise. Given the set of customary enforcement levels Q, they make the expected profit

$$V(x, p, Q) = \int_Q \{(p_S(x) - c)\,\pi(q) + p_{NS}(x, q)\,[1 - \pi(q)]\}\,\mathrm{d}G(q) - p$$

if they buy the land plot from a customary farmer in location x. We can re-write this as

$$V(x, p, Q) = \int_Q [p_S(x)\Pi(q) - c\pi(q)]\,\mathrm{d}G(q) - p,$$

where we substituted for the compounded probability $\Pi(q)$ that we defined in the previous section. The expected profit therefore balances the expected values of urban workers' residential land price, their compounded probability of not being evicted and the broker's certification cost as well as the price paid for the land. A further substitution yields

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

so that the expected profit is the difference between the expected value of the *informed* broker's bid $p^o(x, q)$ and the price paid under asymmetric information p.

In the market for customary land, 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 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 brokers freely enter the market and make no excess profit, implying $V(x, p^*(x), Q^*(x)) = 0$. As before, for the sake of comparison and exposition, we consider the economic parameters that satisfy $0 < \underline{x} < \overline{x} < x_a$. We also focus on the land within the city extent $[0, x_a]$ because the customary land beyond x_a is of no interest for brokers if $x_a > \overline{x}$.[7] For the sake of conciseness, we dispense with reference to x on the variables $a(x)$, $v(x)$, $p(x)$, $Q^*(x)$ and $V(x, \cdot, \cdot)$ in the next two

[7] Indeed, for any $x > x_a$, farming yields a utility lower than the outside utility: $a(x) - u < 0$. For any $x > \overline{x}$, condition (4) fails so that $p^o(x, q) \leq q\,[a(x) - u]$ for all $q \in [q, \overline{q}]$. Hence, for $x > x_a > \overline{x}$, $p^o(x, q) < 0$ and $V(x, p, Q) < 0$ for any set Q.

paragraphs.

Customary land holders are willing to sell their unit of land plot if the offered price p lies above their reservation utility $q\,(a-u)$. The set of customary enforcement levels is therefore given by $Q^*(p) = [\underline{q}, p/(a-u)]$ if $p/(a-u) < \overline{q}$ and $[\underline{q}, \overline{q}]$ otherwise. Here, it is convenient to denote $\underline{p} = \underline{q}\,(a-u) > 0$ and $\overline{p} = \overline{q}\,(a-u) > 0$ $(0 < \underline{p} < \overline{p})$ the land prices enticing supply by none or by all customary landowners. The broker's expected profit can then be written as

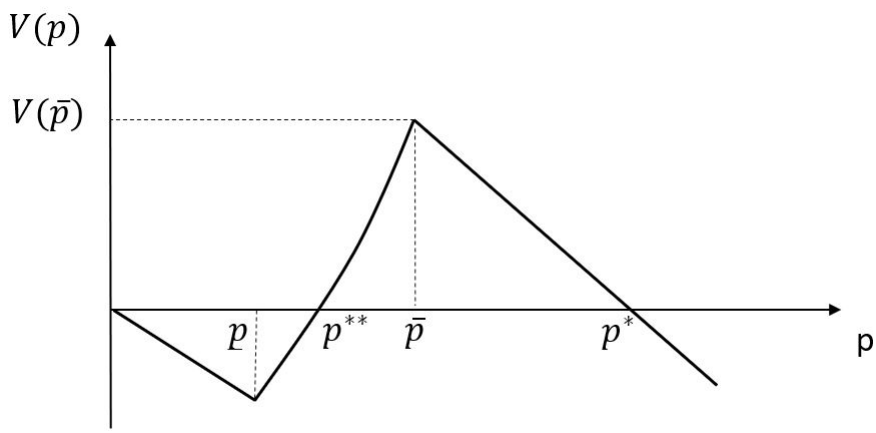
$$\widehat{V}(p) \equiv V(p, Q^*(p)) = \int_{\underline{p}/(a-u)}^{\min\{p,\overline{p}\}/(a-u)} p^o(x,q)\mathrm{d}G(q) - p. \tag{8}$$

The equilibrium is found where brokers make zero expected profit, that is $\widehat{V}(p) = 0$. It is easy to see that the function $\widehat{V}(p)$ is equal to zero at $p = 0$ and is negative and decreasing for $p \in (0, \underline{p}]$. It is also decreasing for $p > \min\{p, \overline{p}\}/\,(a-u)$. In this paper we simplify the discussion of equilibria by assuming that $\widehat{V}(p)$ crosses the zero axis at most once from below for $p \in [p\ \overline{p}]$. A sufficient condition is that

$$\int_{\underline{q}}^{q} p^o(x,q')\mathrm{d}G(q') \ \text{ is a convex function of } q. \tag{9}$$

This is equivalent to saying that $p^o(x,q)g(q)$ is increasing in q. For instance, when $\theta(q)$ is small enough, one just needs to have $\pi(q)g(q)$ a monotone increasing function of q. Under this assumption, the expected profit linearly falls from and below zero on $[0, \underline{p}]$, increases on $(\underline{p}, \overline{p}]$, reaches a maximum at $p = \overline{p}$ and, again, linearly falls on $(\overline{p}, \infty)$. This is shown in Figure 2. A first solution for $V(p) = 0$ is the trivial equilibrium solution $p = 0$ for which no customary landowner supplies land and the land market is inactive (i.e. $Q^*(0) = \emptyset$). This is the unique solution if $\widehat{V}(\overline{p}) < 0$. Otherwise if $\widehat{V}(\overline{p}) > 0$, the function $\widehat{V}(p)$ has three roots $p \in \{0, p^{**}, p^*\}$ $(0 < p^{**} < \overline{p} < p^*)$ and is positive on the interval $[p^{**}, p^*]$. However, only the highest price p^* is robust to overbidding by brokers. Indeed, if all brokers set a price $p < p^* - \varepsilon$ with small enough $\varepsilon > 0$, some brokers can reap the land market by setting the price $p^* - \varepsilon$ and make a positive profit $\widehat{V}(p^* - \varepsilon)$. Hence, under asymmetric information, the land market yields the equilibrium price p^* for all transactions with all types of landowners. To complete the argument, we now reintroduce the reference to the CBD distance x.

Figure 2: Broker's expected profit under asymmetric information



Importantly, because $p^* > \overline{p}$, the larger root is given by

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

which expresses the broker's expected value of residential projects. Like the price $p^o(x,q)$, $p^*(x)$ increases with higher value of certified land p_S and lower certification cost c. It also increases with higher probability $\pi(q)$ if $p_S\left(1-\theta\left(q\right)\right) > c$. Because p_S falls with distance from the CBD, this price also falls with distance to the CBD. Finally, the condition for an equilibrium with price p^* is given by

$$\widehat{V}(x,\overline{p}(x)) \geq 0 \iff \int_{\underline{q}}^{\overline{q}} p^o(x,q)\mathrm{d}G(q) \geq \overline{q}\left[a(x)-u\right].$$

The main difference with land markets with informed brokers lies in the concentration of land prices on its expected value p^*. We have the following proposition:

Proposition 2: *Suppose $0 < \underline{x} < \overline{x} < x_a$ and that condition (9) holds. Then, customary land beyond x_a is neither farmed for the city nor transformed with statutory property rights. Customary land beneath x_a is acquired by brokers if $\widehat{V}(x,\overline{p}(x)) \geq 0$. In other locations, the land market is inactive: land is farmed but there is no attempt to sell it and transform its use and tenure.*

For the land beneath x_a, the land market activity and prices differ compared to markets with fully informed brokers. First, the equilibrium price $p^*(x)$ is the brokers' expected value of the informed brokers' equilibrium prices $p^o(x,q)$. Second, the land

market is active for the set of locations $X^* \equiv \{x : \widehat{V}(x, \overline{p}(x)) \geq 0\}$. It can be checked that, if $p_S(x)(1-\theta(q)) > c$ for all q, an upper shift in the broker's tenure transformation probability $\pi(q)$ raises the expected profit $\widehat{V}(x, \overline{p}(x))$ and therefore enlarges the set X^*. Under the opposite condition, the same conclusion may hold or not depending on the balance of land for which the condition holds and does not hold.

To understand the effect of adverse selection, we must compare the sets of locations X^* and $[0, \overline{x}]$ where the land market is active under asymmetric and under full information. On the one hand, it is easy to show that, under asymmetric information, there is no land transaction beyond $\overline{x}$: $[\overline{x}, x_a] \cap X^* = \emptyset$. Indeed, under complete information there is no transaction at $x \in [\overline{x}, x_a]$ where, by virtue of (4),

$$p^o(\overline{x}, q) - q\left[a(\overline{x}) - u\right] \leq 0, \tag{10}$$

for all q. The above proposition states that the market is inactive under incomplete information if

$$\widehat{V}(x, \overline{p}(x)) = \int_{\underline{q}}^{\overline{q}} p^o(x, q) \mathrm{d}G(q) - \overline{q}\left[a(x) - u\right] < 0.$$

This can however be written as

$$\widehat{V}(x, \overline{p}(x)) = \int_{\underline{q}}^{\overline{q}} \left\{p^o(x, q) - q\left(a(x) - u\right)\right\} \mathrm{d}G(q) - \left(\overline{q} - \int_{\underline{q}}^{\overline{q}} q \mathrm{d}G(q)\right)\left(a(x) - u\right) < 0.$$

The second term in the above expression is strictly negative since $\overline{q} > \int_{\underline{q}}^{\overline{q}} q \mathrm{d}G(q)$. The first term is negative for any $x \in [\overline{x}, x_a]$ since its integrand is negative by virtue of (10). Hence, $\widehat{V}(x, \overline{p}(x)) < 0$ for any $x \in [\overline{x}, x_a]$. On the other hand, by a continuity argument, the same conclusion applies for locations closer to the CBD. Indeed, one may take $x = \overline{x} - \varepsilon$, for all (small enough) ε so that the absolute value of the first term is smaller than that of the second term. So, $[\overline{x} - \varepsilon, x_a] \cap X^* = \emptyset$. Land transformation does not take place at locations $[\overline{x} - \varepsilon, \overline{x}]$ under asymmetric information although it occurs there under symmetric information. We summarize this result in the following proposition:

Proposition 3: *Asymmetric information reduces the geographical extent of urban land transformation into residential areas.*

Although asymmetric information reduces residential geographical extent (with statutory and non-statutory rights), it is not clear whether it diminishes the total residential surface and therefore the number of urban workers. Indeed, in this model, all land plots get transformed under asymmetric information in X^* whereas only part of this land is transformed under symmetric information in $[\underline{x}, \overline{x}]$.

To fix ideas regarding those sets, we focus below on a slightly more restrictive setting than the one in the previous section.

Example. Suppose that the brokers' enforcement probability $\pi(q)$ is linear in the customary right enforcement probability q and that the residential plots without statutory rights are fully insecure (i.e., they will certainly lead to eviction). More specifically, let us consider $\pi(q) = \pi_0 q$, $\theta(q) = \theta_0 q = 0$, $q \in [0, \overline{q}]$ and $\overline{q} < 1/\pi_0$. Non-statutory residential land plots are then exchanged at a zero price $p_{NS}(x) = 0$. Under full information, we have the price $p^o(x, q) = [p_S(x) - c]\,\pi_0 q$ and condition (4) becomes

$$(p_S(x) - c)\,\pi_0 \geq a(x) - u, \tag{11}$$

which is independent of q. Assuming that the LHS falls more rapidly than the RHS, the binding condition (11) yields a constant threshold location $\widehat{x}$ that divides the city in two districts: statutory and non-statutory residential for $x \leq \widehat{x}$ and customary agricultural otherwise. Under asymmetric information, the broker's expected value of a residential project simplifies to

$$p^*(x) \equiv (p_S(x) - c)\,\pi_0 \mathrm{E}(q)$$

where $\mathrm{E}(q) = \int_{\underline{q}}^{\overline{q}} q \mathrm{d}G(q)$, and her maximal expected profit is given by $\widehat{V}(x, \overline{p}(x)) = p^*(x) - \overline{q}\,[a(x) - u]$. Hence, brokers enter the market if and only if

$$(p_S(x) - c)\,\pi_0 \frac{\mathrm{E}(q)}{\overline{q}} \geq a(x) - u. \tag{12}$$

Because $\mathrm{E}(q) < \overline{q}$, the LHS of (12) is smaller than that of (11), so that the solution x^* of the binding condition (12) is smaller than $\widehat{x}$. As a result, the city divides in the same districts as under symmetric information: statutory and non-statutory residential for $x \leq x^*$ and customary agricultural otherwise. However, the residential district is smaller due to adverse selection. Brokers' information asymmetry leads to a land market failure that takes place at locations $x \in (x^*, \overline{x})$. Here, asymmetric information reduces both the residential geographical extent and surface and therefore the number of urban workers, since land in $(x^*, \overline{x})$ is not used for residences.

Corollary: *When the brokers' tenure transformation probability $\pi(q)$ is linear and residential plots without statutory rights are fully insecure, a land market failure exists at the edge of the urban workers' residential area for $x \in (x^*, \overline{x})$. The city includes fewer workers because of asymmetric information.*

5 Model predictions

The model leads to four possible empirical predictions on the price schedules of sales to urban workers and brokers.

First, urban workers buy residential properties with statutory rights at price $p_S(x)$ while, by virtue of condition (2), informed brokers purchase customary land at price $p^o(x,q) = p_S(x)\Pi(q) - c\pi(q)$, where $\Pi(q)$ is the broker's *compounded* probability of land tenure transformation and non-eviction (see equation (3)). The expected price conditional on distance from the city center is given by $\mathrm{E}\left[p^o(x,q)\right] = \mathrm{E}\left[p_S(x)\Pi(q) - c\pi(q) \mid x < \widehat{x}(q)\right]$, where E is the expectation operator over the distribution of enforcement levels q. Hence, the observed ratio of the land price gradients satisfies

$$\frac{\frac{\mathrm{d}}{\mathrm{d}x}\mathrm{E}\left[p^o(x,q)\right]}{\frac{\mathrm{d}}{\mathrm{d}x}p_S(x)} = \mathrm{E}\left[\Pi(q) \mid x < \widehat{x}(q)\right]. \tag{13}$$

Since $\Pi(q) \leq 1$, a first prediction is that this ratio of land price gradients will be lower than one. If one considers only locations $x < \underline{x}$, this ratio simplifies to $\mathrm{E}\left[\Pi(q)\right]$. In other words, the land price gradient should be steeper for plots resold to urban workers with a statutory right than for plots purchased from customary owners by brokers.

Second, in the model of informed brokers, the price for statutory land $p_S(x)$ has zero variance whereas $p^o(x,q)$ has a positive variance

$$\mathrm{var}\left[p^o(x,q)\right] = p_S(x)^2\mathrm{var}\left[\Pi(q) \mid x < \widehat{x}(q)\right] + c^2\mathrm{var}\left[\pi(q) \mid x < \widehat{x}(q)\right].$$

In land price data, prices will however be subject to measurement errors and unobserved characteristics that do not relate to the transformation and eviction risks modeled in this paper. As a result, land prices with statutory rights shall be observed with positive variance $\mathrm{var}\left[p_S(x)\right] > 0$. The second model prediction is that the average of $\mathrm{var}\left[p^o(x,q)\right]$ is larger than the average of $\mathrm{var}\left[p_S(x)\right]$, reflecting the higher risks of customary land sales and the stronger security of the plots transacted with a statutory right.
We now turn to the question of brokers' information asymmetry. Our model provides two tests to detect the presence of asymmetric information and market failure. [8]

First, informed brokers set different prices $p^o(x,q)$ at a same distance from the city center whereas uninformed brokers can only propose a single price $p^*(x)$ that reflects the expected value of eviction risks. Hence, whereas the informed broker model predicts a positive price variance $\mathrm{var}\left[p^o(x,q)\right] > 0$, controlling for observed location and other characteristics, the uninformed broker model predicts a zero variance: $\mathrm{var}\left[p^*(x)\right] = 0$. Remember that in the model, statutory land plots bear no risk and thus have zero price variance: $\mathrm{var}\left[p_S(x)\right] = 0$. Considering measurement errors and unobserved characteristics other than the transformation risks and tenure insecurity, the third prediction is

[8] Note that the tests of information asymmetry that we provide are specific to our urban setting and data availability. 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.

that a similar price variance for non-statutory and statutory plots reveals the existence of information asymmetry.

Second, the spatial pattern of land tenure transformation is different according to whether brokers are informed or not. In general, informed brokers progressively attempt to transform land tenure across the urban space in the interval $[\underline{x}, \overline{x}]$, while uninformed brokers attempt to transform the whole urban space beneath some distance from the city center x^*. This highlights a spatial difference in terms of transaction frequency between the two versions of the model: in the uninformed case, property right conversions abruptly cease beyond the critical location x^*, whereas in the informed case, there can be a smooth phasing out of property right conversions over $[\underline{x}, \overline{x}]$.

6 Empirical analysis

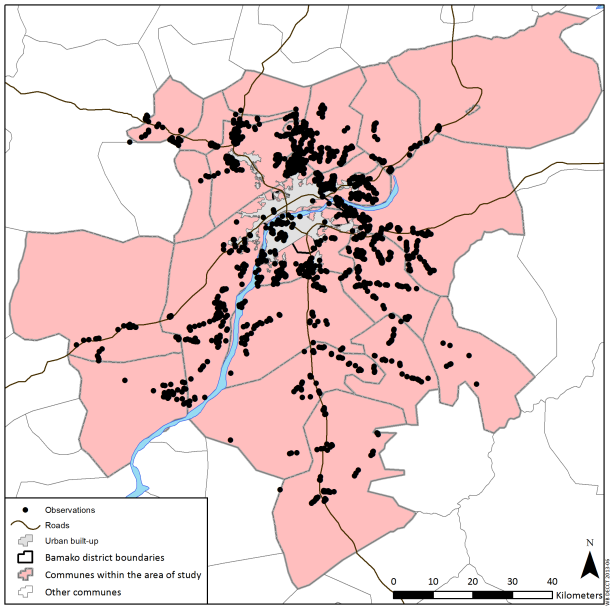
6.1 Data

We use the data of a unique survey of $1,655$ land plots that were transferred as unbuilt land plots in Bamako, Mali, between 2009 and 2012 (Durand-Lasserve et al. 2015). Current information was obtained at the year of the survey (2012) and retroactive questions were asked regarding the situation at the time of the transaction (between 2009 and 2012). The database reports characteristics such as price, tenure status, location (GPS coordinates), intended land use (i.e., residential *vs.* agricultural), surface area, infrastructure and services, municipality, distance to paved main road and river, as well as details on buyers and sellers.[9] The sampling ensures extensive coverage of the Bamako greater area, at regular intervals along paved main roads extending outward from Bamako. The coverage of the survey area makes it possible to draw conclusions regarding the characteristics of the transfers and provides the best possible sample that could be constructed in the Malian context for an empirical analysis. Figure 3 displays the land plots on the Bamako map.

We drop the observations located farther than 40 km from the city center, those without residential or agricultural use and those without some missing data, which leaves $1,259$ observations. We consider two types of land rights: non-statutory rights, which includes both customary land and other plots held without any property rights, and statutory rights, which includes land plots with property rights such as permits to occupy and title deeds. We also consider two land uses: agricultural and residential. Therefore, combining land right and use types, we focus on three categories: statutory residential, non-statutory residential and non-statutory agricultural. We exclude statutory agricultural plots because they make for a tiny minority of plots and lie outside the scope of our model. This reduces our sample to $1,150$ land plots.

[9] 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).

Figure 3: 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.

Table 1 presents the summary statistics by tenure transition between the time of transaction (2009-2012) and the time of the survey (2012). "NS to S" indicates plots with a transition from non-statutory to statutory right. "S to S" and "NS to NS" represent plots that remained statutory and non-statutory, respectively. One can observe that average land prices falls as one sequentially considers plots transacted with a statutory right (S to S), plots for which tenure was recently converted to a statutory rights (NS to S), plots which were transacted without such rights (NS to NS), and finally non-statutory agricultural lands (Agricultural NS to NS). This suggests that status and use are important determinants of land prices. However, it can also be seen that the distance to the CBD and access to water and electricity decrease while the plot area and distance to main road increase. As those factors are also determinants of the price, they may confound the effect of the tenure status on prices.

Table 1: Summary statistics

	Residential						Agricultural	
	S to S		NS to S		NS to NS		NS to NS	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Log(land price) (CFA/m2)	8.16	1.462	6.808	1.403	6.759	1.231	3.952	1.226
Distance to CBD (km)	15.702	5.796	17.737	4.914	20.725	6.646	30.522	6.191
Log(area) (m2)	6.164	0.820	6.363	0.982	6.134	0.92	9.541	1.459
Distance to road (km)	3.295	3.259	3.189	2.71	4.84	4.588	6.674	6.338
Water dummy	0.066	0.249	0.029	0.17	0.024	0.152	0.014	0.117
Electricity dummy	0.022	0.147	0.01	0.099	0.001	0.038	0	0
South bank dummy	0.423	0.495	0.275	0.448	0.545	0.498	0.445	0.499
Number of observations	227		102		675		146	

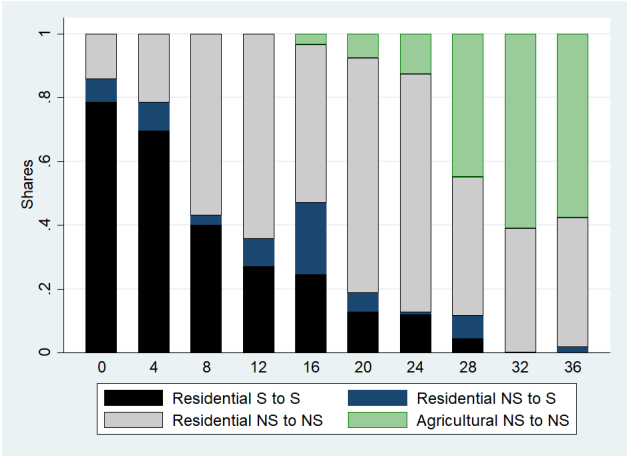
Note: The table presents tenure transitions between the time of transaction (2009-2012) and the time of the survey (2012). Log is the Neperian logarithm. "NS to S" indicates plots with transition from Non-Statutory to Statutory right. "S to S" and "NS to NS" represents plots that remained Statutory and Non-Statutory respectively. Seven plots have been withdrawn as the price data was missing.

Below, we first present basic facts about the tenure and use of land plots, before testing the predictions of the model.

6.2 Land use and tenure mix

Figure 4 presents the share of tenure situations by distance to the city center at the time of the survey. In the figure, the term "Residential" or "Agricultural" refers to the use of the plot at the time of the survey. The black color represents the share of residential plots that were transacted under statutory rights and have statutory rights at the time of the survey (Residential S to S). The blue color represents the share of residential plots which tenure was transformed to statutory rights between the time of the transaction and the time of the survey (NS to S). The gray color represents the residential plots that were not transformed (NS to NS). The green color displays non-statutory agricultural plots (Agricultural NS to NS).[10] As predicted, the figure confirms that the share of agricultural plots is larger away from the center. In line with the model, the figure also confirms that the share of plots with statutory rights is larger at locations closer to the CBD. Note that the share of transitions of residential plots from non-statutory to statutory rights peaks at approximately 16 km from the CBD.

Figure 4: Land tenure and use by distance to the city center (km)



Note: The figure presents the share of property rights by distance to the city center at the time of the survey. The black color shows the share of residential plots that have statutory rights at the time of the survey. The blue color represents the share of residential plots that were transformed to statutory rights. The grey color represents the residential plots that were not transformed. The green color displays the non-statutory agricultural plots.

[10] Although in our model, non-statutory agricultural land does not get transacted, the data include transactions of such land, many of which, however, are non-monetary customary transfers, in line with customary practices. Figure 4 makes use of such "transactions" to characterize the locations of customary land.

Table 1 showed that within less than 3 years (and in some cases within just a few weeks), more than 13 percent of plots ($= 102/(102 + 675)$) that were initially non-statutory at the time of the transaction became statutory. Within 20 km from the city center, we see that 20 percent of initially non-statutory plots have become statutory. Beyond 20km, the percentage of non-statutory plots converted to statutory plots drops to less than 6 percent. In line with the model, this confirms that the conversion process tends to be more intense closer to the city center. Table 2 confirms this trend by showing a probit regression of the transition to statutory status among initially non-statutory plots. The first column shows a negative and significant coefficient on distance to the CBD in the absence of controls. In reality, however, workers' trips to the CBD are not only affected by the geographical distance to the CBD but also by their access to a road. The second column adds the effect of the second spatial variable, namely the distance to the main road. As it can be seen, this variable also has a strong and significant effect on residential plot transitions to statutory rights. Tenure transitions are more likely for higher value of transacted land plots: higher non-statutory land prices and larger plot areas indeed entice brokers to secure their assets by obtaining statutory rights. This is confirmed in the fourth column, which displays significant effects of those two factors. Land price, however, is an endogenous variable determined by exogenous factors such as distance to the CBD and to the main road, access to electricity and water and location characteristics. The third column shows that controlling for those exogenous factors eliminates the impact of price on land statutory transitions, but it does not affect the impact of the distance to the CBD.

Table 2: Transition from Non-Statutory to Statutory Right (Residential, Probit)

Dependent variable: Transition NS to S				
Distance to CBD (km)	-0.041***	-0.047***	-0.056***	
	(0.010)	(0.011)	(0.014)	
Distance to road (km)		-0.080***	-0.081***	
		(0.019)	(0.021)	
Log(area) (m2)			0.25**	0.23**
			(0.080)	(0.071)
Water dummy			-0.41	
			(0.44)	
Electricity dummy			1.09	
			(0.98)	
South bank dummy			-0.42**	
			(0.15)	
Log(land price) (CFA/m2)			0.039	0.13*
			(0.071)	(0.056)
Observations	777	777	777	777

Note: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Year dummies included. Data: survey on Bamako, Mali, 2009-2012. The table reports the probit regression of log of land prices on distance to city center. The sample is restricted to the residential plots that were Non Statutory at the time of transaction.

6.3 Prices

Next, we estimate the differential land price gradients for residential plots with statutory and non-statutory rights. We restrict our attention to the land plots that have statutory rights at both dates of transaction and survey (S to S), and to those that are transformed from non-statutory to statutory rights between transaction and survey dates (NS to S). This restriction allows us to separately identify the land purchases by those among urban workers who purchase formal land and by brokers who purchase land from customary owners before formalizing it as described in our model.

Table 3 displays OLS regressions of the log of the sales price on various sets of price determinants. The first column excludes the determinants associated with distance to the CBD and tenure. Controls include plot area, distance to paved main road, dummies for water connection, electricity connection and South bank location, and year dummies to control for land price inflation. All coefficients have the expected sign and are significant at the 1 percent level (except for access to electricity, which is not significant). The second column adds the effect of distance to the CBD. As in the

theoretical model, distance has a negative and significant coefficient. The third column adds a control for a purchase without a statutory right (coefficient of NS purchase). As in the theory, the absence of statutory rights decreases the value of purchased land plots. The last column adds the combined effect of absence of a statutory right and distance of the CBD. This strengthens the negative impact of purchasing a plot without a statutory right (coefficient of NS purchase), but this impact attenuates with distance to the CBD (coefficient of NS purchase*distance). Accordingly, this negative effect vanishes at about 36 km (1.77/0.049). This empirical result finally confirms our first model predictions: the land price gradient is steeper for statutory than for non-statutory plots. The land gradients are respectively -0.13 and -0.08 ($=-0.13+0.049$) for the former and for the latter. Applying (13), the brokers' average of compounded probability $\mathrm{E}\left[\Pi(q) \mid x < \widehat{x}(q)\right]$ over the city is estimated to be 0.62 (=0.08/0.13).

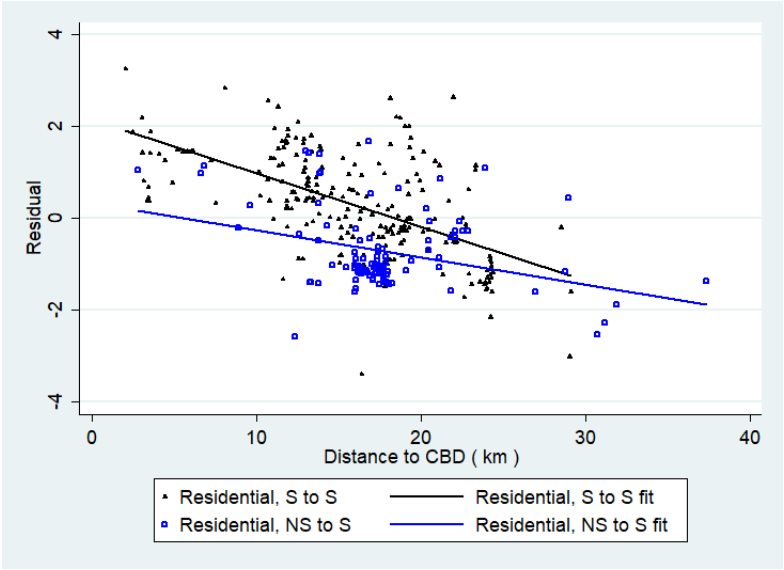
Table 3: Land price gradients and tenure (OLS)

Dependent variable:	Log(land price) (CFA/m2)			
Distance to CBD (km)		-0.13***	-0.12***	-0.13***
		(0.010)	(0.0091)	(0.010)
NS purchase			-0.92***	-1.77***
			(0.11)	(0.38)
NS purchase*Distance				0.049***
				(0.021)
Log(area) (m2)	-0.69***	-0.42***	-0.41***	-0.46***
	(0.080)	(0.067)	(0.061)	(0.064)
Distance to road (km)	-0.12***	-0.12***	-0.13***	-0.12***
	(0.022)	(0.018)	(0.016)	(0.016)
Water dummy	1.04***	0.60*	0.48*	0.50*
	(0.31)	(0.25)	(0.23)	(0.23)
Electricity dummy	0.97	1.16**	1.12**	1.13**
	(0.52)	(0.42)	(0.38)	(0.38)
South bank dummy	0.91***	0.81***	0.68***	0.65***
	(0.14)	(0.12)	(0.11)	(0.11)
Constant	11.9***	12.4***	12.8***	13.3***
	(0.57)	(0.46)	(0.41)	(0.47)
Observations	330	330	330	330
R^2	0.457	0.649	0.715	0.720

Note: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Data: survey on Bamako, Mali, 2009-2012. The table reports the OLS regression of log of land prices at transaction date on controls (including year dummies). All plots are residential and statutory at the time of the survey. A share of plots are Non-Statutory at the time of the purchase (NS purchase)

Figure 5 represents our observations after controlling for plot area, distance to paved main road, dummies for water connection, electricity connection, South bank location and land price inflation. It shows the land price residuals of the regression in the first column of Table 2 as function of the distance to the CBD. The small black triangles denote the residential land plots that remained statutory (S to S) and the small blue squares the residential land plots that were transformed from non-statutory to statutory rights (NS to S). The black and blue lines depict the linear fit on each set of points. The figure confirms our first model predictions according to which the land price gradient is steeper for statutory than for non-statutory plots.

Figure 5: Gradient of residual land prices (in log)



Note: The figure depicts the land price residuals after controlling for plot area, distance to paved main, road, dummies for water connection, electricity connection, South bank location and price inflation (see Table 2 column 1). The small black triangles denote the residential land plots that remained statutory. The small blue squares denote the residential land plots that were transformed from non-statutory to statutory rights. Black and blue lines depict the respective linear fit.

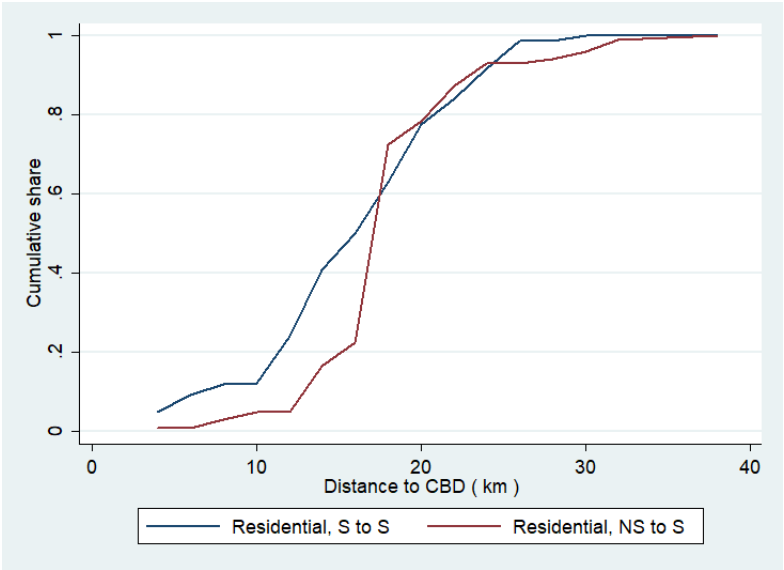
Figure 5 also suggests a smaller variance for the observations of plots that were already statutory when purchased than those that became statutory afterwards. We can formally calculate that, over the whole sample, the average of the squares of residuals is equal to .75 for the former and to 1.10 for the latter. The discrepancy between those numbers rises when we restrict the analysis to observations beneath 18 km from the

CBD: the averages of the squares of residuals become 0.36 and 1.38, respectively. Those numbers therefore confirm our second prediction: land prices have larger variance for plots that experience a tenure transition to statutory rights.

By the same token, the last finding runs against the hypothesis that brokers are uninformed. According to the third prediction of our theoretical analysis, at a same distance from the city center, informed brokers set different prices whereas uninformed broker propose a single price reflecting the expected value of heterogeneous eviction risks. A discrepancy in the price variance for non-statutory and statutory plots therefore provides evidence about the absence of information asymmetry.

We can further check the existence of information asymmetry using our fourth model prediction: property right transformations abruptly cease beyond a critical distance from the CBD under asymmetric information whereas they smoothly phase out under symmetric information. Towards this aim, we compare in Figure 6 the cumulative shares of observations across the geographical space of residential plots that held statutory rights at the purchase time (S to S) and those that did not but acquired them later on (NS to S). The figure shows that the sales of statutory residential plots (blue curve) are mostly uniformly distributed across the urban space between 10km and 28km, whereas the sales of non-statutory land plots (brown curve) that get transformed into statutory residential land plots are more concentrated about 18km from the city center. In the uninformed broker model, there is no tenure transformation beyond the critical location, so that the cumulative frequency distribution is expected to be vertical at that location. The data suggest this is the case, as the tenure transformation peaks at about 18km. However, the absence of a sharp vertical edge makes us hesitant to conclude in favor of a model with only uninformed brokers. On the one hand, the absence of a vertical edge can first stem from brokers' heterogeneity in their capabilities to collect information. Our test would therefore suggest the coexistence of both informed and uninformed brokers. On the other hand, the absence of a vertical edge can also stem from the presence of spatial heterogeneity. One way to check the issue of spatial heterogeneity is to study narrower areas (with reasonable numbers of observations). Figure 7 (a) and (b) in the Appendix reproduces Figure 6 for the left and right banks of the river (resp. north and south of the city). Interestingly, this test confirms information asymmetry in the left bank (see the vertical line at about 18 km from the city center) but suggests a weaker asymmetric information in the right bank. Finally, heterogeneity also partially comes from access to the main paved roads that connect to the CBD. As a significant share of commuting occurs on non-paved roads, it is relevant to investigate whether information asymmetry is detected for plots away from paved roads. Figure 8 in the Appendix reproduces Figure 6 as a function of distance to a paved road and confirms evidence of information asymmetry. This suggests that the brokers that operate in less accessible areas have less information on risks regarding customary land plots.

Figure 6: Cumulative share by tenure transition



Note: The figure depicts the cumulative shares of observations with distance to the city center for residential plots that held statutory rights at the purchase time (blue curve) and those that did not but acquired them (brown curve).

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 and, to a large extent, informal. Although such land use and land tenure conversion is happening at a massive and unprecedented scale, the phenomenon remains largely understudied by economists. Yet, in contexts where customary land property rights are only weakly recognized by authorities, and where the legal transition towards private property rights is not clearly organized, there are reasons to suspect that the process of urban expansion can be problematic. There may indeed be high social costs due to the numerous conflicts arising from contested land transactions. The partial failure to establish statutory property rights on newly developed land may also involve economic inefficiencies as holding and transacting land outside the formal property rights system remains risky.

To shed light on these important issues, we combined a monocentric-city urban economics framework with a theoretical model of land-tenure conversion from customary

to statutory property rights. A key feature of the model is that land tenure is risky and brokers who purchase land from customary owners 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 brokers. Under symmetric information, brokers perfectly evaluate the idiosyncratic formalization probability of each land plot. As a result, we show that the share of customary land smoothly decreases with distance from the city center. Under asymmetric information, brokers are unable to evaluate these risks. As a result, there may be a failure in the land transformation market so that land transformation abruptly ceases at some distance from the city center. The paper then checks the predictions about tenure conversions using a geo-referenced survey of land plots in Bamako, Mali and its peri-urban area. The empirical analysis confirms the main features of the model and concludes that intermediaries may have asymmetric information on the plot that they purchase. Our conclusion regarding the existence of information asymmetry is even clearer for the left bank of Bamako and at a distance from paved roads, suggesting broker heterogeneity across locations.

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 are able to provide an indirect but conclusive empirical test 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 transformation, 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 would help improve the efficiency of the process. Equity issues regarding asymmetric bargaining power in land transactions, dispossession of customary owners 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 in conjunction with measures to reduce the cost of registration in order to ensure that cities can grow in more efficient and equitable ways.

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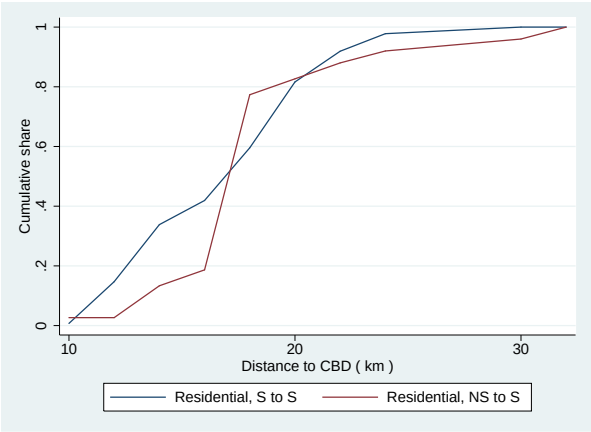
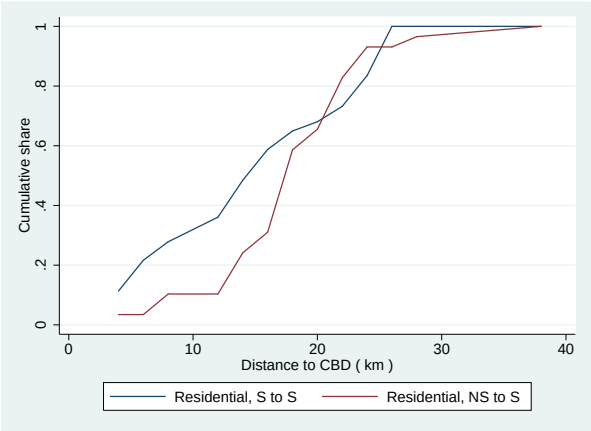
Appendix A

Figure 7: Cumulative share by tenure transition (distance to CBD, right and left banks)



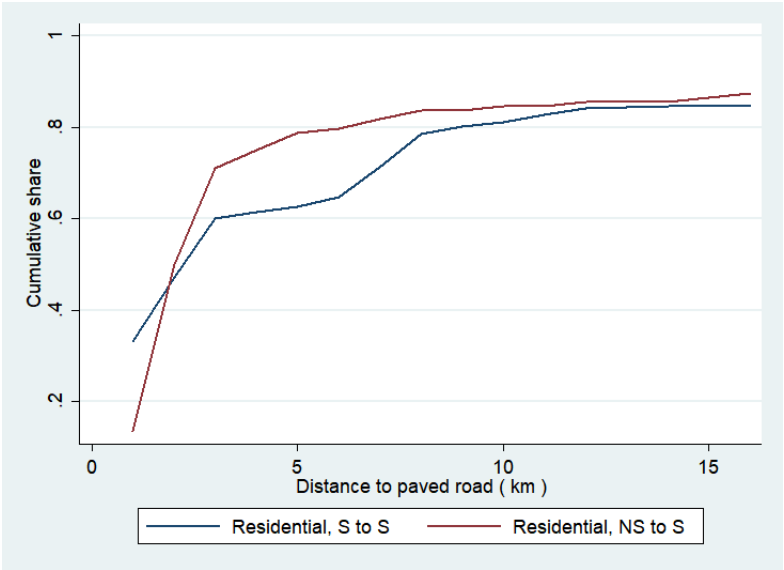
(a) Bamako, right bank (north of the river)



(b) Bamako, left bank (south of the river)

Note: The figure depicts the cumulative shares of observations with distance to the city center for residential plots that held statutory rights at the purchase time (blue curve) and those that did not but acquired them (brown curve), distinguishing between the right bank (sub-figure a) and the left bank (sub-figure b).

Figure 8: Cumulative share by tenure transition (distance to nearest paved road)



Note: The figure depicts the cumulative shares of observations with distance to the nearest paved road for residential plots that held statutory rights at the purchase time (blue curve) and those that did not but acquired them (brown curve).