Trust or Property Rights?

Can Trusted Relationships Substitute for Costly Land Registration in West African Cities?

Lucie Letrouit
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Abstract

The paper studies the market failures associated with land tenure insecurity and information asymmetry in an urban land use model, and analyzes households' responses to mitigate tenure insecurity. When buyers and sellers of land plots can pair along trusted kinship lines whereby deception (the non-disclosure of competing claims on a land plot to a buyer) is socially penalized, information asymmetry is attenuated, but overall participation in the land market is reduced. Alternatively, when owners can make land plots secure by paying to register them in a cadaster, both information asymmetry and tenure insecurity are reduced, but the registration cost limits land market participation at the periphery of the city. The paper then compares the overall surpluses under these trust and registration models and under a hybrid version of the model that reflects the context of today's West African cities where both registration and trusted relationships are simultaneously available to residents. The analysis highlights the substitutability of trusted relationships to costly registration and predicts the gradual evolution of economies towards the socially preferable registration system if registration costs can be sufficiently reduced.

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Trust or property rights? 
Can trusted relationships substitute for costly land registration in West African cities?

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1 Intro

In developing countries, informally holding land is more often the norm than the exception. In sub-Saharan African cities, in particular, a large fraction of landowners—in some cases up to 80 percent—do not hold a formal property right on their land. This high level of informality mirrors the deficiencies of land registration systems which, in sub-Saharan Africa, remain prohibitively costly and unaffordable to most households. It is all the more problematic as informal tenure can have large private and socioeconomic costs. A key reason is the risk of eviction associated with informal land, which reduces investment in land (Besley, 1995) or may reduce labor market participation due to the necessity of spending time guarding one’s land plot (Field, 2007). Informal land tenure also hinders the tradability of land, possibly leading to land misallocation. Eventually, households residing on informal plots are exposed to a wide range of social ills, including crime, poor health from low housing quality, and negative human capital externalities (Galiani and Schargrodsky, 2010, Galiani et al., 2017, Nakamura, 2017).

To our knowledge, the theoretical model presented in this paper is the first to focus on the interaction between social norms and land markets, and how land transactions among trusted parties can address the information asymmetry that has come to characterize today’s urban land markets in sub-Saharan Africa (Durand-Lasserve et al., 2015, World Bank, 2019). In our model, purchasing informal land is risky for buyers, as plot ownership might be contested in the future. In an ideal world, competing land ownership claims could be extinguished through adjudication and registration of land ownership in a cadaster leading to the issuance of a property title. In practice, it can be very costly to do so and this solution is only chosen by a fraction of the population. The objective of our paper is thus to investigate how urban households who do not pay for land registration may rely on an alternative way to address tenure insecurity when transacting informal land. More specifically, we study a mechanism whereby buyers and sellers match in the informal market according to a trusted ethnic relationship that reduces the information asymmetry and the likelihood of purchasing an insecure plot. We formalize this idea in an urban land use model with tenure insecurity and information asymmetry, where we study equilibrium land market transactions and associated inefficiencies. In our framework, plots are of two types: risky plots, which ownership may be contested in the future, and risk-free plots, which ownership cannot be contested. In addition, buyers and sellers of land plots may have reciprocal duties based on trusted ethnic kinship. If a risky plot is exchanged between individuals linked by ethnic kinship without disclosure of the risk to the buyer, the seller will be considered to
have violated his duty and a social penalty will be imposed on him. In that context, a buyer expects that a seller he is ethnically related with will be more likely to sell him a secure plot and the buyer will consequently be ready to pay a premium. Knowing this, sellers may decide whether to transact with kin or non-kin members, depending on the intrinsic risk on their plot, the social penalty and the ethnic premium. An important prediction of the model is that although matching along ethnic lines reduces information asymmetry, it also lowers overall market participation. Alternatively, when owners are offered the possibility to make plots secure by paying to register them in a cadaster, both information asymmetry and tenure insecurity are reduced, but the cost of registration limits transactions at the periphery of the city. We compare the overall surplus under these two polar cases and under a hybrid version of the model, where both registration and trusted relationships are available options, as is the case in many sub-Saharan-African cities.

Our approach relates to two existing trends of literature from anthropology and economics. First, a well-established anthropological literature describes links among groups in a wide range of societies. Individuals from such groups are referred to as “allies”, “kins” or “cousins” and exhibit codified reciprocal duties along those links (Mauss, 1923). These duties may take various forms, including the requirement to treat one another fairly or to exchange gifts such as food or shelter. Such links are very commonly found in sub-Saharan Africa. We found published analyses in the context of Burkina Faso, Burundi, the Gambia, Guinea, Mali, Rwanda, Senegal, Tanzania and Zambia (see Freedman, 1977, Ndiaye, 1992, Fouéré, 2004, Smith, 2004 and 2006, Diallo, 2006, Dunning and Harrison, 2010). In West Africa and central Africa, the social institution underpinning those links is referred to under the generic French term of “cousinage” (referring to the social links between groups of so-called “cousins”), a term that we will use throughout this paper. These cousinage relationships often correspond to alliances between pairs of social groups defined by ethnicity, patronyms and/or the professions traditionally exerted by members of these groups. Although cousinage relationships come from a very old tradition, they are still widely used nowadays. In Senegal, it was found in a survey that 46 percent of Senegalese practice cousinage everyday and an additional 30 percent practice it sometimes (Smith, 2004). Although the

\footnote{An alternative term for cousinage is “joking relationships” [in French, “cousinage à plaisanterie”], which refers to the codified jokes that individuals exchange upon their first encounter. Joking according to ritualized mocking allows to identify the nature and intensity of bilateral relationships and stress reciprocal duties before engaging in social interactions.}

\footnote{For example, the Sérère and Poular are two “allied” ethnic groups in Senegal and the Gambia and the Ba and Diallo are two “allied” family names in Senegal. In Mali, groups that traditionally exerted the profession of blacksmith are linked with all other cases.}

\footnote{In Mali, for instance, cousinage is believed to have been ordained by the 13th century ruler Sundiata Keita, as part of the oral constitution of the Mali Empire.}
anthropological literature has mostly focused on reciprocal social relationships, several authors mention the role of cousinage in markets, as revealed by price bargaining along ethnic lines (see Hagberg 2006 for Burkina Faso, and Birkeland 2007 and Jones 2007 for Mali). In the economics literature, however, only a small number of papers have focused on kin relationships and land markets, with no specific focus on cousinage. Relevant studies include the work of Marx et al. (2019), who show how ethnicity affects the bargaining power of slum dwellers in Kenya, and Macours et al. (2010) and Macours (2014), who study social and ethnic matching on informal rental markets in the Dominican Republic and Guatemala in response to insecure property rights.

The second trend of literature that we build on involves an emerging urban economics literature on land tenure insecurity in developing countries and its implications for land markets. This literature trend began with Jimenez's (1985) seminal model of squatting in which informal dwellers coordinate land invasions to protect themselves from evictions. Brueckner and Selod (2009) further studied the emergence of a city's squatter settlements in a general equilibrium with inelastic land supply. In their model, squatting “squeezes” the formal land sector, explaining the high price of formal land in an equilibrium configuration where formal and informal settlements coexist. Our paper, however, does not involve squatting, whereby land is occupied without being purchased or rented out from its rightful owner, but focuses on the larger context of tenure informality and insecurity, whereby the occupant of a land plot may be its legitimate owner but does not have a fully-fledged property right, leading to the possibility of competing claims and conflicts. A small number of recent models have extended the standard monocentric land use model of urban economics initially developed by Alonso (1964), Mills (1967) and Muth (1969), in order to account for these issues. In Selod and Tobin (2018), urban households compete for land and simultaneously decide the type of property right to purchase from a land administration among a menu of rights that provides various degrees of tenure security. The model leads to an equilibrium with formal and more secure property rights at the proximity of the city center, a prediction that also holds in our model. Cai et al. (2018) extend the Selod and Tobin model to a calibrated dynamic stochastic model with internal migration that allows them study the long term trajectory of formal and informal land uses and the persistence of informal settlements over time. Picard and Selod (2020) extend the canonical model of urban economics to study the conversion of agricultural land into urban residences and the associated changes in land tenure. They introduce

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5Brueckner (2013) further extended the model with the introduction of a rent-seeking organizer. Shah (2014) modified the model to account for squatting on public land. Turnbull (2008) proposed a non-spatial but dynamic model of the landowner-squatter relationship that focuses on the timing of evictions.
information asymmetry between buyers and sellers of risky plots—a feature that is also present in our model—and find that information asymmetry deters land market participation and hinders the land use conversion process at the periphery of the city. Other spatial papers model specific types of informal housing. This is the case of Brueckner et al. (2019), who develop a theory explaining the emergence of a rental market for backyard structures in South African cities, and Pfeiffer et al. (2019), who propose a dynamic land-use model with formal and informal housing, including traditional informal settlements as well as backyards. Other recent studies have focused on the determinants of informal housing and urban slums, stressing the role of migration and the relative elasticities of formal and informal housing supply in determining the amount of informal housing (Alves, 2017, Henderson et al., 2019, Cavalcanti et al., 2019).

Our model builds on the above urban economics literature, especially on Selod and Tobin (2018) and Picard and Selod (2020), as we introduce tenure insecurity and information asymmetry in a monocentric land use model. To our knowledge, however, our model is the first land use model with interpersonal transactions, an important feature that was largely missing in the theoretical literature on land markets in developing countries, in spite of its likely high prevalence. The introduction of ethnic matching allows us to assess and compare the respective advantages of transactions sanctioned by property rights registration and of transactions under trusted relationships. It also allows us to study the coexistence of the two practices within a single city. Our framework generates novel predictions regarding the prevalence of ethnic matching in land markets in the presence of costly registration, and highlights the substitutability of trusted relationships to costly registration as well, as the gradual evolution of economies towards full cadastral coverage as registration costs are reduced.

The paper is organized as follows. We start by presenting a benchmark urban economics model with tenure insecurity in section 2. In section 3, we sequentially present two polar cases: a first extension where households have the possibility to establish a registered property right (see sub-section 3.1) and a second extension where land cannot be registered but where buyers and sellers may pair according to a trusted relationship (see sub-section 3.2). In section 4, we then present a hybrid model—closest to capturing the reality of developing country cities—where both registration and reliance on trusted relationships for transactions of informal land are available options. The final section concludes.

For a model of impersonal transactions and a theory of cadasters, see Arruñada, 2012. The idea of interpersonal transactions regarding land sales were only previously explored in a theoretical model by Lanjouw and Levy (2002) who contrasted land transaction conditions between family members and outside parties in a non-spatial setting.
2 An urban land-use model with tenure insecurity (benchmark model)

We first present a benchmark model based on the standard land use model of urban economics, in which we introduce tenure insecurity. This allows us to derive city structure and surplus in the absence of a property right system that makes land tenure secure.

2.1 Main assumptions

The urban space is represented by a line segment at the extremity of which lies a CBD where all jobs are located. Each location on this segment (denoted by its distance $x$ to the city center) has a unit mass of landowners, each endowed with one land plot. Each landowner decides whether or not to sell his land plot to a potential migrant coming to the city, thereby extracting the migrant’s willingness to pay for residence in that particular location. Because migrants will be working in the CBD, they value proximity to the city center. As migrant buyers are competing with one another, sellers sell their plots to the highest bidder. We consider an open-city model, in which buyers migrate to the city until the expected utility in the city (given by their expected disposable income) is equalized with the rural utility level $u$.\footnote{We assume a linear utility function and a price of the composite good normalized to 1, so that the utility in the city defined as the consumption of the composite good is exactly equal to the expected disposable income.}

In our model, land tenure is insecure for some plots in the sense that a buyer can lose his plot in the future with a non-zero probability. This probability may reflect the numerous conflicts over land ownership that are prevalent in many developing country cities, in particular those that result from unclear initial ownership of the land by the seller, which is ground for competing claims.\footnote{Other conflicts may oppose heirs, customary owners and investors, private parties and public authorities. See Durand-Lasserre et al. (2015) for a full typology of urban land conflicts.} However, not all plots are insecure. There are two possible levels of tenure security $Q \in \{q, 1\}$, with $q < 1$. Insecure plots may be contested and have a probability $q$ of remaining in the hands of their buyer in the future, whereas secure plots are uncontested and have a probability 1 of remaining in the hands of their buyer. When a buyer is evicted from his plot, the plot is simply grabbed by an absentee landowner and can be resold to another migrant. We denote $\pi$ the exogenous proportion of secure plots before the city forms and assume it is uniform across all locations.

The key assumption in our model is the existence of an information asymmetry between sellers
(i.e., initial landowners) and buyers. Whereas sellers know the tenure security level of their plots (i.e.,
you know if there is a competing claim), migrant buyers cannot observe this characteristic before the
transaction takes place. In what follows, we will refer to the initial owners of secure plots as $1$-owners
and to the initial owners of insecure plots as $q$-owners. If landowners decide not to sell their plot to
a migrant, they simply keep it for agriculture and obtain a fixed revenue equal to the agricultural
land rent $R_a$. We assume that $u \leq R_a$, reflecting the fact that migrants are rural laborers who, by
definition, cannot be paid above the agricultural land rent.

We present below the market behavior of buyers and sellers in each location and derive the resulting
spatial extent of the urban land market.

2.2 Sellers and buyers’ behavior

The sellers’ decision to sell is modeled with a binary choice variable $P \in \{0, 1\}$, with $P = 1$ if the
seller transacts with a migrant, and $P = 0$ if the seller does not participate in the land market. We
denote $\pi(x)$ the share of $1$-sellers among the sellers in location $x$ who decide to sell.$^{10}$ We consider
that buyers have rational expectations and can fully anticipate the value $\pi(x)$.

In location $x$, the buyer of a plot can expect to obtain a secure plot with probability $\pi(x)$ and an
insecure plot with probability $1 - \pi(x)$. If the plot is insecure, it is lost with probability $1 - q$. For the
buyer, the expected probability of keeping the plot is thus $\pi(x) + (1 - \pi(x))q$ and that of losing it is
$(1 - \pi(x))(1 - q)$. Furthermore, the buyer knows that, if he is not evicted and is thus able to remain in
the city, he will have utility $y - xt - R(x)$, corresponding to his urban income net of commuting costs
and of the price paid for the plot (denoted $R(x)$). If evicted and having to return to the rural area,
the buyer is not reimbursed for the plot purchase and gets utility $u - R(x)$. It is then easy to see that
the expected utility of a buyer purchasing a plot in $x$ is:

\begin{equation}
(\pi(x) + (1 - \pi(x))q)(y - xt - R(x)) + (1 - \pi(x))(1 - q)(u - R(x))
\end{equation}

We are now ready to derive the bidding behavior of buyers. Equating (1) with the rural utility level
$u$ (given our open city assumption) and inverting the resulting equation in the land price, we obtain
the bid-rent of a buyer of a plot located in $x$:

\begin{equation}
\psi(x, u) = \{\pi(x) + q(1 - \pi(x))\} (y - tx - u)
\end{equation}

$^{10}$ $\pi(x)$ may differ from $\pi$ if the proportions of secure and insecure plots sold in $x$ differ.
This bid-rent measures the buyer's willingness to pay for the plot to exactly attain equilibrium utility $u$. Note that the bid-rent function depends on the buyer's expectation regarding tenure insecurity, so that the buyer's willingness to pay increases with $\pi(x)$, the fraction of 1-sellers among sellers and with $q$, the level of tenure security of risky plots.

As for sellers, their market participation decision will depend on the plot’s location $x$, its intrinsic tenure security level $Q$ and the market price $R(x)$, which we capture with the generic notation $P(x, Q, R)$. In turn, because the benefit $B$ of a landowner will depend on his market participation decision and on the market prevailing price $R(x)$ in location $x$, we express it as $B(P, x, Q, R) \equiv PR(x) + (1 - P)R_a$. The formula expresses gross profit and simply states that landowners who do not participate in the land market ($P = 0$) obtain a benefit of $B = R_a$, while landowners who participate in the market ($P = 1$) obtain a benefit of $B = R(x)$.  

### 2.3 The Competitive Equilibrium

Having characterized the behaviors of both sellers and buyers, we can now define the spatial equilibrium. To do this, however, we need to introduce the additional notations $L_q(x)$ and $L_1(x)$ for the respective quantities of insecure land and secure land that are transacted in $x$. With these notations, the total quantity of land transacted in $x$, can be decomposed as $L(x) = L_q(x) + L_1(x)$.

The set of equilibrium conditions that define the equilibrium are as follows: First, the equilibrium quantity of land that is sold in each location $x$ must be smaller than the initial unit land endowment in that location, which yields the following land use constraint:

$$L_q(x) + L_1(x) \leq 1 \quad \text{for any } x \quad (3)$$

Then, in equilibrium, the market participation decision of the seller for each plot location, tenure security level and price, $P^*(x, Q, R)$, maximizes his gross profit, which leads to the profit maximization condition:

$$P^*(x, Q, R) \in \text{ArgMax}_{P \in \{0, 1\}} B(P, x, Q, R) \quad \text{for any } x \quad (4)$$

Additionally, due to the infinite potential pool of migrants to the city, sellers are able to perfectly extract buyers’ willingness to pay so that the land price is equal to the bid-rent in each location $x$.

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11 Considering that the seller gives up on agricultural production, the net profit from a sale is $PR(x) + (1 - P)R_a - R_a$. 

8
taken at the rural utility level $u$:

$$R(x) = \psi(x, u) \quad \text{for any } x \text{ where } L(x) > 0$$

(5)

Finally, we can directly express the city fringe or “boundary” denoted $x_b$ as the location closest to the CBD such that the gross benefits of 1-sellers and $q$-sellers accounting for their optimal market participation decisions are equal to the agricultural land rent $R_a$. This can be written as:

$$x_b = \min x \text{ s.t. } B^*(x, 1, R) = B^*(x, q, R) = R_a$$

(6)

where $B^*(x, Q, R) \equiv B(P^*(x, Q, R), x, Q, R)$ is the optimal payoff (i.e. the gross profit evaluated at the optimal participation decision) of a seller of a plot in location $x$, endowed with a plot of security level $Q$, and selling at price $R$. Since there is only one price for land irrespective of the tenure security level (given that buyer cannot distinguish between risky and secure plots), the condition boils down to $R(x_b) = \psi(x_b, u) = R_a$, which is the standard city fringe condition. We have the following equilibrium definition:

**Definition 1:** A competitive equilibrium is a set of market participation decisions ($P^*$), prices in each location ($R(x)$), and a city fringe ($x_b$) that satisfies the system of equilibrium conditions (3), (4), (5) and (6).

Note that our equilibrium is defined “ex-ante” in the sense that agents make choices depending on their expectation that a conflict may materialize, but before the existence of a conflict can be observed. It also relies on rational expectations, in the sense that buyers and sellers know the model of the economy and are able to correctly assess the equilibrium proportion of secure plots among transacted plots. The main difference with the standard adverse selection model (see Akerlof 1978) is that, in our model, uncertainty only directly affects buyers who may lose their plot if facing a risk of eviction.

To solve the system, we identify all possible combinations of sellers’ $P$-decisions that are Nash equilibria (i.e., the combinations in which no landowner would gain from revising his $P$-decision given the $P$-decisions of all other landowners). We show in Appendix A that a continuum of equilibria are possible. In other words, there is a continuum of $P$-decisions that are compatible with our equilibrium
conditions (3)-(6). In these equilibria, all owners in the segment \([0, x_a] \) participate in the market. These multiple equilibria only differ with respect to market participation decisions over the segment \( [x_a, x_a^*] \) with \( x_a^* = \frac{1}{2} (y - R_a - u) \) (on this segment any transacted land plot is sold at exactly price \( R_a \)). More specifically, we show in Appendix A that each equilibrium in this continuum of equilibria is characterized by the number of 1- and \( q \)-sellers in each location \( x \in [x_a, x_a^*] \), which must verify \((L_q(x), L_1(x)) \in [0, 1 - \pi] \times [0, \pi] \) and \( B(P, x, Q, R) = R_a \). Let us denote by \( \mathcal{E}_{L_q, L_1} \) the equilibrium characterized by functions \( L_q \) and \( L_1 \) over the interval \( [x_a, x_a^*] \). We show in Appendix A that \( \mathcal{E}_{L_q, L_1} \) is unstable if there exists \( x \in [x_a, x_a^*] \) such that either \( L_q(x) > 0 \) or \( L_1(x) > 0 \) and that any small deviation in \( P \)-decisions from that equilibrium will always trigger a transition towards \( \mathcal{E}_{0,0} \). This equilibrium is therefore the unique stable equilibrium. In that equilibrium, no landowner participates in the land market beyond \( x_a \) so that the city fringe is in \( x_b = x_a \). Our results can be summarized in the following proposition:

**Proposition 1:** There is a single stable equilibrium, in which all landowners between the city center and the city fringe \( x_a = \frac{1}{t} \left[ y - \frac{R_b}{\pi + q(1 - \pi)} - u \right] \) participate in the land market. The equilibrium price curve is \( R(x) = [\pi + q(1 - \pi)] (y - tx - u) \).  

**Proof:** See Appendix A.

Observe that the land price curve is linear with slope \(-[\pi + q(1 - \pi)] t\), where \( \pi + q(1 - \pi) \) is the probability for a buyer to keep a purchased plot. In equilibrium, when marginally moving outwards from the city center, the reduction in land price exactly compensates the increase in expected transport costs (given the probability of keeping the plot and commuting to the city center rather than losing the plot and moving back to the rural area without the need to commute anymore). The equilibrium price slope becomes flatter if plots become more insecure (lower \( q \)) or if sellers with secure plots are scarcer (lower \( \pi \)). As expected, when there is no tenure insecurity in the model (either because \( q = 1 \) or \( \pi = 1 \)), the slope is equal to the certain marginal transport cost as in the standard version of the urban economics model with unit land consumption.

Inspection of the equilibrium city fringe formula for \( x_a \) shows that the city size decreases with the proportion of insecure plots \((1 - \pi)\) and the level of tenure insecurity \((1 - q)\). It is easy to understand
that, when either one of these values marginally increases, the “last” seller at the city fringe prefers to keep his plot under agricultural use, since buyers’ willingness to pay is reduced. As we will see in the following section, this reflects a market failure in the sense that some plots are not transacted, due to tenure insecurity and information asymmetry. Figure 1 represents the equilibrium land price as a function of distance to the CBD (with the slope of the land price written in blue letters), as well as the equilibrium city structure.

Figure 1: City structure and land prices (benchmark model)

Note: This figure represents the equilibrium land price and market participation as a function of distance to the city center. The slope of the land price curve is indicated in blue.

13 Considering a variant of the model with risk aversion, it can be shown that the city size would also decrease with risk aversion. To see this, assume a Von-Neumann Morgenstern context with a CCRA Bernoulli function, \( z \rightarrow \frac{1}{1-\rho} - 1 \), where \( \rho \) is risk aversion. The bid-rent \( \psi(x,u) \) is now implicitly defined by the equation \( u = (1 - q)(1 - \pi(x))\left(\frac{(u-R)^{1-\rho} - 1}{1-\rho}\right) + (\pi(x) + q(1 - \pi(x)))\left(\frac{(u-R)^{1-\rho} - 1}{1-\rho}\right) \). It is defined uniquely, as can easily be seen by deriving the LHS of the equality with respect to \( R \) and by observing that the LHS is only defined if \( u \geq R \). Applying the implicit function theorem, we show that \( \frac{\partial \psi(x,u)}{\partial \rho} < 0 \), which further implies that \( \frac{\partial x}{\partial \rho} < 0 \). In other words, the greater the risk aversion, the smaller the city. Introducing risk aversion is, however, not necessary to derive the main results of our model and would make it much less tractable. We therefore abstract from modeling risk aversion in our model.

14 In Appendix A, we also present a figure that plots the payoffs of sellers underlying their participation decisions (see Figure 6).
2.4 Suboptimality of the equilibrium

The market equilibrium involves an externality, insofar as agents do not internalize the effect of their market participation decision on the composition of transacted plots, which in turn affects other agents’ decisions. Following Fujita (1989), we define the surplus as the city production (sum of wages) minus the costs to organize the city (transport costs, composite good consumption, and foregone agricultural production). Although our framework to solve the equilibrium does not require to specify what happens to the plot after the buyer is evicted (since choices are made ex-ante, i.e. before the realization of a potential conflict), we need to introduce assumptions regarding the use of the land after an eviction in order to be able to write the surplus formula. When the buyer of a land plot is evicted, we assume that the plot is grabbed by an absentee agent and resold at price $R(x)$ to a new migrant worker. The process, however, may not be instantaneous. If there is some friction after the eviction, the plot will remain unoccupied for some time. We denote $\theta \in [0, 1]$, the fraction of time during which an evicted plot is occupied. If $\theta = 0$, the plot is immediately filled with a new occupant. If $\theta = 1$, the plot occupant is never replaced. $\theta$ is assumed to be the same for all land plots. In the competitive equilibrium, recognizing that the composite good consumption is $u$, the surplus can be written as:

$$\Gamma_\theta(q, \pi, u) = \int_0^{x_a} (\pi + (q + \theta(1 - q))(1 - \pi))(y - xt - u - Ra)dx$$

$$= (\pi + (q + \theta(1 - q))(1 - \pi))(y - u - Ra - \frac{x_a}{2}t)x_a$$

\(7\)

When $\theta = 0$, a plot which occupant was evicted is lost to city production and the surplus is:

$$\Gamma_0(q, \pi, u) = (\pi + q(1 - \pi))(y - u - Ra - \frac{x_a}{2}t)x_a$$

When $\theta = 1$, evictions do not disrupt city production and the surplus is:

$$\Gamma_1(q, \pi, u) = (y - u - Ra - \frac{x_a}{2}t)x_a > \Gamma_0(q, \pi, u)$$

As regards the optimal city configuration, it is easy to see that it corresponds to a situation where plots are allocated to a migrant until an optimal city boundary denoted $x_a^*(q, \pi, u)$. Indeed, if a plot is not allocated, its contribution to the surplus is zero. If a secure plot is allocated, it contributes to the city surplus by an amount $y - xt - u - Ra$. If an insecure plot is allocated, it contributes to the city surplus by an amount $y - xt - u - Ra$. This is mathematically equivalent to another definition of surplus that would consider the utility increment from migration to the city net of the opportunity cost of land use.
surplus by an amount \((q + \theta(1 - q))(y - xt - u - Ra)\). \(x^*_a\) is defined as the boundary beyond which no plots are allocated in the optimal city configuration. It is easy to see that \(x^*_a = \frac{1}{\theta}(y - Ra - u) > x_a\), and no informal plot will be sold beyond. The optimal surplus associated with this configuration is thus:

\[
\Gamma^*_\theta(q, \pi, u) = \int_0^{x^*_a} (\pi + (q + \theta(1 - q))(1 - \pi))(y - xt - u - Ra) dx \geq \Gamma_\theta(q, \pi, u)
\]

The gap between the market equilibrium surplus \(\Gamma_\theta(q, \pi, u)\) and the optimal surplus \(\Gamma^*_\theta(q, \pi, u)\) is caused by tenure insecurity \((q \text{ and } \pi)\), which decreases the size of the city to \(x_a < x^*_a\). When tenure insecurity is removed from the model, the surplus rises and the city size \(x_a\) grows to become optimal.\(^{16}\) In contrast, suppressing production disruption does not make the city size optimal, as land owners do not take this parameter into account in their decisions.

Focusing on the optimal surplus, note that it is a function of the model’s parameters \(q, \pi\) and \(u\), as well as \(\theta\). Intuitively, a greater \(u\) reduces both the optimal city size and the incremental gain from city production (as migration to the city is reduced), while a greater \(\pi\) or \(q\) increases both city size and city production. When \(\theta\) increases, however, only city production increases. The optimal surplus is maximum when tenure insecurity or production disruption are removed (i.e. \(\pi = 1, q = 1\) or \(\theta = 1\)). Indeed:

\[
\Gamma^*_1(q, \pi, u) = \Gamma^*_\theta(1, \pi, u) = \Gamma^*_\theta(q, 1, u) = \max_{q, \pi, \theta} \Gamma^*_\theta(q, \pi, u) = \int_0^{x^*_a} y - xt - u - Ra dx
\]

We denote this maximum optimal surplus \(\Gamma^{**}\) and will use it as an optimality benchmark in the rest of the paper. It is reached by the market equilibrium surplus when tenure insecurity is suppressed for any level of production disruption:

\[
\Gamma_\theta(1, \pi, u) = \Gamma_\theta(q, 1, u) = \Gamma^{**}
\]

3 Trust and registration as tenure security devices

The above section showed that land tenure insecurity and information asymmetry cause a market failure, whereby some landowners at the periphery of the city opt out of the market, leading to a sub-optimal urban equilibrium. Tenure insecurity and information asymmetry can be reduced through different institutional settings. In this section, we separately study the introduction in the benchmark

\(^{16}\)It can easily be checked that \(\Gamma^*_\theta(1, \pi, u) = \Gamma_\theta(1, \pi, u) \geq \Gamma_\theta(q, \pi, u)\) and \(\Gamma^*_\theta(q, 1, u) = \Gamma_\theta(q, 1, u) \geq \Gamma_\theta(q, \pi, u)\) for any \(q \in [0, 1]\) and \(\pi \in [0, 1]\). When either \(\pi = 1\) or \(q = 1\), we see that \(x_a = x^*_a\).
model of two such institutional settings. The first is a cadaster/registry of property rights, thanks to which landowners have their registered rights recognized and enforced. The second setting relies on bilateral trusted relationships between buyers and sellers, based on group kinship. We present these institutional settings sequentially before comparing them.

3.1 A model of registration

In the first extension, we add a property rights registration system to the benchmark model. Registration extinguishes competing claims on a land plot and makes it fully secure. Because it is observable by all, it allows buyers to identify a fraction of secure plots (i.e., those which are registered) with certainty. In this extension, sellers have the possibility to register their land before entering a transaction, anticipating that a registered plot will sell at a premium (that capitalizes both the increase in tenure security and the removal of information asymmetry). We assume that there is a registration cost, \( k \), which is the same for all plots, irrespective of the initial tenure security level.

3.1.1 Sellers and buyers’ behavior

An owner now has two choices. He chooses whether to participate in the market (decision \( P \in \{0, 1\} \)) and, conditional on participating in the market, whether to register his plot (decision \( F \in \{0, 1\} \)). If choosing \( F = 1 \), the tenure security level of the plot is reset at the value 1. There are thus two sale situations depending on sellers’ decisions, each commanding a different price. Applying the same bid-rent approach as in the previous section, we see that the buyer of a registered plot will be willing to pay \( \psi(x, u|F = 1) = y - tx - u \) to reach utility level \( u \). Similarly, the buyer of a non-registered plot will be willing to pay \( \psi(x, u|F = 0) = \{\pi(x) + q(1 - \pi(x))\} (y - tx - u) \).

3.1.2 Competitive equilibrium

Given the additional features of the model, the notations are slightly modified in comparison with the benchmark case. As before, we continue to use \( L_1(x) \) and \( L_q(x) \) to denote the quantities of secure and risky land that are transacted, while \( R(x) \) continues to denote the price of informally transacted land. However, we now introduce the notation \( L_f(x) \) to denote the quantity of registered (and transacted) land in each location \( x \), and \( R_f(x) \) to denote the price of formally registered land. We now allow the market participation and the registration decisions to depend on location, the intrinsic tenure security level, and both formal and informal market prices, with the notations \( P(x, Q, R_f, R) \) and
$F(x, Q, R_f, R)$. As for the seller’s gross profit, it is now also generically a function of the registration status of the land and of both formal and informal land prices, hence the notation $B(P, F, x, Q, R_f, R)$.

We can now adapt our definition of the competitive equilibrium as follows:

**Definition 2:** A competitive equilibrium is a set of market participation and registration decisions, prices in each location $x$ and a city fringe that satisfies the following equilibrium conditions:

\[
\begin{align*}
L(x) &= L_f(x) + L_q(x) + L_1(x) \leq 1 \quad \text{for any } x \\
(P^*(x, Q, R_f, R), F^*(x, Q, R_f, R)) &\in \text{ArgMax}_{(P,F)\in\{0,1\}^2} B(P, F, x, Q, R_f, R) \quad \text{for any } x \\
R_f(x) &= \psi(x, u|F = 1) \quad \text{for any } x \text{ where } L_f(x) > 0 \\
R(x) &= \psi(x, u|F = 0) \quad \text{for any } x \text{ where } L(x) > 0 \\
x_b &= \text{min } x \text{ s.t. } B^*(x_b, 1, R_f, R) = B^*(x_b, q, R_f, R) = R_a
\end{align*}
\]

where $B^*(x, Q, R_f, R) \equiv B(P^*(x, Q, R_f, R), F^*(x, Q, R_f, R), x, Q, R_f, R)$ is the optimized payoff (i.e., taken at the optimal participation and formalization decisions) of a seller of a plot of security level $Q$ in location $x$ selling at price $R$ if the plot is informal and $R_f$ if it is formal.

The equilibrium conditions are very similar to (3)-(6), but they also account for the registration decision, registered land, and registered land prices. As in the benchmark version of the model, the city fringe condition allows for one of the two owner types (1- or q-owners) to not participate in the market and comes down to equating the bid rent of the last seller to the agricultural land rent. There is also an additional equation that determines the price of formal land as the upper envelope of formal bid-rents in places where land is registered by sellers. As previously, we solve for the competitive equilibrium by identifying stable Nash equilibria (see Appendix B). The equilibrium structure of the city depends on the level of the registration cost as summarized in the following proposition:

\[\text{In what follows, we only mention stable equilibria. All the stable and unstable equilibria are presented and discussed in the Appendix.}\]
Proposition 2: There exist two formalization cost thresholds, \( k = R_a \frac{(1-q)(1-\pi)}{\pi(1-q)+q} \) and \( \bar{k} = (1-q)(1-\pi)(y-u) \), such that:

- **If** \( k \leq k \) (**Case 1**): The city is fully formal (all owners register and sell their plots). It extends until \( x_b = \hat{x}(k) = \frac{1}{t} [y - R_a - k - u] \).

- **If** \( k < k \leq \bar{k} \) (**Case 2**): The city extends until \( x_b = \bar{x} \) and is organized in two zones, one formal on \([0, \hat{x}(k)] \) (Zone 1) and one informal on \([\hat{x}(k), x_a] \) (Zone 2), where \( \bar{x}(k) = \frac{1}{t} \left( y - \frac{k}{(1-q)(1-\pi)} - u \right) \), with the border \( x_a \) being the same as in the benchmark case (see Section 2 above). The central residential zone \([0, \hat{x}(k)] \) is fully formal, with all owners registering their plot and participating in the market. The price on that segment is \( R_f(x) = y - xt - u \). The peripheral residential zone \([\hat{x}(k), x_a] \) is fully informal, with all owners participating in the market without registering their plot. The informal price is \( R(x) = [\pi + q(1-\pi)] (y - xt - u) \).

- **If** \( k > \bar{k} \) (**Case 3**): The city extends until \( x_a \) and is fully informal (all owners participate in the land market without registering their plot).

**Proof:** See Appendix B.

Case 1 can be viewed as a developed country case where an affordable registration system is available and all land is registered. Case 2 is representative of a developing country context where registration is costly and where formal and informal land uses coexist. There is perfect spatial sorting between registered and non-registered plots, as landowners decide to register their land in the vicinity of the city center (zone \([0, \hat{x}(k)] \)), but not further away. Case 3 corresponds to the unlikely case where the registration cost is so high that no one registers and the equilibrium configuration is exactly the same as in the benchmark model presented in the previous section (just as if registration were not an option). Graphs in Figure 2 represent the equilibrium city structure and land prices in Cases 1 and 2.

Note that the urban fringe in Case 1 (\( \hat{x}(k) \)) is greater than in Case 2 (\( x_a \)). This property is consistent with the observation we previously made that tenure insecurity and information asymmetry

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18 Throughout the rest of the paper, we assume that \( y - u > \max(k, \frac{R_a}{(1-q)(1-\pi)}) \) to ensure the existence of the city and the possibility of having unregistered plots. This implies that \( \frac{k}{k} < k \). It is a stronger assumption than the one we had to justify the existence of the city under the benchmark model.

19 In Appendix B, we also present a figure that plots the payoffs of sellers underlying their participation and registration decisions (see Figure 7).

20 Indeed, observing that \( \hat{x}(k) \) is only defined for \( k \leq k \), we see that \( \hat{x}(k) - x_a = \frac{1}{t} [k - k] > 0 \).
Figure 2: City structure and land prices (registration model)

Note: This figure represents the equilibrium land price, market participation and registration as a function of distance to the city center when $k < \bar{k}$ and when $\bar{k} < k < \hat{k}$. The slopes of the land price curve are indicated in blue.

reduce city size (see Section 2). Also observe that the formal zone boundaries $\hat{x}(k)$ and $\tilde{x}(k)$ are both decreasing functions of $k$, implying that the greater the registration cost, the smaller the formal zone in the city (which covers the whole city in Case 1). As regards Case 2 specifically, we see that, in the informal zone (in the periphery of the city) where all plots are transacted, buyers are unable to distinguish between risky and non-risky plots. Within that zone, there is thus a single land price function for non-registered plots ($R(x)$). Additionally, because a fraction of transacted land is insecure, there is a slower capitalization of land prices when one moves towards the city center, leading to a flatter land price curve in the informal zone than in the formal zone. Finally, the discontinuity between formal and informal land prices in $\hat{x}(k)$ can be explained as follows: Since it is sellers who bear the formalization cost, they formalize in locations where they can extract a land price increment from buyers that is greater than the formalization cost. They stop formalizing in $\tilde{x}(k)$, where the buyers’ utility gain from formalization (and willingness to pay a land price increment) is exactly equal to the formalization cost. The discontinuity in land prices ensures that there is continuity in buyers’ utility and sellers’ profits. Mathematically, we see that if there were no price discontinuity, the utility gain around $\hat{x}(k)$ would be: $y - \hat{x}(k)t - [(\pi + q(1 - \pi))(y - \hat{x}(k)t) + (1 - \pi)(1 - q)u] = k$. 

17
### 3.1.3 Surplus gain from property rights

We can derive the surplus in the city under the registration system. Taking into account, as before, the possibility of productive disruption following an eviction, the surplus is given by:

\[
\Lambda(k) = \begin{cases} 
\int_0^x (y - xt - k - u - R_a) dx & \text{in Case 1 } (k \leq \bar{k}) \\
\int (y - xt - k - u - R_a) dx + ((q + \theta(1-q))(1-\pi) + \pi) \int_{\hat{x}_m(k)}^x (y - xt - u - R_a) dx & \text{in Case 2 } (k < \bar{k} \leq \bar{k})
\end{cases}
\]  

Comparing the competitive surpluses with and without the land registration system (\(\Lambda\) and \(\Gamma\)) yields the following property:

**Proposition 3:** The equilibrium surplus under the registration system is always strictly greater than in the benchmark model for \(k < \bar{k}\) and it is equal to the surplus in the benchmark model for \(k \geq \bar{k}\).

**Proof:** When \(k = 0\), \(\Lambda - \Gamma\) is strictly positive since \(1 > \pi + (q + \theta(1-q))(1-\pi)\) and \(\hat{x} > x_o\). On the interval \([0, \bar{k}]\), we have \(\Lambda - \Gamma = \int_0^{\hat{x}(k)} (y - xt - k - u - R_a) dx - \int_0^{x_m} (\pi + (q + \theta(1-q))(1-\pi))(y - xt - u - R_a) dx\). The gap decreases with \(k\), as \(\frac{\partial(\Lambda - \Gamma)}{\partial k} = -\frac{1}{t}(y - k - u - R_a) < 0\). Next, let us consider \(\Lambda - \Gamma\) for \(k \in [\bar{k}, \bar{k}]\). We have \(\Lambda - \Gamma = \int_0^{\hat{x}(k)} (y - xt - k - u - R_a - (\pi + (q + \theta(1-q))(1-\pi))(y - xt - u - R_a)) dx\). Its derivative is \(\frac{\partial(\Lambda - \Gamma)}{\partial k} = -\frac{1}{t} \left[ y - u - (1 - \theta) \left( \frac{k}{1-q(1-\pi)} - R_a \right) \right]\), which is negative until \(k\) reaches \(k_0 \equiv (1 - \pi)(1-q) \left( \frac{u}{1-q} + R_a \right)\) and positive after. As \(k_0 > \bar{k}\), \(\Lambda - \Gamma\) decreases with \(k\) on the interval \([\bar{k}, \bar{k}]\) and reaches 0 in \(k = \bar{k}\). Thus, \(\Lambda - \Gamma > 0\) for \(k < \bar{k}\) and \(\Lambda - \Gamma = 0\) for \(k \geq \bar{k}\). This completes the proof of Proposition 3.

To understand Proposition 3, observe that \(k\) can be viewed as the extra cost to avoid eviction and the associated production loss. When \(k\) is sufficiently small, some degree of formalization occurs and increases the surplus. Interestingly, the dominance of the registration system does not necessarily require the city to be fully formal (as in Case 2, which is only partially formal). Note, however, that although the introduction of property rights is an improvement over the benchmark model if the registration cost is low enough, it does not completely remove the market failure. In fact, we show in Appendix B that the market equilibrium city structure and the optimal city structure only coincide.
when \( k = 0 \). When the registration cost is low enough (\( 0 < k \leq k_* \)), the equilibrium configuration is completely formal (which solves both the tenure insecurity and information asymmetry problems), and yet, market participation is still reduced at the periphery of the city because of the strictly positive registration cost.

It is also remarkable that the optimum city configuration for the registration model (see Appendix B) actually requires the presence of an informal zone, as long as \( k > 0 \). This is because registration of peripheral plots involves a registration cost that outweighs the incremental production gain net of commuting costs. In the competitive equilibrium, there is an informal zone (between \( \hat{x}(k) \) and \( x_a \)), but its size is sub-optimal. This is due to an externality associated with registration, as landowners choose to register based on the anticipation of buyers’ willingness to pay for a secure plot rather than on buyers’ contribution to production in the city.\(^{22}\)

3.2 A model of trust

We now present a second extension of the benchmark model where landowners do not have the possibility to register their plot (i.e., they cannot remove the risk on their plot) but may instead choose whom they transact with in response to the information asymmetry. More precisely, each individual owner may decide whether to transact with a potential migrant with whom he has an ethnic relationship that involves some amount of trust. Borrowing the language of the anthropological literature on joking relationships, we refer to this behavior as transacting with a cousin (versus transacting with a non-cousin).\(^{23}\) In our setting, there is no need to define groups and specify their numbers, as we just focus on whether landowners transact with a cousin or not (with an infinite pool of cousins potentially supplied by migration to the city). Cousinage relationships (the existence of a trusted relationship) are known and observable by all agents. Our only assumption is that tenure insecurity is location-specific but not group-specific, implying that, in each location, the proportions of risky and secure plots are the same among all groups.

We denote by \( C \in \{c, nc\} \) the landowner’s decision to sell to a cousin \( (C = c) \) or to a non-cousin \( (C = nc) \). As in the benchmark model, buyers do not know the risk associated with the plot they are

---

\(^{21}\)In that case, not only is the market equilibrium optimal, but it reaches the maximum optimal surplus \( \Gamma^{**} \) of the benchmark model with no tenure insecurity (as property rights can be obtained for free).

\(^{22}\)The result that the optimal city structure may require some level of informality when formal property rights are costly to establish was first derived in Cai et al. (2018). Also note that in the presence of agglomeration effects, the externality might be attenuated if sellers anticipate an increase in their own labor income from migration to the city.

\(^{23}\)Although we refer to cousinage relationships, this version of our model encompasses the case of any society where trusted relationships exist within and across groups of individuals.
purchasing \((Q \in \{q, 1\})\). Mirroring the literature on ethnic groups and social sanctions (see Fearon and Laitin 1996, La Ferrara 2003, Habyarimana, et al. 2007), the key assumption in this setting is that selling a low-security plot to a cousin will always be punished with penalty \(J > 0\). Therefore, sellers have an incentive to be more honest in their transactions with cousins than in their transactions with non-cousins.\(^{24}\) The social penalty reflects the ostracism imposed on individuals who betray trust among cousins as codified in the consanguine institution. Given our assumption that tenure security is only location-specific, we denote \(\pi^c(x)\) the proportion of 1-sellers in \(x\), as a fraction of all sellers who transact with a cousin. Similarly, \(\pi^{nc}(x)\) is the proportion of 1-sellers in \(x\), as a fraction of all sellers who transact with a non-cousin.

Observe that land markets are now inter-personal (as opposed to the impersonal land markets presented in the benchmark and in the registration versions of the model). Also note that, because different levels of trust exist between cousins and between non-cousins, there are now two prices for plots, depending on whether the transaction involves cousins or non-cousins. We denote these inter-personal prices \(R^c(x)\) and \(R^{nc}(x)\) when the transaction involves cousins and non-cousins respectively.

3.2.1 Sellers and buyers’ behavior

The expected utilities of a buyer buying from a cousin seller or from a non-cousin seller are respectively:

\[
\begin{align*}
\psi(x, u | C = c) &= \{\pi^c(x) + q(1 - \pi^c(x))\} (y - tx) + (1 - \pi^c(x))(1-q)u - R^c(x) \\
\psi(x, u | C = nc) &= \{\pi^{nc}(x) + q(1 - \pi^{nc}(x))\} (y - tx) + (1 - \pi^{nc}(x))(1-q)u - R^{nc}(x)
\end{align*}
\]

Because we have an open city, migration will occur until buyers obtain the same utility level as in the rural area (which we still denote \(u\)). Inverting the above utility functions in the land price gives us the bid-rent functions in each location of the city, both for transactions among cousins and among non-cousins:

\[
\begin{align*}
\psi(x, u | C = c) &= \{\pi^c(x) + q(1 - \pi^c(x))\} (y - tx - u) \\
\psi(x, u | C = nc) &= \{\pi^{nc}(x) + q(1 - \pi^{nc}(x))\} (y - tx - u)
\end{align*}
\]

Anticipating buyers’ willingness to pay (given by the above bid-rent functions), landowners choose whether to participate in the market (decision \(P \in \{0, 1\}\)) and whom to sell to (decision \(C \in \{c, nc\}\)).

Let us now detail the sellers’ profit associated with each decision. If a seller decides not to participate
in the land market, he receives the agricultural rent $R_a$. An owner of a secure plot selling to a cousin buyer $(C = c, Q = 1)$ receives a payment $R^c(x)$. An owner of an insecure plot selling to a cousin buyer $(C = c, Q = q)$ receives a payment $R^c(x)$, but faces the social penalty $J$ that reduces his/her benefit to $R^c(x) - J$.

Finally, an owner selling to a non-cousin buyer receives a payment $R^{nc}(x)$ and there is no social penalty if the transacted plot is insecure.

### 3.2.2 Competitive equilibrium

We can now adapt the equilibrium definition to the inter-personal market setting. The decision to participate in the market is now a function of the interpersonal prices. It can be denoted $P(x, Q, R^c, R^{nc})$.

The decision to sell to a cousin or a non-cousin is also a function of the same arguments and is denoted $C(x, Q, R^c, R^{nc})$. The profit of a seller can now be generically expressed as $B(P, C, x, Q, R^c, R^{nc})$. In this version of the model, we decompose transacted land, not only according to its intrinsic tenure insecurity, but also according to the potential cousinage relationship between buyers and sellers. This requires the introduction of the notations $L^c(x)$ and $L^{nc}(x)$ for land transacted between cousins and non-cousins respectively. With these additional notations, we have the following equilibrium definition:

**Definition 3:** An equilibrium is a set of market participation decisions, “cousinage” decisions, prices in each location $x$ and a city fringe that satisfies the following equilibrium conditions:

\[
\begin{align*}
L(x) &= L_q(x) + L_1(x) = L^c(x) + L^{nc}(x) \leq 1 \quad \text{for any } x \quad (14) \\
(P^*(x, Q, R^c, R^{nc}), C^*(x, Q, R^c, R^{nc})) \\
&\in \text{ArgMax}_{(P, C) \in \{0,1\} \times \{c, nc\}} B(P, C, x, Q, R^c, R^{nc}) \quad \text{for any } x \quad (15) \\
R^c(x) &= \psi(x, u|C = c) \quad \text{for any } x \text{ where } L^c(x) > 0 \quad (16) \\
R^{nc}(x) &= \psi(x, u|C = nc) \quad \text{for any } x \text{ where } L^{nc}(x) > 0 \quad (17) \\
x_b &= \min x \text{ s.t. } B^*(x_b, 1, R^c, R^{nc}) = B^*(x_b, q, R^c, R^{nc}) = R_a \quad (18)
\end{align*}
\]

where $B^*(x, Q, R^c, R^{nc}) \equiv B(P^*(x, Q, R^c, R^{nc}), C^*(x, Q, R^c, R^{nc}), x, Q, R^c, R^{nc})$ is the optimized payoff (i.e., for the optimal participation and cousinage decisions) of a seller of a plot of security level $Q$ in location $x$ selling at price $R^c$ if the buyer is a cousin and at price $R^{nc}$ if he is not.

\footnote{$J$ captures the disutility experienced by landowners when they are punished. Although it can be non-monetary in nature, landowners behave as if their monetary benefit were reduced by $J$.}
Condition (14) states that the quantity of transacted land must be smaller than the initial endowment in location $x$. It also provides the decomposition of the total amount of transacted land by tenure security, as well as by cousinage. Condition (15) characterizes the optimal market participation and cousinage decisions of sellers. Conditions (16) and (17) reflect sellers’ extraction of buyers’ willingness to pay under different cousinage situations. Condition (18) characterizes the city fringe.

Before solving the equilibrium, we derive the following two lemmas regarding cousinage decisions.

**Lemma 1:** In a stable equilibrium, 1-owners only sell to cousin buyers.

**Proof:** See in Appendix C.

Lemma 1 implies that it is only possible to acquire a secure plot if transacting with a cousin. Yet, transactions between cousins involve information asymmetry, as insecure plots may also be sold to cousin buyers.

**Lemma 2:** In a stable equilibrium, if there are transactions between non-cousins, they must always involve insecure plots ($Q = q$).

**Proof:** This is a direct consequence of Lemma 1. Because 1-owners never sell to non-cousins, any transaction between non-cousins must therefore involve insecure plots ($Q = q$).

Lemma 2 implies that there is no information asymmetry in transactions between non-cousins. With Lemmas 1 and 2, we see that transactions between cousins pool risky and non-risky plots, whereas transactions between non-cousins clearly separate a subset of risky plots. With these lemmas in mind, let us now solve for the equilibrium. We show that the city structure depends on the value of the social penalty $J$ (see full details in Appendix C). Intuitively, the main qualitative difference when increasing the social penalty is that $q$-owners tend to sell more to non-cousins (in order to avoid the social penalty) and are more likely to drop out of the market. For ease of presentation and without major loss in generality, we will focus, in the rest of this subsection, on the case where $J \leq J = \pi R^1 \frac{1-s}{q}$, which encompasses situations in which cousinage is relatively mild, as practiced in urban areas in Senegal for instance (as observed by Smith, 2004). In that case, however, transactions only occur among

\[26\] As we will see later in the subsection, the institution of cousinage is socially justified when $J$ is sufficiently small.
cousins. We present the other cases where $J > J_a$ and where non-cousins may transact with each other in Appendix C.

We have the following proposition:

**Proposition 4:** Let us denote the social penalty threshold $J_a = \pi R_a \frac{1 - q}{q}$, and the zone boundary thresholds $x(J) = \frac{1}{t} \left( y - \frac{R_a + J}{\pi (1 - q) + q} - u \right)$ and $\bar{x}(J) = \frac{1}{t} (y - (R_a + J) - u)$. The city extends until the city boundary $x_a^*$ and is organized in the three following zones, moving outward from the city center:

- **Zone 1 (fully residential):** On $[0, x(J)]$, all landowners (irrespective of the tenure security level of their plot) participate in the land market and exclusively sell to cousins. The unique price in each location $x$ is $R^c(x) = [\pi + q(1 - \pi)] (y - xt - u)$.

- **Zone 2 (mixed agricultural and residential, partial market participation of $q$-sellers):** On $[\bar{x}(J), x(J)]$, all 1-sellers and a share of $q$-sellers participate in the land market and exclusively sell to their respective cousins. The mass of $q$-sellers selling to cousins in $x$ is $L_q^c(x, J) = \frac{\pi (1 - q) (y - xt - u)}{R_a + J - q (y - xt - u)} - \pi$. The unique price in each location $x$ is $R^c(x) = R_a + J$.

- **Zone 3 (mixed agricultural/residential, $q$-sellers dropping out of the market):** On $[\bar{x}(J), x^*_a]$, all 1-sellers participate in the land market and sell to their cousins, whereas all $q$-sellers keep their plots under agricultural use. The unique price in location $x$ is $R^c(x) = y - xt - u$.

**Proof:** See the proof of the Extended Proposition 4 in Appendix C.

Given Lemmas 1 and 2, $q$-owners participating in the market face a trade-off between selling to a non-cousin, and selling to a cousin at a higher price while facing the social penalty $J$. Since the penalty is sufficiently low, $q$-owners always prefer to sell to their cousins. In terms of city size, we see that the city extends all the way to $x^*_a > x_a$. Indeed, the cousinage institution reduces the asymmetry of information as compared to the benchmark model, so that some 1-owners now have an incentive to sell further away from the city center (to their cousins). This leads to a larger city, with plots under urban and agricultural use coexisting at the periphery (i.e., not all landowners decide to participate in the market).

---

27We derive in Appendix C all the other city configurations for $J > J_a$. In four of these cases, there are zones where some or all $q$-owners sell to both cousins and non-cousins. We also show the intuitive result that the number of $q$-owners selling to cousins decreases when the penalty increases.
Figure 3 shows the spatial configuration of the city. On Zone 1, the fully urban part of the city, the slope of the land price curve is \(-(\pi + q(1 - \pi))t\). As before, land prices exactly compensate expected commuting costs on this zone. Zone 2 and 3 correspond to the peri-urban part of the city, where some plots are residential and others remain agricultural. On Zone 2, some q-owners (but not all q-owners) drop out of the market. Thus, their net profit from informal sales (that are conducted exclusively with cousins) is equalized to the agricultural land rent. This explains the flatness of the land price curve and the price set at a markup that is exactly equal to \(J\) above the agricultural land rent.  

On Zone 3, only 1-owners participate in the market. Thus, the slope of the land price curve is again equal to \(-t\). Since \(\bar{x}(J)\) tends towards \(x_a^*\) when the social penalty tends towards zero, this zone tends to disappear for low values of \(J\). When \(J \to 0^+\), Zone 3 disappears (see Figure 3, with \(\bar{x}(J) \to x_a^*\)) and we are left with only two zones in the city ( Zones 1 and 2), where the land price in Zone 2 tends towards the flat agricultural land rent.  

![Figure 3: City structure and land prices (trust model)](image)

Note: This figure represents the equilibrium land price, market participation and ethnic matching as a function of distance to the city center when \(J < \bar{J}\). The slopes of the land price curve are indicated in blue.

\[\frac{\partial R^c(x)}{\partial x} = (1 - q)(y_u - xt - u) \frac{\partial \pi^c(x)}{\partial x} - (\pi^c(x) + q(1 - \pi^c(x))) = 0.\]

\[\text{In Appendix C, we present a figure that plots the payoffs of sellers underlying their participation and cousinage decisions (see Figure 10).}\]
3.2.3 Surplus gains from cousinage

We now derive the competitive surplus of the city, which can be expressed as a function of \( J \). For instance, in the case \( J < J \), it can be written as:

\[
\Phi(J) = \int_0^{\bar{x}(J)} (y - xt - u - R_a)dx + (q + \theta(1-q))(1-\pi) \int_0^{\bar{x}(J)} (y - xt - u - R_a)dx \\
+ (q + \theta(1-q)) \int_{\bar{x}(J)}^{\bar{x}(J)} L_c(x, J)(y - xt - u - R_a)dx
\]

For \( J > J \), the formula for \( \Phi \) changes with the city configurations presented in Appendix Figure 9. \( \Phi \) is a continuous and decreasing function of \( J \). The surplus difference between the cousinage and benchmark competitive equilibria, \( \Phi - \Gamma \), is thus also continuous and a decreasing function of \( J \). We show in Appendix C that \( \Phi - \Gamma > 0 \) when \( J \) is close to 0 and \( \Phi - \Gamma < 0 \) in \( J = \bar{J} \). We therefore have the following proposition.

**Proposition 5:** There exists a penalty threshold \( J_0(\theta) \in [0, \bar{J}] \) such that, for \( 0 < J < J_0(\theta) \) (respectively \( J > J_0(\theta) \)), cousinage increases (respectively decreases) the city surplus in comparison with the benchmark model.

**Proof:** See Appendix C.

The intuition underpinning the proposition is as follows: Low values of the social penalty increase the surplus (in comparison with the benchmark model), as they incentivize participation to the market and cousinage relationships that address information asymmetry through trusted transactions among cousins. When the penalty increases, however, the market participation of owners of insecure plots is reduced (since \( \bar{x}(J), \bar{x}(J) \) and \( L_c(x, J) \) are all decreasing function of \( J \)), which tends to mitigate the benefits from cousinage, as too few plots are sold on the market. For larger values of the penalty, the latter effect dominates the former, and the surplus might be lower under the trust model than under the benchmark model. Another way to look at this result is to note that the merit of cousinage is to introduce trust among cousins (through the threat of punishing deception), but that the threat itself needs to be small, as it tends to deter market participation.

\[\text{Note that, because } J \text{ is non-monetary, it is not directly accounted for in the city surplus definition and only affects this surplus indirectly, through the modification of landowners' decisions.}\]
3.3 Theoretical dominance: trust or registration?

We can now compare the surplus under the registration and the trust models. It is intuitive to see that the registration system has a greater potential to increase the surplus because it removes both tenure insecurity and asymmetry of information. On the contrary, reliance on cousinage can only, at best, remove information asymmetry by allowing buyers to better assess the quality of the plot they purchase, so that sellers of secure plots can get a higher benefit and also sell at the periphery of the city. When the formalization cost \( k \) tends towards zero, the competitive equilibrium under the registration model yields an optimal city size \( x^*_n \) (i.e., the city size under the benchmark model with no tenure insecurity) with full market participation of all landowners throughout the city. The trust model also yields a city of similar size, but some landowners find it more profitable to keep their land under agricultural use and do not participate in the market. When the formalization cost \( k \) tends towards zero, tenure insecurity is completely suppressed through registration, whereas this is never the case in the trust model for any intensity of the cousinage penalty. Therefore, when registration costs tend towards zero, the registration system dominates the trust system. However, considering more realistic situations where the registration cost is non zero, the comparison of the two property right systems becomes more complex. In fact, their ranking depends on the relative size of the registration cost \( k \) and the social penalty \( J \). This result is detailed in the following proposition:

**Proposition 6:** The ranking of the registration and trust models (in terms of competitive surplus attained) depends on the relative intensities of the registration cost \( k \) and the cousinage penalty \( J \). For low values of \( k \), the registration system is always preferable (irrespective of the value of the social penalty \( J \)). For high values of \( k \), there exists a threshold for the cousinage penalty below which (respectively above which) the trust model performs better (respectively worse) than the registration model. Mathematically, it means that there exists a positive threshold \( \hat{k}(\theta) \in [0, \bar{k}] \) such that:

- If \( k < \hat{k}(\theta) \), the competitive surplus is always greater under the registration model, irrespective of the value of the cousinage penalty \( J \);

- If \( \hat{k}(\theta) < k < +\infty \), there exists a threshold \( \hat{J}(k, \theta) \) such that, if \( J < \hat{J}(k, \theta) \) (respectively \( J > \hat{J}(k, \theta) \)), the competitive surplus under the trust model is greater (respectively smaller) than the competitive surplus under the registration model.

\[^{31}\text{In Appendix C, we show that } \hat{J}(k, \theta) \text{ is increasing in } k. \text{ This means that the larger the registration cost, the larger the value of the social penalty threshold below which the trust model is preferable to the registration model.}\]
**Proof:** See Appendix C.

Proposition 6 implies that, for any sufficiently low value of the registration cost, the registration model is always preferable. Trusted relationships can only efficiently substitute for registration in cases where registration costs are high and social penalties are low. The proposition can be illustrated graphically by Figure 4. To better visualize our result, observe that the equation of the upward sloping segment starting in $\hat{k}(\theta)$ is $\hat{J}(k, \theta)$. The combination of registration costs and social penalties below that line (the yellow area up to $\bar{k}$, defined in Proposition 2) is such that the trust system maximizes the city surplus, as compared to the registration system. According to Proposition 2, in the zone $k > \bar{k}$, the city under the registration system is fully informal and the total surplus under the registration system is thus constant and independent of $k$ (and equal to the benchmark surplus in the absence of a property registration system). Since Proposition 5 tells us that the trust system increases the benchmark surplus if and only if $J < J_0(\theta)$, the trust system dominates the registration system in the yellow area beyond $k = \bar{k}$ and below $J = J_0(\theta)$.

**Figure 4:** The ranking of registration and trust models

Note: This graph represents which of the registration or the trust equilibrium yields the greater surplus for different combinations of the registration cost ($k$) and the social penalty ($J$).
4 A hybrid model with trust and registration

In the preceding section, we sequentially presented two types of property rights regimes: an impersonal system based on the registration of land property rights, and an interpersonal system based on trusted relationships between land buyers and sellers. In fact, both regimes usually co-exist in today’s sub-Saharan African cities, due to the fact that the introduction of formal/modern property rights that allow for impersonal exchange has not replaced the traditional institutions that make interpersonal exchange possible.

In this section, we investigate what this coexistence of systems implies in terms of city structure and surplus. To do this, we combine the features of both our registration and trust models in a single urban land use model. As shown in Appendix D, we find that the overall structure of the city depends on both the value of the registration cost $k$ and the cousinage penalty $J$. For the sake of brevity, we only present results for the most likely but most complex case where the formalization cost is high ($\underline{k} < k < \bar{k}$) and where $J$ is low ($J < \underline{J}$, as in Section 3).$^{32}$

4.1 Competitive equilibrium

In the hybrid version of the model, landowners may decide to participate in the land market or not. If participating, they may decide to register their land or to sell it informally. If selling it informally, they may choose to sell it to a cousin or to a non-cousin.$^{33}$ The three decisions of landowners can be written as functions of location, the plot’s intrinsic level of tenure security, the formal price of land, and the informal prices of land sold to cousins and to non-cousins. The benefit of a seller is a function of the same variables and of his market participation, registration and cousinage decisions. This leads to the following updated version of the equilibrium definition:

$^{32}$Throughout this section, we assume, in addition to the previous sections’ assumptions, that $y - u > R_{\alpha} \frac{1}{\pi q(1-\pi)}$. This somewhat stronger hypothesis reduces the number of cases to be studied without changing the intuition of the model (See Appendix D for details).

$^{33}$Observe that cousinage and registration decisions are exclusive of one another. Once a landowner registers his plot, transactions occur at arm’s length, so that ethnic bilateral relations do not play any role.
Definition 4: An equilibrium is a set of market participation, registration, and “cousinage” decisions, prices in each location $x$ and a city fringe that satisfies the following equilibrium conditions:

\[
\begin{align*}
L(x) &= L_f(x) + L_q(x) + L_1(x) \leq 1 \quad \text{for any } x \\
(P^*(x, Q, R_f, R^c, R^{nc}), F^*(x, Q, R_f, R^c, R^{nc}), C^*(x, Q, R_f, R^c, R^{nc})) &\in \text{ArgMax}_B B(P, F, C, x, Q, R_f, R^c, R^{nc}) \quad \text{for any } x \\
R_f(x) &= \psi(x, u|F = 1) \quad \text{for any } x \text{ where } L_f(x) > 0 \\
R^c(x) &= \psi(x, u|F = 0, C = c) \quad \text{for any } x \text{ where } L^c(x) > 0 \\
R^{nc}(x) &= \psi(x, u|F = 0, C = nc) \quad \text{for any } x \text{ where } L^{nc}(x) > 0 \\
x_b &= \min x \text{ s.t. } B^*(x_b, 1, R_f, R^c, R^{nc}) = B^*(x_b, q, R_f, R^c, R^{nc}) = R_a
\end{align*}
\]

where $B^*(x, Q, R_f, R^c, R^{nc}) \equiv B(P^*, F^*, C^*, x, Q, R_f, R^c, R^{nc})$ is the optimized payoff (i.e. after taking the optimal participation, formalization and cousinage decisions) of a seller of a plot of security level $Q$ in location $x$ selling at price $R_f$ if the plot is formal, $R^c$ if the plot is informal and the buyer is a cousin, and at price $R^{nc}$ if the plot is informal and the buyer is not a cousin.

We now have 6 equilibrium conditions. As before, condition (19) says that the quantity of land sold must be smaller than the initial endowment in location $x$. Condition (20) characterizes the optimal market participation, registration and cousinage decisions of sellers. Conditions (21)-(23) reflect sellers’ extraction of buyers’ willingness to pay under the different land tenure situations (as regards security and registration) and social link configurations, where $L^c(x)$ is the quantity of land transacted informally with a cousin ($C = c$) or a non-cousin buyer ($C = nc$). Condition (24) characterizes the city fringe.

Before presenting the equilibrium, observe that Lemmas 1 and 2 remain valid in the hybrid model (i.e., 1-owners always sell to their cousins and transactions between non-cousins always involve insecure plots). The structure of the competitive equilibrium city now depends on both the intensity of the cousinage penalty and on the registration cost, as illustrated by the following proposition (see Appendix D for the full and detailed resolution and for the resolution of the equilibrium for other values of $k$ and $J$):

\[^{34}\text{Observe that } L_q(x) + L_1(x) = L^c(x) + L^{nc}(x)\]
Proposition 7: In equilibrium, the city is organized in four zones. Denoting the boundary zone threshold \( \hat{x}(k, J) = \frac{1}{t} \left( y - \frac{k - J}{(1-q)(1-\pi)} - u \right) \), we have:

- **Zone 1 (mixed formal and informal residential zone):** On \([0, \hat{x}(k, J)]\), all owners (irrespective of the initial tenure security level of their plot) participate in the market. Some q-owners register their plot before the sale (in quantity \( L^q(x, k, J) = 1 - \frac{\pi(1-q)(y-xt-u)}{(1-q)(y-xt-u)+J-k} \)), though some do not and sell exclusively to their cousins. 1-owners do not register their secure plots and sell them exclusively to their cousins. The informal price in each location \( x \) is \( R^c(x) = y-xt-u-k+J \) and the formal price for registered plots is \( R^f(x) = y - xt - u \).

- **Zone 2 (informal residential zone, full market participation):** On \([\hat{x}(k, J), \bar{x}(J)]\), all owners (q- and 1-owners) sell their plot informally and exclusively to cousins. In each location \( x \), the price for these informal sales is \( R^c(x) = (\pi(1-q) + q)(y-xt-u) \).

- **Zone 3 (mixed informal residential and agricultural zone, partial market participation of q-owners):** On \([\bar{x}(J), \hat{x}(J)]\), all 1-owners and some q-owners sell their plots exclusively to cousins. The rest of q-owners drop out of the market. The mass of q-owners selling their plot in \( x \) to cousins is \( L^q_c(x, J) = \frac{\pi(1-q)(y-xt-u)}{R_a + J - q(y-xt-u)} - \pi \). The price in each location \( x \) is \( R^c(x) = R_a + J \).

- **Zone 4 (mixed informal residential and agricultural zone, all q-owners dropping out of the market):** On \([\hat{x}(J), x^*_a]\), all 1-owners sell their plot exclusively to cousins and all q-owners drop out of the market. The price in each location \( x \) is \( R^c(x) = y - xt - u \).

- **The city boundary is at** \( x^*_b = x^*_a = \frac{1}{t} [y - R_a - u] \).

**Proof:** See Appendix D.

The structure of the city and the corresponding equilibrium land prices are represented on Figure 5.\textsuperscript{35} In the central residential zone (Zone 1, which has mixed registered and non-registered plots), the registered price curve has slope \(-t\), reflecting the standard trade-off between proximity to the center and land prices under full tenure security. There is a constant markup between the registered price curve and non-registered price curve equal to \( k - J \). This ensures that q-sellers are indifferent

\textsuperscript{35}In Appendix D, we present a figure that plots the payoffs of sellers underlying their participation, registration and cousinage decisions (see Figure 18).
between registering at cost $k$ and selling informally to cousins while incurring social penalty $J$. On the peripheral residential zone (Zone 2, where all plots are non-registered), the slope of the land price curve is $-(\pi(1-q) + q)t$, reflecting the trade-off between the informal land price and expected transport costs. Zones 3 and 4 are the greater periphery of the city, where residential and agricultural land uses coexist. As in Section 3.2, it is easy to see that, since $\bar{x}(J)$ tends towards $x^*_a$ when the social penalty tends towards zero, Zone 4 tends to disappear for low values of $J$ and the greater periphery is then mostly Zone 3, where the land price tends towards the agricultural land rent.

![Figure 5: City structure and land prices in the hybrid model](image)

Land prices

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>$\hat{x}(k, J)$</td>
</tr>
<tr>
<td>Zone 2</td>
<td>$x(J)$</td>
</tr>
<tr>
<td>Zone 3</td>
<td>$\bar{x}(J)$</td>
</tr>
<tr>
<td>Zone 4</td>
<td>$x^*_a$</td>
</tr>
</tbody>
</table>

Note: This figure represents the equilibrium land price, market participation, registration and ethnic matching as a function of distance to the city center when $k > k$ and $J < J$.

The slopes of the land price curve are indicated in blue.

We have the following proposition:

**Proposition 8:** *Registration and bilateral trust relationships are substitutes:* If the registration cost increases, some landowners will shift from registering their plots to engaging in trusted relationships. If the social penalty increases, some landowners will shift from engaging in trusted relationships to registering their plots.

**Proof:** Let us first look at an increase in $k$. Inspection of $\hat{x}(k, J)$ in Proposition 7 shows that it is a
decreasing function of $k$ and an increasing function of $J$, whereas $L_{fq}(x)$ is a decreasing function of $k$ and an increasing function of $J$. It follows that an increase in $k$ reduces both the zone over which plots are registered (Zone 1) and the proportion of landowners registering their plot in each location, resulting in an unambiguous reduction in the overall number of registered plots. Landowners who do not register their plots anymore while remaining in Zone 1 all resort to bilateral trusted relationships. Landowners who are now within the boundaries of Zone 2 also all resort to trusted relationships. The resulting effect is an unambiguous increase in the overall number of transactions under trusted relationships. Let us now focus on an increase in $J$. Considering that $\hat{x}(k, J)$ is shifted to the right, $x(J)$ and $\bar{x}(J)$ are shifted to the left, $L_{q, S=1}(x, J)$ is reduced and $L_{qf}(x, k, J)$ is increased, it is easy to see that fewer landowners resort to trusted relationships and more to registering their plot.

The above proposition illustrates how, in a context of costly registration, social relationships can partially address information asymmetry issues at the periphery of the city in the hybrid model, as it did in the trust version of the model. This is in line with the persistence of trusted relationships in the periphery of sub-Saharan African cities (as documented by Smith 2004) where registration is relatively scarce (see Selod and Tobin 2018, and Picard and Selod 2020). It also predicts that, if registration becomes more affordable over time, the role of ethnic relationships governing land transaction could be phased out. In the polar case with $k = 0$, ethnic relationships are not mobilized anymore. Mathematically, we see that, when $k$ tends towards zero, $\hat{x}(k) = \frac{1}{t} [y - R_a - k - u]$ tends towards $x^*_a$ and the informal zone of the city disappears.

Finally, we try to compare the surplus under the hybrid model with that of the trust and registration models. Recall that the model involves several externalities associated with the agents’ private decisions to participate in the market, register and transact with cousins. It is thus not straightforward to predict how the hybrid model will rank in comparison with the other two models. Although the comparison is mathematically intricate, we are able to show the following proposition for small values of the cousinage penalty:

**Proposition 9:**

- When the registration cost is sufficiently low, the registration model leads to a greater surplus than the hybrid model, which itself leads to a greater surplus than the trust model.

- When registration cost is sufficiently high, the hybrid and trust models provide greater surpluses than the registration model.
**Proof:** See Appendix D

The intuition for the first part of the first item in Proposition 9 is straightforward. When registration costs are low, adding the possibility of registration to the trust model allows for an efficient substitution of registration to trusted relationships. This substitution, which occurs close to the city center reduces both the risk of conflict and information asymmetry, whereas trusted relationships only addressed information asymmetry without reducing the risk of conflict. The possibility of cheap registration allows all owners of risky plots to enter the market, with a fraction of them deciding to register. The second part of the first item in Proposition 9 sheds light on the desirability of a full registration system when the registration cost becomes low. In that case, the possibility of circumventing registration through trusted relationships is harmful as it leaves tenure risks intact. In this context, it makes sense for governments to make registration compulsory.

On the contrary, the second item in Proposition 9 reflects the fact that, when registration costs are high, adding the possibility of establishing trusted relationships in the registration model allows some owners to forego costly registration for trusted relationships that relatively efficiently addresses information asymmetry and encourages more low-risk plot owners to sell at the outskirt of the city. In the case of developing countries where registration costs are likely to be high, our results thus indicate that the existence of trusted relationships can be an efficient substitute to an inefficient land administration.\(^{36}\)

## 5 Conclusion

In this paper, we proposed a series of models to shed light on alternative ways whereby households respond to the fundamental issue of tenure insecurity in sub-Saharan African cities. We first developed a pure registration model with information asymmetry between buyers and sellers that produced a series of results. First, the model made explicit how formal property rights protect land owners by making land tenure secure, but also how they facilitate transactions by reducing asymmetries of information between potential buyers and sellers (as all market participants know that formally recognized property rights cannot be contested). The model also showed that when registration costs

\(^{36}\)Finally, note that it is technically difficult to compare the surpluses of the hybrid and trust models. But it is possible to exhibit sufficient conditions for the hybrid model to dominate the trust model in the vicinity of \(k\).
are high, the proportion of formal land plots decreases with distance to the city center, a pattern that is observed in many sub-Saharan African cities (see e.g., Durand-Lasserre et al., 2015, Bertrand, 2016, World Bank, 2019 for evidence of this in the case of Bamako, Mali and Yaoundé, Cameroon). Finally, the model predicted that at the periphery of the city, plots are pooled on the informal periurban land market irrespective of their intrinsic risk, and that the existence of information asymmetry leads to a reduction in the city size, compared to the case with perfect information or with no formalization cost. As in Picard and Selod (2020), the latter result reflects a market failure that stems from information asymmetry in a context of tenure insecurity.

We then developed a model without registration but with ethnic matching along trusted relationships and interpersonal obligations between sellers and buyers. The pure trust model showed that, in some cases, trust can remove information asymmetry by generating a separating equilibrium where, on the informal market, riskless plots are sold to “allied” buyers and risky plots to “non-allied” buyers. Trusted relationships, however, cannot address the intrinsic problem of tenure insecurity (which requires a formal property right system). The size of the city is also greater because, although some owners of risky plots drop out of the market, owners of riskless plots can get a higher profit from their sale and therefore do not drop out of the market. Further comparing our trust and our registration settings, we found that the registration system is potentially more efficient, because it can reduce tenure insecurity in addition to addressing information asymmetry. The registration cost, however, tends to limit market transactions at the periphery of cities so that, when registration costs are very high, the pure registration model is not necessarily the best option.

Eventually, we developed a hybrid model where both registration and trusted relationships are possible, leading to the following conclusions: First, the model predicts that registration will occur in central parts of the city, whereas trust will be relied upon mainly in peri-urban areas. This is consistent with the observation that land transactions in peri-urban areas often involve interpersonal relationships. Second, we found that trusted relationships are a substitute to registration: A higher registration cost leads more people to engage in ethnic matching. Conversely, if policies are able to bring down the cost of registration, the model predicts that ethnic matching will be phased out. Although we focused on the role of registration cost in deriving our result, the transition towards a full registration system could be accelerated by cultural change and the weakening of the norms governing kinship relationships (Canut and Smith 2006). Finally, our hybrid model showed that when registration costs are high, allowing households to transact informally along trusted relationships leads to a greater
economic surplus. This second best result implies that, as long as registration costs remain high, informal transactions need not be discouraged and can even improve the efficiency of the economy. In a sense, this mirrors an ongoing debate in the policy world regarding the role played by the different tenure situations along a “continuum of land rights” (UN Habitat, 2012) and the contributions of these tenure situations to the overall welfare. Proponents of this approach have claimed that the promotion of freehold titles as the unique acceptable solution to hold land has been misguided and our results lend some credit to their position. Even though the continuum approach focuses on the benefits of weaker but more affordable documentation to legitimize property, our focus on one of the extremities of the continuum where land is held without any documentation shows that informal transactions can be beneficial when made according to trusted relationships. In fact, it should not be forgotten that land tenure is above all a social relationship and that registration is just an impersonal means of recognition of this relationship. However, as property rights become more affordable, the pure registration model becomes preferable and informal land transactions reduce rather than increase the surplus. In that context, the establishment of a fully formal land system will result in secure, denser, and more productive cities. We leave the study of underlying factors governing these changes and the speed at which they could happen for future research.
References


6 Appendix A - Benchmark model

6.1 Proof of Proposition 1 - Competitive equilibrium in the benchmark model

To derive the competitive equilibrium, we study, in each $x$, all possible combinations of participation decisions that $1$- and $q$-owners may take to satisfy (4) subject to (5). We then study the stability of these configurations and retain only the stable one. We finally verify that this stable configuration verifies the equilibrium conditions (3)-(6).

Sellers’ participation decisions and spatial city configuration We consider the three possible cases in terms of $1$-sellers’ participation decisions, i.e. $L_1(x) = \pi$, $L_1(x) \in [0, \pi]$ or $L_1(x) = 0$. For each case, we then derive the implications for the participation decisions of $q$-sellers and find the set of compatible city locations for these participation decisions.

- Let’s start with the case $L_1(x) = \pi$, which means that all 1-owners participate in the market. Because $q$-owners face the same payoff function as 1-owners (since they cannot be distinguished from one another), all of them also participate in the market so that $L_q(x) = 1 - \pi$. Therefore, the proportion of 1-sellers among all sellers in $x$, $\pi(x) \equiv \frac{L_1(x)}{L_1(x) + L_q(x)}$, is equal to $\pi$. Plugging this expression into the participation constraint of 1-sellers $B(P = 1, x, Q = 1, R) \geq R_a$ simplifies to $x \leq \frac{1}{4}(y - R_a - u) \equiv x_a$ as defined in Proposition 1. We have shown that:

$$L_1(x) = \pi \Rightarrow (L_1(x), L_q(x)) = (\pi, 1 - \pi) \Rightarrow x \leq x_a$$

- Let’s consider the second case $L_1(x) \in [0, \pi]$, which means that only a fraction of 1-owners located in $x$ sell their land, requiring indifference between participation and non-participation with $B(P = 1, x, Q = 1, R) = \{\pi(x) + q(1 - \pi(x))\} (y - xt - u) = R_a$. Because $q$-owners face the same payoff as 1-owners, they are also indifferent between participation and non-participation in the market. The above indifference condition provides an explicit formula for $\pi(x)$ and thus for the ratio $\frac{L_q(x)}{L_1(x)} = \frac{(y - xt - u - R_a)}{R_a - q(y - xt - u)}$. Observe that the numerator in this ratio represents the maximum net gain that a seller can obtain from a sale in location $x$ (since the buyer of a plot would be willing to pay $y - xt - u$ if he knew for sure that the plot is secure). Given that plots are transacted in $x$ under information asymmetry, the numerator of $\frac{L_q(x)}{L_1(x)}$ is necessarily positive, which implies $x < \frac{1}{4}(y - R_a - u) \equiv x_a^*$. Furthermore, in order to have $\frac{L_q(x)}{L_1(x)} > 0$, we must also...
have $R_a - q(y - xt - u) > 0$, which requires that $x > \frac{1}{t}(y - \frac{R_a}{q} - u \equiv x^q_a)$. We have shown that:

$$L_1(x) \in ]0, \pi[ \Rightarrow (L_1(x), L_q(x)) \in ]0, \pi[ \times ]0, 1 - \pi[ \Rightarrow x \in ]x^q_a, x^*_a[$$

- In the third case, $L_1(x) = 0$, which means that 1-owners prefer not to sell. As 4-owners have the same payoffs as 1-owners, they also prefer not to sell, so that $L_1(x) = L_q(x) = 0$. Observe that we are in a polar case where the function $\pi(x)$ is actually not defined. From a buyer’s perspective, given the shares of secure and insecure plots in location $x$, if a plot were to be offered on the market, it would be a secure plot with probability $\pi$. Non-participation thus requires $R_a \geq (\pi + (1 - \pi)q)(y - xt - u)$, where the RHS is the willingness to pay of a buyer in $x$. The latter inequality boils down to $x \geq x_a$. We have shown that:

$$L_1(x) = 0 \Rightarrow (L_1(x), L_q(x)) = (0, 0) \Rightarrow x \geq x_a$$

We have derived necessary conditions for the three above cases. Since it can easily be checked that $x^q_a < x_a < x^*_a$, this implies the following spatial configuration:

- For any $x \leq x^q_a$, we have $(L_1(x), L_q(x)) = (\pi, 1 - \pi)$.
- For any $x \geq x^*_a$, we have $(L_1(x), L_q(x)) = (0, 0)$.
- On the interval $x \in ]x^q_a, x_a[$, one may encounter any $(L_1(x), L_q(x)) \in ]0, \pi[ \times ]0, 1 - \pi[ \text{ (second case)}$ or $(L_1(x), L_q(x)) = (\pi, 1 - \pi)$ (first case).
- For $x = x_a$, one may encounter any $(L_1(x), L_q(x)) \in ]0, \pi[ \times ]0, 1 - \pi[ \text{ (second case)}$ or $(L_1(x), L_q(x)) = (\pi, 1 - \pi)$ (first case) or $(L_1(x), L_q(x)) = (0, 0)$ (third case).
- On the interval $x \in ]x_a, x^*_a[$, one may encounter any $(L_1(x), L_q(x)) \in ]0, \pi[ \times ]0, 1 - \pi[ \text{ (second case)}$ or $(L_1(x), L_q(x)) = (0, 0)$ (third case).

**Stability of the different configurations** The multiplicity of solutions for $L_1(x)$ and $L_q(x)$ on $x \in ]x^q_a, x^*_a[$ implies that we potentially have a continuum of equilibria. To study the stability of each of the possible combinations identified, we look at whether each combination is robust to a small deviation in the participation decisions made by sellers in $x$. We have three cases, depending on whether we have full-participation, no-participation or partial participation in the market. We have the following results for each one of these cases:
• The full-participation case \(((L_1(x), L_q(x)) = (\pi, 1-\pi))\) is stable on \([0, x_a]\). To show this, observe that the participation constraint of owners is \(\{\pi + q(1-\pi)\} (y - xt - u) > R_a\). If a mass \(\epsilon\) of owners stops selling, owners will now compare \(\{\pi(x) + q(1-\pi(x))\} (y - xt - u)\) and \(R_a\) to decide whether to participate in the market. As buyers will expect deviant owners to include \(\epsilon\pi\) 1-owners and \(\epsilon(1-\pi)\) q-owners, \(\pi(x)\) remains unchanged and equal to \(\pi\). It follows that the market participation constraint is unchanged so that deviant sellers will come back to their initial decision.

• The no-participation case \(((L_1(x), L_q(x)) = (0, 0))\) is stable on \([x_a, x^*_a]\). To show this, observe that this case is characterized by the participation constraint \(R_a > (\pi + (1-\pi)q)(y - xt - u)\), where the RHS is the expected plot price in case of a land sale (given the proportions of 1 and q-owners). If a mass \(\epsilon\) of owners starts selling, buyers will expect these deviant owners to include \(\epsilon\pi\) 1-owners and \(\epsilon(1-\pi)\) q-owners, leading to \(\pi(x) = \pi\). As in the previous case, the participation constraint is unchanged, so that deviant owners come back to their initial decision.

• The partial participation cases \(((L_1(x), L_q(x)) \in [0, \pi] \times [0, 1-\pi])\) are not stable on \([x_a^q, x^*_a]\). To show this, observe that these cases are characterized by equality \(L_1(x) - L_q(x) \epsilon\) of them are 1-sellers and that \(L_1(x) - L_q(x) \epsilon\) are q-sellers. Denoting \(\eta = e^{-\pi(L_1(x))} - L_q(x)\), the price of a land plot becomes \(\pi(x) \eta(x) (1 - q) + q (y - xt - u)\) where \(\pi(x, \eta) = L_1(x) + q(\pi - L_1(x))\). It can easily be shown that \(\pi(x, \eta) > R_a\). Consequently, the deviation triggers a cumulative process whereby all owners enter the market until we reach the stable configuration with full participation \((L_1(x), L_q(x)) = (\pi, 1-\pi)\).

First, consider \(x < x_a\). This is equivalent to \(\pi(1 - q) + q (y - xt - u) > R_a\). And, as we know that \(\pi(x)(1 - q) + q (y - xt - u) = R_a\), we clearly have: \(\pi(x) < \pi\). Consider now that a mass \(\epsilon\) of owners start selling. Buyers expect that \(\pi - L_1(x) \epsilon\) of them are 1-sellers and that \(L_1(x) - L_q(x) \epsilon\) are q-sellers. Denoting \(\eta = e^{-\pi(L_1(x))} - L_q(x)\), the price of a land plot becomes \(\pi(x)(1 - q) + q (y - xt - u)\) where \(\pi(x, \eta) = L_1(x) + q(\pi - L_1(x))\). It can easily be shown that \(\pi(x, \eta) > R_a\).

Second, consider \(x > x_a\). This is equivalent to \(\pi(1 - q) + q (y - xt - u) < R_a\). And, as we know that \(\pi(x)(1 - q) + q (y - xt - u) = R_a\), we clearly have \(\pi(x) > \pi\). Consider that a

---

\(^{37}\)This is because all owners that were initially not selling are equally likely to start selling. The formula is obtained by recognizing that a mass \(\pi - L_1(x)\) of 1-owners and \(1 - \pi - L_q(x)\) of q-owners was initially not participating in the market.
mass $\varepsilon$ of owners start selling. Here again, buyers expect that
\[
\frac{\pi - L_1(x)}{1 - L_1(x) - L_q(x)}\varepsilon
\]
of them are 1-sellers and that
\[
\frac{1 - \pi - L_q(x)}{1 - L_1(x) - L_q(x)}\varepsilon
\]
are $q$-sellers. The price of a land plot becomes $\Pi(x, \eta)$, as defined in the previous case. However, we now have $\frac{\partial \Pi}{\partial \eta} < 0$ because $\pi(x) > \pi$. The new price of land is therefore decreased by the deviation and becomes strictly smaller than $R_a$. This triggers a cumulative process whereby all owners stop participating in the market until we reach the stable equilibrium with no participation $(L_1(x), L_q(x)) = (0, 0)$.

On each interval for $x$, we select the only stable cases. This leads to a unique possible configuration with full sale of all 1-plots and $q$-plots on $[0, x_a]$ and no sale on $]x_a, +\infty[$.

**Compatibility with equilibrium conditions** It is easy to verify that the selected stable Pareto-optimal configuration satisfies the 4 equilibrium conditions for each $x \in [0, x_a]$:

- $L_1(x) + L_q(x) = 1$ so that (3) is verified.
- $B(P = 1 | x, Q \in \{q, 1\}, R) = (\pi(1 - q) + q)(y - tx - u) > R_a$ so that (4) is verified.
- $R(x) = (\pi(1 - q) + q)(y - tx - u)$ so that (5) is verified.
- $\pi(1 - q) + q)(y_u - tx_a - u) = R_a$ so that (6) is verified.
6.2 Payoffs of land owners

Figure 6: Payoffs of land owners

Note: This figure represents the equilibrium payoffs of sellers as a function of distance to the city center and their market participation decisions. The slope of the payoff curves are indicated in blue.

7 Appendix B - Registration model

7.1 Proof of Proposition 2 - Competitive equilibrium in the registration model

For this proof, we denote $L_{f_q}(x)$ (resp. $L_{f_1}(x)$) the mass of plots in $x$, that were originally of tenure security $q$ (resp. 1) and that are registered by owners before being sold. Therefore, we have $L_f(x) = L_{f_q}(x) + L_{f_1}(x)$.

To derive the competitive equilibrium, we follow the same steps as in the proof of Proposition 1: we study, in each $x$, all possible combinations of participation and registration decisions that 1-
and q-owners may take to satisfy (9) subject to (10 and 11). In each location, we determine which combinations of participation and formalization decisions are possible and study their stability. We then select the unique stable configuration and verify that it satisfies the equilibrium conditions (8)-(12).

Sellers’ participation and registration decisions and spatial city configuration In a fashion similar to the proof of Proposition 1 for the benchmark model, we show below that the decisions of all sellers in \( x \) can be uniquely characterized by the pair of variables \( (L_{f_1}(x), L_1(x)) \) given that uniquely determine \( L_{f_q}(x) \) and \( L_q(x) \). We now analyze the seven possible combinations of decisions, i.e.: \( (L_{f_1}(x), L_1(x)) = (\pi, 0), (L_{f_1}(x), L_1(x)) = (0, \pi), (L_{f_1}(x), L_1(x)) = (\alpha, \pi - \alpha), (L_{f_1}(x), L_1(x)) = (0, 0), (L_{f_1}(x), L_1(x)) = (0, 0), (L_{f_1}(x), L_1(x)) = (0, 0) \) and \( (L_{f_1}(x), L_1(x)) = (\alpha, \beta) \) where \( \alpha > 0, \beta > 0 \) and \( \alpha + \beta \in [0, \pi] \):

- If \( (L_{f_1}(x), L_1(x)) = (\pi, 0) \) (i.e., all 1-owners register their plot and sell), then the payoff maximization constraint, the symmetry between 1- and q-owners’ decisions (because of their identical payoffs), and the equivalence \( \hat{x}(k) < \hat{x}(k) \Longleftrightarrow k > \frac{1}{\pi} \) imply that:

\[
(L_{f_1}(x), L_{f_q}(x), L_1(x), L_q(x)) = (\pi, 1 - \pi, 0, 0)
\]

\[
\Rightarrow (k > \frac{1}{\pi} \text{ and } x < \hat{x}(k)) \text{ or } (k < \frac{1}{\pi} \text{ and } x < \hat{x}(k)).
\]

- If \( (L_{f_1}(x), L_1(x)) = (0, \pi) \) (i.e., all 1-owners sell informally), then the payoff maximization constraint and the equivalence \( \hat{x}(k) < x_a \Longleftrightarrow k > \frac{1}{\pi} \) imply:

\[
(L_{f_1}(x), L_{f_q}(x), L_1(x), L_q(x)) = (0, 0, \pi, 1 - \pi) \Rightarrow k > \frac{1}{\pi} \text{ and } \hat{x}(k) < x < x_a.
\]

- If \( (L_{f_1}(x), L_1(x)) = (\alpha, \pi - \alpha) \) with \( \alpha \in [0, \pi] \) (i.e., all 1-owners sell, some informally and some after registering their plot), then the payoff maximization constraint implies: \( L_q(x) = \frac{L_{f_1}(x)k}{(1-q)(y-\hat{x}u)} - k \). The conditions \( L_q(x) > 0 \) and \( L_1(x) < \pi \) are incompatible so that this combination is in fact not possible.

- If \( (L_{f_1}(x), L_1(x)) = (0, 0) \) (i.e., no 1-owner participates in the market), then the payoff maximization constraint and the equivalence \( x_a > \hat{x}(k) \Longleftrightarrow k > \frac{1}{\pi} \) imply:

\[
(L_{f_1}(x), L_{f_q}(x), L_1(x), L_q(x)) = (0, 0, 0, 0)
\]

\[
\Rightarrow (k > \frac{1}{\pi} \text{ and } x > x_a) \text{ or } (k < \frac{1}{\pi} \text{ and } x > \hat{x}(k)).
\]
• If \((L_f_1(x), L_1(x)) = (\alpha, 0)\) with \(\alpha \in ]0, \pi[\) (i.e., some owners sell after registering their plot), indifference between not participating in the market and selling after registering implies that the interval for \(x\) is a singleton that corresponds to the limit of the formal zone, \(\hat{x}(k)\). Because we have a continuous framework, we can overlook this border case of measure zero.

• If \((L_f_1(x), L_1(x)) = (0, \alpha)\) where \(\alpha \in ]0, \pi[\) (i.e., some owners sell informally), then the payoff maximization constraint and the conditions \(\pi > L_1(x) > 0\) and \(1 - \pi > L_q(x) > 0\) imply:

\[
(L_f_1(x), L_q(x), L_1(x), L_q(x)) = (0, 0, \alpha, \gamma(\alpha))
\]

where \(\alpha \in ]0, \pi[\) and \(\gamma(\alpha) = \left(\frac{R_a}{y_1 - xt - u} - q\right) = \alpha \left(1 - \frac{R_a}{y_1 - xt - u}\right)\). Therefore, \(\max (x_\alpha, \hat{x}(k)) < x < \bar{x}_\alpha\).

• If \((L_f_1(x), L_1(x)) = (\alpha, \beta)\) with \(\alpha > 0, \beta > 0\) and \(\alpha + \beta \in ]0, \pi[\) (i.e., some owners participate in the market, some of them sell informally, and some after registering their plot). If this case occurs, it will only be for the singleton \(x = \hat{x}(k)\). We discount this case of measure zero.

**Stability of the different configurations** We now determine which of the four remaining cases are robust to a small deviation in the decisions of sellers (which cases are stable). The proof follows a reasoning similar to that of the benchmark case (see Appendix A).

- The full registration and full participation case \(((L_f_1(x), L_1(x)) = (\pi, 0))\) is stable on \([0, \hat{x}(k)]\) if \(k > k\) (idem on \([0, \hat{x}(k)]\) if \(k < k\)). To show this, we consider deviations on the registration and participation decisions:

  - If a mass \(\epsilon\) of owners stop registering to sell informally, then buyers expect that there are \(\epsilon\pi\) 1-owners and \(\epsilon(1 - \pi)\) q-owners. Therefore, \(\pi(x) = \pi\) and the same payoff maximization constraint, \(y - xt - u - k > (\pi(1 - q) + q)(y - xt - u)\) and \(y - xt - u - k > R_a\), are still verified. Therefore, deviant owners come back to their initial registration decisions.

  - If a mass \(\epsilon\) of owners stop participating in the market, land prices are unchanged at \(y - xt - u\). Therefore, deviant owners come back to their initial decisions.
• The no-registration and full participation case (i.e., \((L_{f1}(x), L_1(x)) = (0, \pi)\)), in zone \([x, \pi]_k\) if \(k > \tilde{k}\), is stable. This is because:

- If a mass \(\epsilon\) of owners start registering their plot before selling, then buyers expect them to be in proportions \(\epsilon \pi 1\)-owners and \(\epsilon(1 - \pi) q\)-owners. Thus, \(\pi(x)\) remains equal to \(\pi\) and the payoff maximization constraint is unchanged. Therefore, deviant owners come back to their initial decisions.

- If a mass \(\epsilon\) of owners stop participating in the market, then buyers expect them to be in proportions \(\epsilon \pi 1\)-owners and \(\epsilon(1 - \pi) q\)-owners. Thus, \(\pi(x)\) remains equal to \(\pi\) and the payoff maximization constraint is unchanged. Therefore, deviant owners come back to their initial decisions.

• The no-participation case (i.e., \((L_{f1}(x), L_1(x)) = (0, 0)\)), in zone \([x, +\infty]_k\) if \(k > \tilde{k}\) and in zone \([x, +\infty]_k\) if \(k < \tilde{k}\) is stable. Indeed we see that:

- If a mass \(\epsilon\) of owners start selling on the informal market, then buyers will expect them to be in proportions \(\epsilon \pi 1\)-owners and \(\epsilon(1 - \pi) q\)-owners. Therefore, \(\pi(x) = \pi\). The payoff maximization constraint is unchanged and deviant owners come back to their initial decisions.

- If a mass \(\epsilon\) of owners start selling on the formal market, then the payoff maximization constraint is unchanged and deviant owners come back to their initial decisions.

• The no-registration but partial participation case (i.e., \((L_{f1}(x), L_1(x)) = (0, \alpha)\) with \(\alpha \in [0, \pi]\), possible when \(\max (\underline{x}_\alpha, \bar{x}(k)) < x < \bar{x}_\alpha\) with the payoff maximization constraint \((y - xt - u) \frac{L_1(x)(1-q)}{L_1(x)+L_q(x)} + q = R_\alpha\), is not stable, for the same reason as in the benchmark model.

We select the only stable combination on each interval:

• When \(k > \tilde{k}\), we have:

  - Full registration and full participation on \([0, \bar{x}(k)]\)

  - No formalization but full participation on \([\bar{x}(k), x_a]\)

  - No participation on \([x_a, +\infty]\)
• When \( k \leq \bar{k} \), we have:

  - Full registration and full participation on \([0, \hat{x}(k)]\)
  
  - No participation on \([\hat{x}(k), +\infty[\]

**Compatibility with equilibrium conditions**  It is easy to verify that the configuration selected satisfies the 6 equilibrium conditions (8)-(12) when \( k > \bar{k} \) and when \( k \leq \bar{k} \).

### 7.2 Payoffs of land owners

**Figure 7: Payoffs of land owners**

Note: This figure represents the equilibrium payoffs of sellers as a function of distance to the city center, their market participation and registration decisions when \( k < \bar{k} \) and when \( \bar{k} < k < \bar{\bar{k}} \). The slopes of the payoff curves are indicated in blue.

**7.3 Suboptimality of the competitive equilibrium in the registration model**

To determine the optimal configuration, we compare the contributions to the surplus associated with each decision of 1- and \( q \)-owners. For a secure plot, an informal allocation contributes more to the surplus than a formal allocation (if \( k > 0 \)), because the formalization cost is avoided. An informal
allocation is preferable over keeping the plot under agricultural use if and only if \( y - xt - u - R_a > 0 \), i.e. \( x < x^*_a \). For an insecure plot, a formal allocation is preferable over an informal allocation if and only if \( y - xt - u - R_a - k > (\theta(1 - q) + q)(y - xt - u - R_a) \), i.e. \( x < \bar{x}(k, \theta) = \frac{1}{t} (y - \frac{k}{(1-q)(1-\theta)} - u - R_a) \). An informal allocation is preferable over keeping the plot under agricultural use if and only if \( q(y - xt - u - R_a) \geq 0 \), i.e. \( x \leq x^*_a \). Since \( \bar{x}(k, \theta) < x^*_a \), we do not need to compare the contribution of a formal allocation with that of a non-allocation (i.e., the plot remaining agricultural). The optimal allocation therefore consists of two zones: On \([0, \bar{x}(k, \theta)]\), all \( q \)-plots are registered and allocated to a migrant whereas all \( 1 \)-plots are allocated informally to a migrant. On \([\bar{x}(k, \theta), x^*_a]\), all plots are allocated informally. The optimal city has the structure depicted in Figure 8.

Figure 8: Optimal city structure in the registration model

8 Appendix C - Trust model

8.1 Proof of Lemma 1

We reason by contradiction. Let’s assume that, at a stable equilibrium, \( 1 \)-sellers do not only sell to cousins, then they either (i) sell to both cousins and non-cousins or (ii) they sell only to non-cousins. To show that \( 1 \)-sellers only sell to cousins, we sequentially show that (i) and (ii) cannot be true:

- If there is a stable equilibrium in which \( 1 \)-sellers sell both to cousins and non-cousins, then we have \( \pi^c(x) > 0 \) and \( \pi^{nc}(x) > 0 \) and the payoff of \( 1 \)-sellers is the same when selling to a cousin or a non-cousin, which means that:

\[
\psi(x, u|C = c) = \psi(x, u|C = nc)
\]
Given that we have, by definition:

\[
\begin{aligned}
\psi(x, u| C = c) &= \{\pi^c(x) + q(1 - \pi^c(x))\} (y - tx - u) \\
\psi(x, u| C = nc) &= \{\pi^{nc}(x) + q(1 - \pi^{nc}(x))\} (y - tx - u)
\end{aligned}
\]

the equality of payoffs implies \(\pi^c(x) = \pi^{nc}(x)\). Then, the payoff of \(q\)-sellers selling to cousins is \(\psi(x, u| C = c) - J\) and the payoff of \(q\)-sellers selling to non-cousins is \(\psi(x, u| C = nc) = \psi(x, u| C = c)\). Thus, \(q\)-sellers all prefer to sell to non-cousins and do so. Therefore, \(\pi^c(x) = 1\) (all sellers selling to cousins are 1-sellers), while \(\pi^{nc}(x) < 1\) (because 1-sellers only make up a limited proportion of the sellers selling to non-cousins). This contradicts \(\pi^c(x) = \pi^{nc}(x)\) and thus our initial assumption.

- If there is a stable equilibrium in which 1-sellers sell only to non-cousins, then we have \(\pi^{nc}(x) > \pi^c(x) = 0\) and the payoff of 1-sellers is strictly larger when selling to a non-cousin than when selling to a cousin, which means that:

\[\psi(x, u| C = nc) > \psi(x, u| C = c)\]

Then, the payoff of \(q\)-sellers selling to cousins is \(\psi(x, u| C = c) - J\) and the payoff of \(q\)-sellers selling to non-cousins is \(\psi(x, u| C = nc)\), which is strictly larger than \(\psi(x, u| C = c) - J\). Thus, \(q\)-sellers all prefer to sell to non-cousins and do so. Therefore, all sellers sell to non-cousins and \(\pi^{nc}(x) = \pi\).

A deviating 1-seller selling to a cousin would get a payoff of \(\{\pi + q(1 - \pi)\} (y - tx - u)\), as the buyer would assume that a probability \(\pi\) for the seller to be a 1-seller. This payoff is exactly equal to \(\psi(x, u| C = nc)\), so that the deviating seller would not come back to selling to a non-cousin and would increase \(\pi^c(x)\) to 1, thereby triggering a transition away from the equilibrium where 1-sellers sell only to cousins. Thus, this equilibrium would be unstable, which contradicts our initial assumption.

Both cases have led to a contradiction. Consequently, at a stable equilibrium, 1-sellers only sell to cousins.
8.2 Proof of Proposition 4 - Competitive equilibrium in the trust model

Here, we provide a more complete version of Proposition 4. Proposition 4 corresponds to the first case (low value of the social penalty) highlighted in the Extended Proposition 4.

Extended Proposition 4

Extended Proposition 4: Denoting the social penalty thresholds \( J = \pi R_a \frac{1-q}{q} \) and \( \bar{J} = R_a \frac{1-q}{q} \), and the zone boundary thresholds \( \bar{x}(J) = \frac{1}{q}(y - R_a + J - u) \) and \( \bar{x}(J) = \frac{1}{q}(y - (R_a + J) - u) \), there are five possible cases, depending on the magnitude of the cousinage penalty.\(^{38}\)

- **Case 1**: \( J < \bar{J} \). The city boundary is at \( x_a^* \) and the city is organized in the three following zones, moving outward from the city center:

  - **Zone 1 (fully residential)**: On \([0, \bar{x}(J)]\), all landowners (irrespective of the tenure security level of their plot) participate in the land market and exclusively sell to cousins. The unique price in each location \( x \) is \( R^c(x) = [\pi + q(1 - \pi)](y - xt - u) \).

  - **Zone 2 (mixed agricultural and residential, partial market participation of q-sellers)**: On \([\bar{x}(J), \bar{x}(J)]\), all 1-sellers and a share of q-sellers participate in the land market and exclusively sell to their respective cousins. The mass of q-sellers selling to cousins in \( x \) is \( L_q^c(x, J) = \frac{\pi(1-q)(y-xt-u)}{R_a + J - q(y-xt-u)} - \pi \). The unique price in each location \( x \) is \( R^c(x) = R_a + J \).

  - **Zone 3 (mixed agricultural/residential, q-sellers dropping out of the market)**: On \([\bar{x}(J), x_a^*]\), all 1-sellers participate in the land market and sell to their cousins, whereas all q-sellers keep their plots under agricultural use. The unique price in location \( x \) is \( R^c(x) = y - xt - u \).

- **Case 2**: \( J < J \leq \bar{J} \). The city boundary is at \( x_a^* \) and the city is organized in four zones, moving outwards from the city center: (i) a zone where all 1-owners and q-owners sell to a cousin; (ii) a zone where all 1-owners sell to a cousin and all q-owners sell (a fraction of them selling to cousins and the rest to non-cousins); (iii) a zone where all 1-owners and a share of q-owners sell to their respective cousins; and (iv) a zone where all 1-owners sell to their cousins whereas q-owners do not participate in the land market.

\(^{38}\)Here we assume that \( y - \frac{R_a}{q} - u > 0 \), which is necessary to exclude unrealistic cases where risky plots never get sold under high values of \( J \). It is a more restrictive assumption than our previous condition \( y - \frac{R_a}{\pi + q(1-q)} - u > 0 \) for a non-degenerate city to exist under the benchmark model.
• **Case 3**: \(\pi(1-q)(y-u) > J > \bar{J}\). The city boundary is at \(x^*_a\) and the city is organized in four zones, moving outwards from the city center: (i) a zone where all \(1\)-owners and \(q\)-owners sell to a cousin; (ii) a zone where all \(1\)-owners sell to a cousin and all \(q\)-owners sell (a fraction selling to cousins and another fraction to non-cousins); (iii) a zone where all \(1\)-owners sell to their cousins and \(q\)-owners all sell to non-cousins; and (iv) a zone where all \(1\)-owners sell to their cousins, whereas \(q\)-owners do not participate in the land market.

• **Case 4**: \((1-q)(y-u) > J > \pi(1-q)(y-u)\): The city structure is identical to Case 3, but without zone (i).

• **Case 5**: \(J > (1-q)(y-u)\): The city structure is identical to Case 3, but without zones (i) and (ii).

**Proof of Extended Proposition 4**

For this proof, we denote \(L^c_1(x)\) the quantity of secure land sold to cousins, \(L^c_q(x)\) the quantity of insecure land sold to cousins and \(L^{nc}(x)\) the quantity of (insecure) land sold to non-cousins. Note that we have \(L^c_1(x) + L^c_q(x) + L^{nc}(x) = L_1(x) + L_q(x)\).

To derive the competitive equilibrium, we study, in each \(x\), all possible combinations of participation and cousinage decisions that \(1\)- and \(q\)-owners may take to satisfy (15) subject to (16 and 17). We then study the stability of these combinations. In some locations, we will see that more than one combination is possible and stable. In that case, we select the Pareto-dominant combination, i.e. the combination that unambiguously benefits owners the most (as \(1\)-owners and \(q\)-owners prefer the same combinations). We check that this configuration satisfies the equilibrium conditions (14)-(18).

**Sellers’ participation and cousinage decisions and spatial city configuration**

Given Lemmas 1 and 2, it is clear that the decisions taken by all sellers in location \(x\) can be uniquely characterized by the triple \((L^c_1(x), L^c_q(x), L^{nc}(x))\). We distinguish the following situations:

• If \((L^c_1(x), L^c_q(x), L^{nc}(x)) = (\pi, 1-\pi, 0)\), then, denoting \(x(J) = \frac{1}{t}(y - \frac{J}{\pi(1-q)} - u)\), the payoff maximization constraint implies:

\[
(L^c_1(x), L^c_q(x), L^{nc}(x)) = (\pi, 1-\pi, 0) \Rightarrow (J > J_{\bar{x}}(J) \text{ and } x < x(J)) \text{ or } (J < J_{\bar{x}}(J) \text{ and } x < x(J))
\]
• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, 0, 1 - \pi)\), then, denoting \(\bar{x}(J) \equiv \frac{1}{t} \left( y - \frac{J}{1-q} - u \right) \) and \(x_a^\pi = \frac{1}{t} \left( y - \frac{R_a}{q} - u \right)\), the payoff maximization constraint implies:

\[
(L_1^c(x), L_q^c(x), L^{nc}(x)) = (\pi, 0, 1 - \pi) \Rightarrow (J > J' \text{ and } \bar{x}(J) < x < x_a^\pi).
\]

• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, \alpha, 1 - \pi - \alpha)\) where \(\alpha \in [0, 1 - \pi]\), then the payoff maximization constraint implies \(L_q^c(x) = \pi \left(1-q\right)(y-x-t-u) - \pi\) and:

\[
(L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, \alpha, 1 - \pi - \alpha) \text{ where } \alpha \in [0, 1 - \pi]\Rightarrow (J > J' \text{ and } \bar{x}(J) > x > x(J)) \text{ or } (J > J' \text{ and } x_a^\pi > x > \bar{x}(J)).
\]

• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, 0, 0)\), then the payoff maximization constraint implies:

\[
(L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, 0, 0) \Rightarrow (J > J' \text{ and } x_a^\pi > x > x_a^\pi) \text{ or } (J < J' \text{ and } x_a^\pi > x > \bar{x}(J))
\]

• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (\alpha, 0, 0)\) where \(\alpha \in [0, \pi]\), then it is easy to see that the payoff maximization constraint implies that the case is in fact not possible.

• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (0, 0, 0)\), then the payoff maximization constraint implies:

\[
(L_1^q(x), L_q^c(x), L^{nc}(x)) = (0, 0, 0) \Rightarrow x > x_a.
\]

• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, \alpha, 0)\) where \(\alpha \in [0, 1 - \pi]\), then the payoff maximization constraint implies \(L_q^c(x, S=1) = \pi \left(1-q\right) \frac{y-a-x-t-u}{R_a+J-q(y-a-x-t-u)} - \pi\) and:

\[
(L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, \alpha, 0) \text{ where } \alpha \in [0, 1 - \pi]\Rightarrow (J > J' \text{ and } \bar{x}(J) > x > x_a^\alpha) \text{ or } (J > J' \text{ and } \bar{x}(J) > x > \bar{x}(J)).
\]

• If \((L_1^q(x), L_q^c(x), L^{nc}(x)) = (\pi, \alpha, \beta)\) where \(\alpha > 0, \beta > 0\) and \(\alpha + \beta \in [0, 1 - \pi]\), then the payoff maximization constraint implies that it is possible only on the singleton \(x = x_a^\pi\). We discard this case of measure zero.
Stability of the different configurations  Using the same approach as before, it can easily be shown that:

- All “corner” combinations (where all 1-owners in a given location adopt the same decisions, and all q-owners adopt the same decisions) are stable. As before, this is done by showing that a small enough deviation in participation and cousinage decisions does not change the strict ranking of owners’ decisions so that they return to their initially optimal decisions.

- We now show that the case \((L_1^c(x), L_q^c(x), L_{nc}(x)) = (\pi, \alpha, 1 - \pi - \alpha)\) where \(\alpha \in [0, 1 - \pi]\) is stable on \([x_2(J), \bar{x}(J)]\) if \(J > \bar{J}\) (respectively on \([x_1(J), x_q^a] \) if \(\bar{J} > J > J\):)

  - If a mass \(\epsilon\) of owners who used to sell to cousins stop selling (or start selling to non-cousins), buyers expect these deviant owners to include \(\epsilon \frac{\pi}{\alpha + \pi}\) 1-owners and \(\epsilon \frac{\alpha}{\alpha + \pi}\) q-owners. Therefore, the land price for transactions between cousins and the land price for transactions between non-cousins remain unaltered. All payoffs and the payoff maximization constraint are preserved, so that deviant owners come back to their initial decisions.

  - If a mass \(\epsilon\) of owners who used to sell to non-cousins stop selling, land prices and thus payoffs remain unaltered. Therefore, deviant owners come back to their initial decisions.

  - If a mass \(\epsilon\) of owners who used to sell to non-cousins start selling to cousins (those can only be q-owners), the land price for transactions between cousins is reduced from \(\left(\frac{\pi(1-q)}{\alpha + \pi} + q\right) (y - xt - u) - J\) (which is equal to \(q(y - xt - u)\) since q-owners are indifferent between selling to cousins and non-cousins) to \(\left(\frac{\pi(1-q)}{\alpha + \epsilon + \pi} + q\right) (y - xt - u) - J\). It is easy to see that the new price is lower than the former price, so that q-owners now strictly prefer selling to non-cousins, while 1-owners still prefer selling to cousins. Therefore, 1-owners do not change their decisions and some q-owners shift from selling to cousins to selling to non-cousins. This cumulative shift lasts until the benefit obtained by q-owners when selling to cousins becomes equal to their benefit when selling to non-cousins. At this point, we are back to the initial combination of owners’ decisions.

- The case \((L_1^c(x), L_q^c(x), L_{nc}(x)) = (\pi, \alpha, 0)\) for \(\alpha \in [0, 1 - \pi]\) is stable on \([x_2^c, \bar{x}(J)]\) if \(\bar{J} > J > J\) and on \([x_2(J), \bar{x}(J)]\) if \(\bar{J} > J > J\):

  - If a mass \(\epsilon\) of owners stop selling to cousins, then buyers assume that deviant owners include
\( \epsilon - \pi \) 1-owners and \( \epsilon - \alpha \) q-owners. Therefore, the price of land transacted between cousins is unaltered, payoffs are preserved and deviant owners come back to their initial decisions.

- If a mass \( \epsilon \) of owners starts selling to non-cousins, payoffs are unaltered and they come back to their initial decisions.

- If a mass \( \epsilon \) of owners starts selling to cousins, then they must be q-owners as all 1-owners are already selling. The price of land transacted between cousins is reduced from \( \left( \frac{\pi(1-q)}{\alpha + \pi} + q \right) (y - xt - u) - J \) (which is equal to \( R_a \)) to \( \left( \frac{\pi(1-q)}{\alpha + \pi} + q \right) (y - xt - u) - J \), which is strictly below the agricultural rent \( R_a \). Therefore, although 1-owners still prefer selling to cousins, q-owners now strictly prefer keeping their land under agricultural use. Consequently, 1-owners do not change their decisions and some q-owners shift from selling to cousins to keeping their land under agricultural use. This cumulative shift lasts until the benefit obtained by q-owners when selling to cousins becomes equal to the agricultural rent. At this point, we are back to the initial combination of owners’ decisions.

**Selection of the Pareto-dominant configuration** In the periphery of the city, several stable combinations are possible, depending on the relative size of \( J \) and \( R_a \). These combinations include the no-participation case and either the partial or the total participation case. As before, we selected the situation unambiguously preferred by owners. We therefore obtain the following city structure, depending on \( J \):

- If the cousinage penalty \( J \) is low, i.e. \( J < J^* \), then the city is organized in three zones:

  - **Zone 1:** On \([0, x(J)]\), all owners participate in the market and sell their plot to a cousin.
    
    The price on that segment is \( R^c(x) = [\pi + q(1 - \pi)](y - tx - u) \).

  - **Zone 2:** On \([x(J), \pi(J)]\), all 1-owners and a share of q-owners sell their plot to cousins.
    
    The number of q-owners selling their plot in \( x \) is \( L_q^c(x) = \frac{\pi(1-q)(y-xt-u)}{R_a + J - q(y-xt-u)} - \pi \). The price is \( R^c(x) = R_a + J \).

  - **Zone 3:** On \([\pi(J), x_a^*]\), all 1-owners sell their plot to cousins, while all q-owners keep their plot for agricultural use. The price is \( R^c(x) = y - xt - u \).

- The city boundary is at \( x_a^* = \frac{1}{\pi} [y - R_a - u] \).
• If the cousinage penalty $J$ is intermediate, i.e. $\underline{J} < J < \overline{J}$, then the city is organized in four zones:

  - Zone 1: On $[0, \bar{x}(J)]$, all owners participate in the market and sell their plot to a cousin.
    The price on that segment is $R^c(x) = [\pi + q(1 - \pi)](y - tx - u)$.

  - Zone 2: On $[\bar{x}(J), \bar{x}^q(J)]$, all owners participate in the market. 1-owners only sell to cousins, while $q$-owners sell both to cousins and non-cousins. The prices on that segment are $R^c(x) = q(y - tx - u) + J$ and $R^{nc}(x) = q(y_u - xt - u)$.

  - Zone 3: On $[\bar{x}^q(J), \bar{x}^a(J)]$, all 1-owners and a share of $q$-owners sell their plot. They all sell to cousins. The number of $q$-owners selling their plot in $x$ is $L^c_q(x) = \frac{\pi(1-q)(y-xt-u)}{\theta_a+J-q(y-xt-u)} - \pi$.
    The price is $R^c(x) = R_a + J$.

  - Zone 4: On $[\bar{x}(J), \bar{x}^a(J)]$, all 1-owners sell their plot to cousins, while all $q$-owners keep their plot for agricultural use. The price is $R^c(x) = y - xt - u$.

  - The city boundary is at $x^* = \frac{1}{t} [y - R_a - u]$.

• If the cousinage penalty $J$ is high, i.e. $\bar{J} < J$, then the city is organized in four zones:

  - Zone 1: On $[0, \bar{x}(J)]$, all owners participate in the market and sell their plot to a cousin.
    The price on that segment is $R^c(x) = [\pi + q(1 - \pi)](y - tx - u)$.

  - Zone 2: On $[\bar{x}(J), \bar{x}^q(J)]$, all owners participate in the market. 1-owners only sell to cousins, while $q$-owners sell both to cousins and non-cousins. The prices on that segment are $R^c(x) = q(y - tx - u) + J$ and $R^{nc}(x) = q(y_u - xt - u)$.

  - Zone 3: On $[\bar{x}^q(J), \bar{x}^a(J)]$, all owners participate in the market. 1-owners only sell to cousins, while $q$-owners only sell to non-cousins. The price of secure plots on that segment is $R^c(x) = y - xt - u$ and the price of insecure plots is $R^{nc}(x) = q(y - xt - u)$.

  - Zone 4: On $[\bar{x}^q(J), \bar{x}^a(J)]$, all 1-owners sell their plot to cousins, while all $q$-owners keep it for agricultural use. The price is $R^c(x) = y - xt - u$.

  - The city boundary is at $x^* = \frac{1}{t} [y - R_a - u]$. 55
Compatibility with equilibrium conditions It is easy to show that the equilibrium selected on each interval of $J$ satisfies equilibrium conditions (14)-(18).

Figure 9 summarizes the results of the Extended Proposition 4.

Figure 9: City structure in the trust model

Note: This figure represents the city structure as a function of distance to the city center and for different levels of the social penalty ($J$).
8.3 Payoffs of land owners

Figure 10: Payoffs of land owners

\( \Phi \) decreases with \( J \) on \([0, J]\). First, note that, as long as \( x < x_a^* \), the surplus is increased if a plot is sold rather than kept under agricultural use. This is because in each \( x \), the contribution to the (net) surplus of a secure plot is either \( y - xt - u - R_a > 0 \) if the plot is sold (to a cousin or a non-cousin) or 0 (if it is kept under agricultural use). Similarly, the (net) contribution to the surplus of an insecure plot is either \( (q + \theta(1 - q))(y - xt - u - R_a) > 0 \) or 0. Second, note that, in each \( x \), the share of transacted plots decreases with \( J \), for \( J > 0 \). This is because the numbers of transacted secure plots on \([0, x_a^*]\) and the number of transacted insecure plots on \([0, x_d^2]\) do not vary with \( J \), whereas the number of insecure plots transacted on \([x_d^2, x_a^*]\) decreases with \( J \). To see this, note that the number of insecure plots sold in \( x \in [x_d^2, x_a^*] \) is
\[
\begin{cases}
\frac{\pi(1-q)(y-xt-u)}{R_a+J-q(y-xt-u)} - \pi & \text{if } 0 < \frac{\pi(1-q)(y-xt-u)}{R_a+J-q(y-xt-u)} - \pi < 1 \\
0 & \text{if } \frac{\pi(1-q)(y-xt-u)}{R_a+J-q(y-xt-u)} - \pi \leq 0 \\
1 & \text{if } \frac{\pi(1-q)(y-xt-u)}{R_a+J-q(y-xt-u)} - \pi \geq 1,
\end{cases}
\]

where \( \frac{\pi(1-q)(y-xt-u)}{R_a+J-q(y-xt-u)} - \pi \) clearly decreases with \( J \).

Furthermore, the surplus under the trust model is strictly greater than the surplus in the benchmark model when \( J \to 0^+ \). Indeed, in that case, the equilibrium city in the trust model replicates the equilibrium city in the benchmark model, while adding an additional built-up zone \([x_0, x^*_a]\). Eventually, when \( J \geq \bar J \), the surplus is independent on \( J \) and equal to:

\[
\Phi = \pi \int_0^{x^*_a} (y-xt-u-R_a)dx + (q+\theta(1-q))(1-\pi) \int_0^{x^*_a} (y-xt-u-R_a)dx
\]

which is strictly below the surplus of the benchmark model.\(^{39}\)

### 8.5 Proof of Proposition 6

Let us define \( \Omega(k,J) = \Lambda(k) - \Phi(J) \). It is clear that \( \psi \) is a continuous function of \( k \) and \( J \). It decreases with \( k \) and increases with \( J \). Additionally, it is clear that \( \Omega(0, +\infty) > 0 \), \( \Omega(0, 0^+) > 0 \), \( \Omega(+\infty, 0^+) < 0 \) and \( \Omega(+\infty, +\infty) \geq 0 \).

\( \Omega(0, 0^+) > 0 \), \( \Omega(+\infty, 0^+) = \Omega(\bar k, 0^+) < 0 \) and \( \Omega(., 0^+) \) increasing implies that there exists \( \hat k(\theta) \in [0, \bar k] \) such that \( \Omega(\hat k(\theta), 0^+) = 0 \).

For all \( k \in [0, \hat k(\theta)] \), we have \( \Omega(k, 0^+) > 0 \). Thus, \( \Omega(k, J) > 0 \) for all \( J \) and the registering system is always better than the social norm (i.e., whatever the intensity of the social norm).

For all \( k \in [\hat k(\theta), +\infty] \), we have \( \Omega(k, 0^+) < 0 \), \( \Omega(k, +\infty) > 0 \) (because \( \Omega(+\infty, +\infty) > 0 \)) and \( \Omega(k, .) \) is increasing. Thus, there exists \( \tilde J(k, \theta) \) such that \( \Omega(k, J) < 0 \) for all \( J < \tilde J(k, \theta) \) and \( \Omega(k, J) > 0 \) for all \( J > \tilde J(k, \theta) \). It is clear that \( \tilde J \) is an increasing function of \( k \), as \( \Omega(., .) \) increases with \( k \), and that \( \tilde J \) is constant for \( k > \bar k \).

Consequently, the registering system is preferable to the social norm only if the social penalty is high enough and the social norm is preferable if the social penalty is low enough.

\(^{39}\)Because \( \Phi - \Gamma = -\frac{(1-\pi)(1-q)^2 R_a^2 (q(\pi+q(1-\pi))+(1-q)(\pi+2(1-\pi)q)\theta)}{2\pi^2 (\pi+q(1-\pi))^2} < 0 \).
9 Appendix D - Hybrid model

9.1 Proof of Proposition 7 - Competitive equilibrium in the hybrid model

Similarly to the previous versions of the model, to derive the competitive equilibrium, we study, in each $x$, all possible combinations of participation, registration and cousinage decisions that 1- and $q$-owners may take to satisfy (20) subject to (21, 22 and 23). We then study their stability. In some locations, we will see that more than one combination is possible and stable. In that case, we select the Pareto-dominant combination that unambiguously benefits owners the most (we will see that 1-owners and $q$-owners prefer the same combinations).

We then verify that the selected configuration satisfies the equilibrium conditions (19)-(24).

Determination of sellers’ possible participation and cousinage decisions

Given Lemmas 1 and 2, which still hold in this hybrid version of the model, it is clear that the decisions taken by all sellers in location $x$ can be uniquely characterized by the 5-uple of variables $(L_{f1}(x), L_{fq}(x), L_1^c(x), L_q^c(x), L^{nc}(x))$. We therefore can have the following combinations:

- If $(L_{f1}(x), L_{fq}(x), L_1^c(x), L_q^c(x), L^{nc}(x)) = (0, 0, \pi, 1 - \pi, 0)$, the payoff maximization constraint has different implications depending on the values of $k$ and $J$:
  
  - If $k > R_a \frac{1-q}{q}$:
    
    $(L_{f1}(x), L_{fq}(x), L_1^c(x), L_q^c(x), L^{nc}(x)) = (0, 0, \pi, 1 - \pi, 0)$
    
    $\Rightarrow (\pi k > J > \pi R_a \frac{1-q}{q}$ and $x(J) > x > \hat{x}(k, J))$
    
    or $(\pi R_a \frac{1-q}{q} > J$ and $x(J) > x > \hat{x}(k, J))$

  - If $R_a \frac{1-q}{q} > k > k$:
    
    $(L_{f1}(x), L_{fq}(x), L_1^c(x), L_q^c(x), L^{nc}(x)) = (0, 0, \pi, 1 - \pi, 0)$
    
    $\Rightarrow (k(\pi(1-q) + q) - R_a(1-q)(1-\pi) > J$ and $x(J) > x > \hat{x}(k, J))$

  - If $k > k$:
    
    $(L_{f1}(x), L_{fq}(x), L_1^c(x), L_q^c(x), L^{nc}(x)) = (0, 0, \pi, 1 - \pi, 0)$ is impossible.

We assume, without changing the model’s main results, that $\hat{k} > R_a \frac{1-q}{\pi q}$, which allows to reduce the number of possible cases to be studied.
• If \((L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 0, 0, 1 - \pi, \), then the implications of the payoff maximization constraint also depends on \(k\) and \(J\). Denoting \(\ddot{x}(k) \equiv \frac{1}{q} \left(y - \frac{k}{1-q} - u\right)\), these implications are:

- If \(k > R_a \frac{1-q}{q}\):
  \[
  (L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 0, , 1 - \pi) \\
  \Rightarrow (J > k \text{ and } x^a_q > x > \ddot{x}(k)) \text{ or } (k > J > R_a \frac{1-q}{q} \text{ and } x^a_q > x > \ddot{x}(J))
  \]

- If \(k < R_a \frac{1-q}{q}\):
  \[
  (L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 0, , 1 - \pi) \text{ is impossible.}
  \]

• If \((L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 0, 0, 1 - \pi, 0), then the payoff maximization constraint implies that this case is impossible.

• If \((L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 1 - \pi, 0, 0, 0), then the payoff maximization constraint implies:

  - If \(k > \bar{k}\):
    \[
    (L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 1 - \pi, 0, 0, 0) \Rightarrow \ddot{x}(k) > x
    \]

  - If \(k < \bar{k}\):
    \[
    (L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 1 - \pi, 0, 0, 0) \Rightarrow \ddot{x}(k) > x.
    \]

• If \((L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 1 - \pi, \pi, 0, 0), the payoff maximization constraint implies:

  - If \(k > R_a \frac{1-q}{q}\):
    \[
    (L_{f1}(x), L_{fq}(x), L_{c1}^e(x), L_{c1}^v(x), L_{nc}(x)) = (0, 1 - \pi, 0, 0, 0) \Rightarrow (J > k \text{ and } \ddot{x}(k) > x)
    \]

  - If \(k < R_a \frac{1-q}{q}\):
\[(L_{f1}(x), L_{fq}(x), L_q^c(x), L_q^{nc}(x))\]

\[= (0, 1 - \pi, \pi, 0, 0) \Rightarrow (J > k \text{ and } \hat{x}(k) > x).\]

- If \((L_{f1}(x), L_{fq}(x), L_q^c(x), L_q^{nc}(x)) = (0, 0, 0, 0, 0),\) then the payoff maximization constraint implies:

\[\Rightarrow (k > k \text{ and } x > x_a) \text{ or } (k < k \text{ and } x > \hat{x}(k)).\]

- If \((L_{f1}(x), L_{fq}(x), L_q^c(x), L_q^{nc}(x)) = (0, \beta, \pi, 1 - \pi - \beta, 0)\) where \(\beta \in [0, 1 - \pi],\) then the payoff maximization constraint implies:

- If \(k > R_a \frac{1 - q}{q};\)

\[\Rightarrow (\pi k > J \text{ and } \hat{x}(k, J) > x) \text{ or } (k > J > \pi k \text{ and } \hat{x}(k) > x)\]

- If \(k < \hat{k} < k < R_a \frac{1 - q}{q};\)

\[\Rightarrow (\pi (1 - q) + q)k - R_a (1 - \pi) (1 - q) > J \text{ and } \hat{x}(k, J) > x\]

\[or (k > J > (\pi (1 - q) + q) c - R_a (1 - \pi) (1 - q) \text{ and } \hat{x}(k) > x)\]

- If \(k < R_a \frac{1 - q}{q};\)

\[\Rightarrow (J < k \text{ and } \hat{x}(k) > x).\]

- If \((L_{f1}(x), L_{fq}(x), L_q^c(x), L_q^{nc}(x)) = (0, \beta, \pi, 0, 1 - \pi - \beta)\) where \(\beta \in [0, 1 - \pi],\) then the payoff maximization constraint implies that it is only possible on the singleton \(x = \hat{x}(k).\) As this case has measure zero, we disregard it.

- If \((L_{f1}(x), L_{fq}(x), L_q^c(x), L_q^{nc}(x)) = (0, 0, \pi, 1 - \pi - \beta, \beta)\) where \(\beta \in [0, 1 - \pi],\) then the payoff maximization constraint implies:
If \( \pi k > R_{a \frac{1-q}{q}} \):

\[
(L_{f1}(x), L_{fq}(x), L_{c1}(x), L_{cq}(x), L_{nc}(x)) = (0, 0, 0, 1 - \pi - \beta, \beta)
\]

\[
\Rightarrow (k > J > \pi k \text{ and } \bar{x}(J) > x > \bar{x}(k))
\]

or \((\pi k > J > R_{a \frac{1-q}{q}} \text{ and } \bar{x}(J) > x > \bar{x}(k))\)

or \((R_{a \frac{1-q}{q}} > J > \pi k \text{ and } x_{a}^{q} > x > \bar{x}(J))\)

- If \( k > R_{a \frac{1-q}{q}} > \pi k \):

\[
(L_{f1}(x), L_{fq}(x), L_{c1}(x), L_{cq}(x), L_{nc}(x)) = (0, 0, 0, 1 - \pi - \beta, \beta)
\]

\[
\Rightarrow (k > J > R_{a \frac{1-q}{q}} \text{ and } \bar{x}(J) > x > \bar{x}(k))
\]

or \((R_{a \frac{1-q}{q}} > J > \pi k \text{ and } x_{a}^{q} > x > \bar{x}(J))\)

- If \( R_{a \frac{1-q}{q}} > k \):

\[
(L_{f1}(x), L_{fq}(x), L_{c1}(x), L_{cq}(x), L_{nc}(x)) = (0, 0, 0, 1 - \pi - \beta, \beta)
\]

where \( \alpha \in ]0, 1 - \pi [ \) is impossible.

- If \( (L_{f1}(x), L_{fq}(x), L_{c1}(x), L_{cq}(x), L_{nc}(x)) = (0, 0, 0, 0, 0) \)

\[
\Rightarrow (J > R_{a \frac{1-q}{q}} \text{ and } x_{a}^{q} > x > x_{a}^{q}) \text{ or } (R_{a \frac{1-q}{q}} > J \text{ and } x_{a}^{q} > x > \bar{x}(J))
\]

- If \( k < R_{a \frac{1-q}{q}} \):
\begin{align*}
(L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) &= (0, 0, \pi, 0, 0) \\
\Rightarrow (J > k \text{ and } x^*_a > x > \hat{x}(k)) \text{ or } (k > J \text{ and } x^*_a > x > \bar{x}(J)).
\end{align*}

- If \((L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) = (0, 0, \pi, 0, 0)\) where \(\beta \in ]0,1-\pi]\), denoting \(J_{aux} = (k(\pi(1-q) + q) - R_a(1-\pi)(1-q))\), then the payoff maximization constraint implies:
  - If \(k > R_a \frac{1-q}{q}\):
    \begin{align*}
    (L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) &= (0, 0, \pi, 0, 0) \text{ where } \beta \in ]0,1-\pi]\ \\
    \Rightarrow (R_a \frac{1-q}{q} > J > \pi R_a \frac{1-q}{q} \text{ and } \bar{x}(J) > x > x^*_a) \\
    \text{or } (\pi R_a \frac{1-q}{q} > J \text{ and } \bar{x}(J) > x > \bar{x}(J))
    \end{align*}
  - If \(k < k < R_a \frac{1-q}{q}\):
    \begin{align*}
    (L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) &= (0, 0, \pi, 0, 0) \text{ where } \beta \in ]0,1-\pi]\ \\
    \Rightarrow (k > J > J_{aux} \text{ and } \bar{x}(J) > x > \hat{x}(k)) \\
    \text{or } J_{aux} > J \text{ and } \bar{x}(J) > x > \bar{x}(J))
    \end{align*}
  - If \(k < k\):
    \begin{align*}
    (L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) &= (0, 0, \pi, 0, 0) \text{ where } \beta \in ]0,1-\pi]\ \\
    \Rightarrow (k > J > 0 \text{ and } \bar{x}(J) > x > \hat{x}(k)).
    \end{align*}

- In all other combinations of decisions where some \(q\)-owners participate in the market (proportion \(L^c_q(x) + L^{nc}(x) + L_{fq}(x) \in ]0,1-\pi]\) and all \(1\)-owners participate in the informal market \((L^c_1(x) + L_{f1}(x) = \pi)\), the payoff maximization constraint implies that the corresponding interval for \(x\) is reduced to a singleton or the empty set.

- The payoff maximization constraint implies that the six following cases are reduced to a singleton or the empty set:
  - \((L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) = (\alpha, 0, \pi - \alpha, 1-\pi, 0)\) where \(\alpha \in ]0,\pi]\)
  - \((L_{f1}(x), L_{fq}(x), L^c_1(x), L^c_q(x), L^{nc}(x)) = (\alpha, 0, \pi - \alpha, 0, 1-\pi)\) where \(\alpha \in ]0,\pi]\)
\[(L_{f1}(x), L_{fq}(x), L_c^1(x), L_c^q(x), L_{nc}(x)) = (\alpha, \beta, \pi - \alpha, 1 - \pi - \beta, 0)\] where \(\alpha \in ]0, \pi[\) and \(\beta \in ]0, 1 - \pi[\)

\[- (L_{f1}(x), L_{fq}(x), L_c^1(x), L_c^q(x), L_{nc}(x)) = (\alpha, \beta, \pi - \alpha, 0, 1 - \pi - \beta)\] where \(\alpha \in ]0, \pi[\) and \(\beta \in ]0, 1 - \pi[\)

\[- (L_{f1}(x), L_{fq}(x), L_c^1(x), L_c^q(x), L_{nc}(x)) = (\pi, \beta, 0, 0, 1 - \pi - \beta)\] where \(\beta \in ]0, 1 - \pi[\)

- 1-sellers do not participate in the market but \(q\)-sellers do.

- \(q\)-owners do not participate in the market and 1-owners participate, at least partially, with cousinage decisions different from the cases previously analyzed.

**Stability of the equilibria** Using the same approach as before, it can easily be shown that:

- All “corner” combinations (where all 1-owners in a given location adopt the same decisions, and all \(q\)-owners adopt the same decisions) are stable. As before, this is done by showing that a small enough deviation in participation and cousinage decisions does not change the strict ranking of owners’ decisions so that they return to their initially optimal decisions.

- The case \((L_{f1}(x), L_{fq}(x), L_c^1(x), L_c^q(x), L_{nc}(x)) = (0, \beta, \pi, 1 - \pi, 0)\) where \(\beta \in ]0, 1 - \pi[\) is stable:

  - If a mass \(\epsilon\) of owners stop selling to cousins (i.e. they start formalizing, or they start selling to non-cousins, or they stop selling altogether), then buyers assume that deviant owners include \(\epsilon \frac{\pi}{1-\beta}\) 1-owners and \(\epsilon \frac{1-\pi-\beta}{1-\beta}\) \(q\)-owners. Therefore, the price of land transacted between cousins is unaltered, payoffs are preserved and deviant owners come back to their initial decisions.

  - If a mass \(\epsilon\) of owners start selling to cousins (i.e. if a mass \(\epsilon\) of \(q\)-owners stops formalizing), then buyers assume that deviant owners include only \(q\)-owners, as 1-owners were already all selling to cousins. Therefore, the price of land transacted between cousins is reduced and it becomes strictly more attractive for \(q\)-owners to sell after registration than to sell informally to cousins (while it remains more attractive for 1-owners to sell informally to cousins, because they do not face the social penalty). Therefore, the mass of \(q\)-owners selling informally to cousins decreases in favor of the mass of \(q\)-owners selling after registration.
until q-owners become indifferent between the two options. We are back to the initial configuration.

- Other deviations to owners’ behaviors (e.g. when a mass of owners stop formalizing and sell to non-cousins) do not affect land prices (in our example, it is q-owners who start to sell to non-cousins, which does not affect the price of informal land traded between non-cousins). Because land prices are not affected, these deviations do not affect the ranking of payoffs and the deviations are reversed back to the initial configuration.

- The case \((L_{f1}(x), L_{fq}(x), L_c^c(x), L_c^q(x), L_{nc}^c(x)) = (0, 0, \pi, \beta, 1 - \pi - \beta)\) where \(\beta \in [0, 1 - \pi]\) is unstable (the proof is essentially the same as in previous sections and is available upon request).

- The case \((L_{f1}(x), L_{fq}(x), L_c^c(x), L_c^q(x), L_{nc}^c(x)) = (0, 0, \pi, \beta, 0)\) where \(\beta \in [0, \pi]\) is stable (the proof is the same as in the previous sections and is available upon request).

The stable configurations are presented in Figures 11, 12 and 13 for all possible combinations of \(k\) and \(J\) values. In those figures, we indicate with “1 :” and “q :” the decision of 1-owners and q-owners respectively, where “\(C = c\)” and “\(C = nc\)” refer to their decision to sell informally to cousins and non-cousins respectively, “\(f\)” refers to registering and participating in the market, “no sale” refers to staying out of the market, and “partial” qualify any of the above decisions to indicate that only a fraction of 1-owners or q-owners take that decision. For instance, on the first graph of Figure 11, “1 : \(C = c, q : C = nc\)” indicates that all 1-owners informally participate in the market and sell to cousins and all q-owners informally participate in the market and sell to non-cousins.

Selection of the Pareto-dominant configurations When several stable configurations are possible for given values of \(J\) and \(k\), we select the one that benefits owners the most (as 1-owners and q-owners prefer the same combinations). The Pareto-dominant configuration is highlighted in red for each \(k\) and \(J\) value. For example, when \(k > Ra \frac{1 - q}{\pi q} \) and \(J > J > \pi R a \frac{1 - q}{1 - \pi (1 - q)}\) (i.e. bottom left graph in Figure 11), there are two possible configurations on \(x \in [0, \hat{x}(k)]\), one in which all 1-owners register their plot and one in which they sell informally. They prefer the second configuration where they sell informally, because it allows them to avoid incurring the registration cost.

Compatibility with equilibrium conditions It is easy to verify that the stable and Pareto-dominant configuration satisfies the 6 equilibrium conditions (19)-(24).

We present the spatial structure of the city for all values of \(k\) and \(J\) on Figures 14, 15, 16 and 17.
Figure 11: Hybrid model equilibria (high registration cost)

Note: This figure represents the stable equilibria for varying values of the registration cost $k$ and the social penalty $J$. In case of multiple equilibria, the dominant equilibria are highlighted in red. Non participation in the market is not represented.
Figure 12: Hybrid model equilibria (intermediate registration cost)

Note: This figure represents the stable equilibria for varying values of the registration cost $k$ and the social penalty $J$. In case of multiple equilibria, the dominant equilibria are highlighted in red. Non-participation in the market is not represented.
Figure 13: Hybrid model equilibria (low and very low registration cost)

Note: This figure represents the stable equilibria for varying values of the registration cost $k$ and the social penalty $J$. In case of multiple equilibria, the dominant equilibria are highlighted in red. Non-participation in the market is not represented.
Figure 14: Hybrid model equilibrium city structure (high registration cost: $k > k > R_a \frac{1-q}{q}$)

Note: This figure represents the city structure as a function of distance to the city center for high registration costs ($k$) and for different levels of the social penalty ($J$).
Figure 15: Hybrid model equilibrium city structure (intermediate registration cost: $k > R_a \frac{1-q}{q} > \pi k$)

Note: This figure represents the city structure as a function of distance to the city center for intermediate registration costs ($k$) and for different levels of the social penalty ($J$).
Figure 16: Hybrid model equilibrium city structure (low registration cost: $R_a \frac{1-q}{q} > k > k$)

Note: This figure represents the city structure as a function of distance to the city center for low registration costs ($k$) and for different levels of the social penalty ($J$).
Figure 17: Hybrid model equilibrium city structure (very low registration cost: $k > k$)

Note: This figure represents the city structure as a function of distance to the city center for very low registration costs ($k$) and for different levels of the social penalty ($J$).
9.2 Payoffs of land owners

Figure 18: Payoffs of land owners, depending on their participation, registration and cousinage decisions.

Note: This figure represents the equilibrium payoffs of sellers as a function of distance to the city center, their market participation, registration and ethnic matching decisions when \( J < J^* \) and \( k > k^* \). The slopes of the payoff curves are indicated in blue.

9.3 Proof Proposition 9

City surplus comparisons can be performed using the surplus formulas. It is easier, however, to derive the proof of Proposition 9 by comparing city structures in the trust, registration and hybrid models.

When \( k = 0 \) and \( J \to 0^+ \), the hybrid model city extends between 0 and \( x^*_a \) and, in each location, all sellers sell informally, except a mass \( L_{fq}(x) \) of \( q \)-sellers, who sell after registering. In the trust model, all sellers sell informally on \([0, x_a]\) and all sellers sell informally on \([x_a, x^*_a]\), except a mass \( L^*_q(x) = \frac{\pi(1-q)(y-xt-u)}{R_a+J-q(y-xt-u)} - \pi \) of \( q \)-sellers in each location \( x \). In each location on interval \([0, x^*_a]\), a \( q \)-plot that is sold after registration yields a higher surplus than a \( q \)-plot that is sold informally or kept under agricultural use. Indeed, \( y - xt - u - R_a > (q + \theta(1-q))(y - xt - u - R_a) \) and \( y - xt - u - R_a > 0 \).
Consequently, denoting $\Theta(k,J)$ the surplus in the hybrid model, it is clear that, when $k = 0$ and $J \to 0^+$, we have $\Theta(0,J) - \Phi(J) > 0$ and the surplus in the hybrid model is greater than in the trust model. As both city surpluses are clearly continuous for $J \in ]0, +\infty[$ and $k \in ]0, +\infty[$, this result holds for $J$ sufficiently small and $k$ sufficiently small.

When $k = 0$ and $J \to 0^+$ also, the registration model city corresponds to a fully formal zone between 0 and $x_a^*$. As all plots are registered before sale at no cost, tenure insecurity disappears and the surplus reaches its optimum. Therefore, it is clear that the surplus in the registration model is greater than in the hybrid model ($\Theta(k,J) - \Lambda(k) < 0$) when $k = 0$ and $J \to 0^+$. As all city surpluses are continuous for $J \in ]0, +\infty[$ and $k \in ]0, +\infty[$, this result holds for $J$ sufficiently small and $k$ sufficiently small.

When $k = \bar{k}$ and $J \to 0^+$, the cities in the hybrid model and in the trust model are the same and yield the same surplus.

When $k = \bar{k}$ and $J \to 0^+$, we have $\dot{x}(k) = 0$. The city in the registration model is fully informal (i.e., yellow zone between location 0 and $x_a$) and the city in the hybrid model is fully informal between location 0 and $x_a$ (i.e., yellow zone) and informal with partial participation in the market between $x_a$ and $x_a^*$ (i.e., light green zone). Consequently, the city in the hybrid model corresponds to the city in the registration model, plus an additional zone in the periphery. Thus, the city surplus is greater in the hybrid than in the registration model ($\Theta(k,J) - \Lambda(k) > 0$) when $k = \bar{k}$ and $J \to 0^+$. As all city surpluses are clearly continuous for $J \in ]0, +\infty[$ and $k \in ]0, +\infty[$, this result holds for $J$ sufficiently small and $k$ sufficiently large.