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## Policy Research Working Paper

# Urbanization and Property Rights

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### Abstract

Since the industrial revolution, the economic development of Western Europe and North America was characterized by continuous urbanization accompanied by a gradual phasing-in of urban land property rights over time. Today, however, the evidence in many fast urbanizing low-income countries points towards a different trend of "urbanization without formalization", with potentially adverse effects on long-term economic growth. This paper aims to understand the causes and the consequences of this phenomenon, and whether informal city growth could be a transitory or a persistent feature of developing economies. A dynamic stochastic equilibrium model of a representative city is developed, which explicitly accounts for the joint dynamics of land property rights and urbanization. The calibrated baseline model describes a city that first grows informally, with the growth of individual incomes leading to a phasedin purchase of property rights in subsequent periods. The model demonstrates that land tenure informality does not necessarily vanish in the long term, and the social optimum does not necessarily imply a fully formal city, neither in the transition, nor in the long run. The welfare effects of policies, such as reducing the cost of land tenure formalization, or protecting informal dwellers against evictions are subsequently investigated, throughout the short-term transition and in the long-term stationary state.

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## URBANIZATION AND PROPERTY RIGHTS\*

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### 1 Introduction

Over the past two centuries, the world has witnessed unprecedented changes in the form of massive population growth, continuous urbanization, and economic development. With the advent of the Industrial Revolution (1760-1840), countries in Western Europe and North America began to shift from agrarian towards industrialized societies. This involved migration from rural areas to cities, which, combined with a decline in urban mortality, caused urban populations to grow at an unprecedented pace. As a result, urbanization rates began to pick up steadily. The proportion of people residing in cities increased dramatically over that period, starting from a low rate of approximately one-tenth throughout the Middle Ages and the early modern period (Bairoch 1988) and reaching today 81.5 percent in North America and 73.4 percent in Europe (United Nations, 2014). Simultaneously, North America and Western Europe experienced unprecedented economic development as urbanization accompanied a profound structural transformation of their economies whereby employment in the agricultural sector decreased and a large manufacturing sector emerged in cities (Bairoch and Goertz 1986, Michaels et al. 2012). At the same time, declining transport costs facilitated trade between cities, which further stimulated industrial growth. To the extent that cities also facilitated innovation, in particular through dynamic knowledge and human capital externalities (Lucas 1988, Romer 1990, Glaeser et al. 1992, Black and Henderson 1999, Bertinelli and Black 2004), it is fair to say that they acted as engines of growth (Henderson 2005 and 2010, Quigley 2009). The dynamics of urbanization both stimulated and were accelerated by economic development. Urban population growth contributed to increase labor productivity (and thus income) thanks to pervasive and significant agglomeration effects whereby workers become more productive when cities become larger (Duranton, 2014a). This positive relation is represented on the cross-sectional graph plotting per capita GDP against the urbanization rate for 189 countries (see Figure 1, Panel A below). In accordance with this graph, it is roughly estimated that a one percentage point increase in the urbanization rate is associated with a five point increase in per capita gross domestic product (see Duranton 2014b). A similar relation emerges when plotting U.N. estimates of per capita production for a cross section of large cities against the corresponding country's urbanization rate (see Figure 1, Panel B below). The latter graph suggests that cities tend to be more productive in countries which are more urbanized.

Several authors contend that these evolutions in the cities of Western Europe and North America were made possible by the emergence of institutions conducive to economic growth (North 1990 and 1991, Chong and Calderón 2000), such as financial development (Bondenhorm and Cuberes 2010), the degree of democratization (Henderson and Wang 2007), and property rights (Acemoglu et al. 2005). Improvement in land property rights, in particular, played a crucial role as it favored the development of manufacturing activities by lowering transaction costs for the transfer of land to the emerging industries that were locating in cities and by making investments not only more secure but also more productive (Knack and Keefer 1995). By stimulating the development of

### Figure 1: Urbanization, Productivity, and Economic Growth



Source: World Bank. 189 countries. The urbanization rate on the horizontal axis is the percentage share of population living in cities in 2012. The vertical axis represents the natural log of GDP per capita in 2011 U.S. dollar (reproduced from Duranton, 2014b).

(b) Urbanization and city-level productivity



Source: Global Urban Indicators (1998).

impersonal markets (Arruñada 2012) and enabling the reallocation of land to more productive uses, institutions defining and facilitating the enforcement of land property rights very likely improved economic efficiency (as argued by Coase 1960 and Demsetz 1967). Even though only a few empirical studies investigated the role played by property rights on urban development, these studies all consistently point towards a significant and positive effect. DeLong and Shleifer (1993) estimate that during the 800 years prior to the Industrial Revolution, West European cities in which property rights were more secure—because they were ruled by an elite made of merchants rather than princes—grew faster than other cities. Acemoglu et al. (2005) show that both urbanization and income growth occurred faster in West European countries than in East European countries because of the emergence of property rights institutions in the former group of countries that served the interests of Atlantic trade between 1500 and the Industrial Revolution. Looking at population density in Britain in the decades surrounding the industrial revolution (between 1660 and 1830), Bogart and Richardson (2009) show that the counties where the transfer of property rights were facilitated by Acts of Parliament experienced faster urbanization.<sup>1</sup>

It is important to note that the emergence or reform of property rights institutions is in many instances endogenous and responds to the changing economic context. In theory, property rights institutions will emerge or be strengthened as the benefits of property rights increase (Demsetz 1967, Anderson and Hill 1975, Bubb 2013) and as the political groups that benefit from property rights become sufficiently powerful to weigh in on the legal and institutional framework governing property rights (Libecap 1986, Feder and Feeny 1991). In the historic examples that we already mentioned, this is illustrated by the pressure exerted by Atlantic traders in Western Europe post 1500 to improve institutions that facilitated their activities (Acemoglu et al. 2005) or, in the specific context of Great Britain around the Industrial Revolution, by the public demand for Parliament acts to simplify rules governing land inheritance (Richardson and Bogart 2008). Both in Western Europe and North America, however, the emergence of efficient urban land property rights institutions took considerable time and property rights were only progressively phased in (Konig 1974), possibly due to various political, technical and economic constraints. The political constraints that hindered the development of property rights systems mainly involved the opposition of landowners to registration because of their fear of increased taxation (Offer 1981, Bourillon et al. 2008). It has been theorized, more generally, that landowners may have opposed any form of public protection of property rights (Sonin 2003) as they favored private and selective enforcement of property rights—for which they had a comparative advantage—over public enforcement mechanisms (Kerekes and Williamson, 2010). In addition to such political factors, technical challenges also played an important role in delaying the completion of functioning land property rights systems as illustrated by the repeated attempts over different centuries to establish a complete cadaster in France where manually mapping properties remained extremely costly and time-consuming until the 19th century (Bourillon et al. 2008). Last but not least, a large

<sup>&</sup>lt;sup>1</sup>The authors focus on "estate acts" which relaxed "strict settlements" whereby land had to descend intact from one generation to the other and was encumbered by a complex system of assignment of stipends to relatives.

part of the demand for property rights may have been constrained by the high costs of access to property rights (e.g. registration fees) until a decrease in the costs or until economic development and the ensuing increases in wealth made property rights affordable to a large fraction, if not all the population.<sup>2</sup>

It is clear that the dynamic process of urbanization and the development of urban land property rights systems have been intertwined, with emerging property rights institutions facilitating urbanization and, in turn, with urbanization creating the conditions for further improvements of property rights institutions and for the dissemination of property rights. These dynamics are illustrated by the spatial expansion of European cities which often occurred outside the jurisdiction of the existing property rights system until coverage of the system was later extended to these areas or until the demand for property rights in these areas was expressed and met. In this context, residential informality (defined as the lack of formal property rights) initially rose with the spatial expansion of the city before being progressively resorbed over time. Today, nearly all urban dwellers hold a property right in the cities of the developed world.

There are important differences, however, when comparing the process of urbanization and evolution of land property rights systems in developing countries to that of North America and Western Europe. First, the timing and pace of urbanization turned out to be different in the developing world. Contrary to Western Europe and North America, it is only in the twentieth century that developing countries began to urbanize (see Figure 2), with a pace of urbanization that proved much higher than that of earlier industrializing countries at similar stages of urbanization. Strikingly, Latin America rapidly caught up with developed countries and is now more urbanized than Europe (with 79.5 percent of the Latin America's population residing in cities). As for the Middle East, it has been more than half urban for more than three decades. Today, only Asia and Africa remain predominantly rural (with respective urbanization rates of 47.5 and 40.0 percent). It is in these still predominantly rural regions, however, that the urban population is growing at the fastest rate, with many large cities growing by 4 or 5 percent annually.<sup>3</sup> In Africa, in particular, as a result of these high population growth rates, the urban population is expected to increase almost threefold over the next 35 years, reaching 1.3 billion inhabitants in total. This will raise tremendous challenges for African cities as their net population gain is expected to outweigh in just 35 years the current urban population of Europe and North America combined.

Second, in many parts of the developing world, dysfunctional urban land property rights systems continue to prevail (Durand-Lasserve and Selod, 2009). In African cities in particular, the inconsistent and inappropriate legal frameworks governing land, the poor capacity of land administrations, the lack of political will to reform land laws and practices, and the lucrative

 $<sup>^{2}</sup>$ In different country contexts, it is often the case that the cost of accessing property rights is inflated by the rent capture behaviors of land administrations or by "palliative" service industries (e.g. lawyers, notaries) who favor dysfunctional systems that increase the demand for their own service (Offer 1981, Arruñada 2012).

 $<sup>^{3}</sup>$ Most of this growth originates from rural urban migration as two thirds of the growth can be attributed to migration to cities and only one third to natural growth (see Jedwab et al. 2015).



Figure 2: Historical rates of urbanization in developed and developing regions (a) Urbanization rates (1300-1980, four regions)

Source: Bairoch 1988 (Table 31.1, p.495)



(b) Urbanization rates for the developing world  $\left(1900\text{-}2010\right)$ 

Source: Reproduced from Jedwab, Christiaensen and Gindelsky (2015).

rent-seeking behavior of numerous stakeholders in the land sector combine to prevent large fractions of the population from accessing land under secure property rights (Durand-Lasserve et al. 2015). In this context, informal settlements have become a key feature of urbanization in developing countries, reflecting both the low income levels and the institutional weaknesses of these countries. In Sub-Saharan Africa in particular, it is believed that between 60 and 80 percent of the urban population live in informal settlements (UN-Habitat 2010). As informal settlements are very often slums<sup>4</sup>, they may hinder the economic development of cities and exacerbate poverty through a variety of channels including lack of investment in education (Benabou 1993), adverse labor market outcomes (Rospabé and Selod 2006), high criminality (Glaeser and Sims 2015), and a negative impact on health (Sclar et al. 2006). The lack of formal land property rights in informal settlements further immobilizes capital that is "locked" and cannot be used for productive activities (de Soto 2000, Safavian et al. 2006).<sup>5</sup> More generally, distorted land markets in cities are a major source of inefficiency that hinder economic activities (Duranton et al. 2015). As a result, some countries (mostly African ones) are urbanizing with insecure land rights and in the absence of economic growth.<sup>6</sup>

In view of all the above, the key question raised in our paper is the extent to which the dynamics of urbanization in developing countries will replicate or will diverge from the experience of North America and Western Europe. It is indeed not clear a priori whether the combination of rapid urbanization with distorted property rights systems will affect the timing of urbanization and growth along a path that is comparable to that of industrialized countries, or, on the contrary, if it will set developing economies on a different path of "messy urbanization" with persisting slums and limited long-run economic growth. Projecting the experience of North America and Western Europe onto urbanization in the developing world, there seems to be an implicit consensus among development experts that the first scenario will be happening. In this respect, the "modernization" view of slums sees them as transitory (Marx et al. 2013) and bound to disappear with increases in income as in the case of developed countries: slums, which were quite common in 19th century cities in Europe (Offer 1981), have become almost inexistent in the cities of developed countries. Figure 3 (Panel A) plots the percentage of urban dwellers living in slums on the urbanization rate for a selection of developing countries. In support of this assumption, it shows a negative cross-sectional relation, and thus suggests that the pursuit of urbanization will indeed reduce slums. Similarly, longitudinal data over a short time period (15 years) also indicate a decrease in the prevalence of slums in almost all the countries in the

<sup>&</sup>lt;sup>4</sup>There is a high correlation between informal settlements and slums. The UN definition of slums includes a high prevalence of households residing under insecure tenure due to weak property rights as one of the possible criteria that determine slums.

 $<sup>{}^{5}</sup>$ De Soto's intuition that real property rights should enable their holders to use their property as collateral to obtain credit rests on the assumptions that low-income households in slums are credit constrained and that financial institutions would agree to provide mortgage credit to these households and would accept their properties as collateral (Woodruff 2001).

<sup>&</sup>lt;sup>6</sup>See Fay and Opal (2000) for the seminal paper identifying the puzzle of "urbanization without growth", and Jedwab (2015) for an explanation based on the resource curse leading to the development of "consumption cities" that do not trigger a virtuous circle of industrialization.

Figure 3: Urbanization and slum prevalence



Source: United Nations, Indicators for monitoring the Millennium Development Goals Note: Countries are identified with the corresponding three-letter ISO code.

### sample (Figure 3, Panel B).

The likelihood of the first scenario to occur, however, hinges upon the assumption that property rights will continue to become increasingly accessible (as evidenced by Figure 3, Panel B), either under existing institutions or because improved institutions will emerge and facilitate access to property rights. Whereas much progress has been achieved to improve land governance in the developing world (see Deininger et al. 2012), some countries seem to be marred in a status quo of inadequate property rights systems and are unable to push forward institutional reforms in the land sector. There are a number of reasons for this inertia. As noted by North (1990), bad institutional systems can persist over time with the creation of new organizations that have no incentive to create more efficient rules. Moving away from weak property rights systems may be difficult as those who benefit from the weaknesses (e.g., palliative service industries or land grabbers) exercise political clout to prevent reforms. Weak property rights systems may also persist given path dependency in the building of property rights institutions (Libecap et al. 2011, Arruñada 2012). The specific context of high inequality and corruption in developing countries may further make the collective design and enforcement of adequate property rights systems particularly problematic. Even when appropriate legal frameworks are in place, the degree of enforcement of property rights may be weak (Coase 1960, Firmin-Sellers 1995) or the pricing of property rights can be excessive in comparison with private benefits (Feder and Feeny 1991), limiting the "take up" of property rights.

These observations imply that different paths are possible. In the case of countries which, for some reason, have reached efficient land property rights institutions, can it be anticipated that urbanization will lead to a virtuous circle where a functioning land market with secure property rights will enable growth-enhancing agglomeration? For countries with inefficient land property rights institutions, will the same occur with a delay? Or will these economies follow a different urbanization trajectory with limited growth and persisting slums over the long run?

To our knowledge, the joint dynamics of urbanization and of the evolution of land property rights has not been studied. The small empirical literature on urban property rights has mainly been concerned with assessing the capitalization of characteristics associated with formal vs. informal land tenure such as tenure security (Jimenez 1982 and 1984, Friedman et al. 1998, Kim 2004) or transferability (Lanjouw and Levy 2002), or on measuring the effect of formalization (i.e. transforming informal into formal tenure) on a variety of social and economic outcomes including increased labor market participation, reduced child labor, housing improvement, health, and the facilitation of market transactions (see Field 2005 and 2007, Field and Torero 2006, Galiani and Schargrodsky 2010, Macours et al. 2010). As for the emerging theoretical literature, it has mainly been concerned with explaining the demand for informal land tenure. In the wake of Jimenez (1985), a series of papers have explained how squatting can be sustained in an equilibrium where eviction may occur with some probability (Jimenez 1985, Hoy and Jimenez 1991, Turnbull 2008) or where eviction is absent as squatters take action to guard against eviction (Brueckner and

Selod 2009, Brueckner 2013, Shah 2014).<sup>7</sup> Departing from the restricted focus on squatters, Selod and Tobin (2015) model the formalization choices of households in a context where land plots may be appropriated by others due to multiple sales. In their model, higher endogenous land prices in the core city provide greater incentives to formalize than at the periphery. Because all these models are static—with the only exception of Turnbull (2008), who explores the strategic choices of landowners regarding the timing of squatter eviction—none of them accounts for the transformation of property rights over time under evolving land prices.

Our paper fills this important gap by proposing a theory that accounts for the joint dynamics of urbanization and the evolution of property rights. We model urbanization through the migration of heterogeneous agents from a representative rural area to a representative city. The prevalence of land tenure informality is determined by urban dwellers' decisions whether and when to purchase a property right. As land prices increase with agglomeration, formalization becomes more desirable. However, formalizing may be too costly for less productive workers. These workers who may not be able to afford both a land plot and a land title, will postpone the decision to formalize, making themselves potential prey to land grabbers. The model can flexibly account for the variety of situations regarding urbanization dynamics as its behavior critically depends on key parameters regarding institutional quality (the cost and enforcement strength of land property rights), the potential for agglomeration effects, and macroeconomic uncertainty. Contrary to the modernization view of slums, and in line with the observation that "informality may be here to stay", it allows us to exhibit plausible contexts in which land tenure informality remains in the long run. Deconstructing common-sense intuitions, the model also sheds lights on situations where some level of informality is actually socially desirable. This is because, under the parameters of the economy, informality provides access to the city to low income workers who would not be able to contribute to the urban economy under compulsory formal property rights. In this context, enforcement of strict eviction policies would be counter-productive. The model also provides insights into leaving urbanization to the market, which can be suboptimal under adverse structural parameters, in particular when the potential for agglomeration is low and when land administration charge high fees.

The rest of the paper is organized as follows. Section 2 below presents the model which takes the form of a discrete-time dynamic stochastic game under infinite time but a finite number of states and actions. Section 3 then presents our concepts of social planner and decentralized solutions. Section 4 explains our calibration before Section 5 presents the main results from simulations.

### 2 The model

We consider an economy with a set of N individuals. Individuals live forever and may either reside in the rural area or in the city. In the city, individuals are exposed to a risk of conflict

 $<sup>^7\</sup>mathrm{For}$  a detailed survey, see Brueckner and Lall (2014).

over land that may result in their eviction from the plot they occupy (a "land grab"). Urban dwellers can nevertheless pay to establish a property right on their plot instead of holding it informally. Whereas informally holding a plot does not provide tenure security, formally held plots are protected against land grabs and their owners cannot be evicted. Formally, let us denote  $x_t^i = (x_t^{U,i}, x_t^{F,i})$  the vector of state variables for a representative individual *i* at time t.  $x_t^{U,i}$  is the location variable for individual *i*. It takes value 1 if the household resides in the urban area and 0 if the individual resides in the rural area at time *t*.  $x_t^{F,i}$  is the property right variable.  $x_t^{F,i}$  takes value 1 if the household holds a property right at time *t* and 0 otherwise. We assume that property rights can only be obtained in the urban area so that living in the rural area with a property right is never a possibility in the model.<sup>8</sup>

When living in the city over the period (t, t + 1), the individual *i* earns a wage  $w_t^{U,i}$  for his work during the period but faces a congestion costs  $c_t$ , which we assume to be the same for all individuals. If residing in the rural area, the individual earns rural income  $w_t^R$  which we assume is the same for all rural dwellers.<sup>9</sup> There is no congestion cost in the rural area. Wages and the urban congestion cost will be endogenous in the model. In addition, if settling in the city at time *t*, an individual must purchase a land plot at a price  $R_t$  on the land market. Although the price of land is endogenous in the city, because land is abundant in the rural area, we assume for simplicity that the price of land in the rural area is equal to zero without any loss of generality.<sup>10</sup>

In our dynamic setting, the land price in the city is determined at the beginning of each period by a macro-economic relation that accounts for city composition and economic conditions (see below). The prevailing land price then drives location choices and grabbing decisions within the period, which in turn affects the fundamentals of the land price for the next period. We assume that there are absentee landlords who, in each period, sell land to urban in-migrants upon arrival to the city and purchase it from voluntary out-migrants upon departure from the city, as well as from land grabbers who resell grabbed land. In our modeling, absentee landlords are price takers over a single period of time. They play the role of "market makers" allowing for a simplified representation of the land market.<sup>11</sup>

<sup>&</sup>lt;sup>8</sup>The prevalence of property rights in rural areas is very low in many countries. This is the case for instance when tenure in rural areas is overwhelmingly customary. Some countries may not have a land registration system or a cadastre for rural areas. Relaxing this assumption would not change the main outcomes of the model while adding unnecessary complexity.

<sup>&</sup>lt;sup>9</sup>Productivity in the rural area is low and does not depend on individual intrinsic characteristics.

 $<sup>{}^{10}</sup>R_t$  could also be interpreted as the time-varying difference between the urban and rural land prices. Under this alternative definition—which would assume an initial land endowment in the rural area for each individual—  $R_t$  would be much smaller than under the previous definition as it would only represent the fraction of income needed to complement the proceed of the rural land sale to purchase an urban plot. The two definitions for  $R_t$ are mathematically equivalent in our setting under the assumption of a zero price for rural land.

 $<sup>^{11}</sup>$ The existence of absentee landlords is also a standard assumption in static urban economics model where they sell land to households competing for land (see Fujita 1989).

### 2.1 Decisions

At the beginning of each period (t, t + 1), an individual makes two choices: whether to migrate and whether to purchase a property right.

Let us denote  $\mathbf{d}_{\mathbf{t}}^{\mathbf{i}} = (d_t^{U,i}, d_t^{F,i})$  the vector of choice variables made by individual *i*, where  $d_t^{U,i}$  is the migration decision and  $d_t^{F,i}$  is the land tenure decision.

 $d_t^{U,i}$  takes the value 1 when the individual decides to migrate to (or remain in) the urban area between time t and t + 1, and the value 0 if the individual decides to migrate to (or remain in) the urban area between time t and t + 1.

Because property rights provide protection against land grabs, formality is preferable over informality. It is, however, costly to establish: an individual residing on an informal plot in the city at time t needs to decide whether to pay a formalization fee  $f_t$  to obtain a property right between time t and t+1 or not to pay anything and continue to hold the plot informally.<sup>12</sup> The fee is proportional to the value of the land:

$$f_t = \mu R_t \tag{1}$$

with  $0 < \mu < 1$ . It is a one-time payment (e.g. registration in a cadastre) and does not need to be paid again in subsequent periods as long as the individual uses the plot, i.e. as long as the individual remains in the city.  $d_t^{F,i}$ , the land tenure choice variable, takes the value 1 when the individual decides to establish a property right between time t and t + 1 and takes the value 0 otherwise.

### 2.2 Shocks

Individuals move in and out of the urban area and in and out of residential formality throughout their infinite lifetime. Movements between locations and between land tenure situations are governed by migration and land tenure decisions (as individuals may seek property rights when residing in the city) in the face of productivity shocks and land grab shocks.

Let us start with shocks and denote  $\epsilon_t^i = (\epsilon_t^P, \epsilon_t^{G,i})$  the *vector* of shocks faced by individual *i* in period (t, t+1).

Firstly,  $\epsilon_t^P$  is a negative productivity shock (such as a weather shock) that affects the wage in the rural area in period (t, t + 1).  $\epsilon_t^P$  takes the value 1 when the shock occurs and 0 otherwise. This occurs with exogenous probability  $\pi^P$ .

 $<sup>^{12}</sup>$ In practice, fees can be paid for the formalization of an informally held plot, or following transactions of formal plots to ensure that they do not revert to informality (for instance by paying to update the registry with the new owners' name).

Secondly,  $\epsilon_t^{G,i}$  is a "land grab opportunity" that affects informal urban dwellers to the potential benefits of land grabbers.  $\epsilon_t^{G,i}$  takes the value 1 if an opportunity to grab the plot of individual *i* arises between time *t* and *t* + 1 and 0 otherwise. The shocks  $\epsilon_t^{G,i}$  for i = 1, ..., I are assumed to be *i.i.d.* and occur with exogenous probability  $\pi^G$ .  $\pi^G$  reflects tenure insecurity on informal plots. It may reflect the probability that an agent of the land administration or a judge will be willing to facilitate an eviction. It also inversely reflects the degree of protection that informal dwellers may have under current legislation and practices (e.g. if evictions are banned by local authorities and if this ban is implemented, then  $\pi^G = 0$ ). Only plots faced with a land grab opportunity ( $\epsilon_t^{G,i} = 1$ ) and which are not held formaly ( $x_t^{F,i} = 0$ ) will be grabbed or evicted. We will present this in more detail below, after a brief presentation of the timing of decisions and shocks..

### 2.3 Timing of decisions and shocks

In the model, state variables  $(x_t^{U,i} \text{ and } x_t^{F,i})$  are defined at discrete points in time generically denoted t. Decisions  $(d_t^{U,i} \text{ and } d_t^{F,i})$  and shocks  $(\epsilon_t^P \text{ and } \epsilon_t^{G,i})$  occur within time periods generically denoted [t, t+1).<sup>13</sup> We specify here the exact timing of events within a period [t, t+1). We assume the following sequence: at time t, individuals are located either in the city or the rural area and may or may not have a property right. Shortly after time t, individuals simultaneously decide where they want to locate (possibly relocate) and whether they want to purchase a property right (if they have not done so earlier for the plot they occupy). Immediately after this decision is made, they may then migrate (possibly involving the sale or purchase of land from absentee landlords) and pay for the property right for those settling in the city and wishing to formalize. In the first half period (t, t + 0.5), the city faces land grab opportunity shocks (idiosyncratic probabilities of land grab opportunities are drawn). At time t + 0.5, land plots exposed to grabbing are grabbed if unprotected (see below). . Land grab activities can affect urban wages for the second half of the period (through a change in the city composition as individuals that lose their plot are forced to move to the rural area shortly after time t+0.5).<sup>14</sup> The rural productivity shock occurs at t + 0.5 and affects location decisions in the next period. It is important to note here that, in order to be consistent with the nature of our shocks and our modeling of the land market, we assume a period length of several years (exactly 10 years in our simulations).<sup>15</sup>

 $<sup>^{13}</sup>$ We index these middle-of-the-period shocks, along with intermediary variables introduced later, with subscript t.

<sup>&</sup>lt;sup>14</sup>The relocations that occur shortly after time t+0.5 only reflect land grabs and do not result from the location decision which is made at time t and implies relocation shortly after time t.

<sup>&</sup>lt;sup>15</sup>We assume that land can be fully purchased within one period, which requires a mid-term time horizon. Choosing relatively long periods does not qualitatively alter the results of the model. Calibrated parameters are chosen accordingly.

### 2.4 Migration

Individuals may choose to migrate between the rural area and the city in response to the difference in the urban and rural incomes (net of housing and congestion costs) and given tenure insecurity in the city and the possibility to formalize and the cost of formalization. In our model, in each period, the rural-urban difference in income is affected by the rural productivity shock at time t+0.5, implying:

$$w_s^R = \begin{cases} W_{t,1}^R \equiv w^R & \text{for } s \in (t, t+0.5] \\ W_{t,2}^R \equiv w^R (1 - \eta \varepsilon_t^P) & \text{for } s \in (t+0.5, t+1] \end{cases}$$
(2)

where  $w^R$  is agricultural productivity in the "good" state of the nature, and  $w^R (1 - \eta \varepsilon_t^P)$  is agricultural productivity in the "bad" state of the nature when the rural productivity shock  $\varepsilon_t^P$ (e.g. low rainfall) kicks in.  $\eta$  is the rural income elasticity to the shock with  $0 < \eta < 1$ .

### 2.5 Land grabs / evictions

Formal and informal residents in the city may grab land from other informal residents after a land grab opportunity arises  $(\epsilon_t^{G,i}=1)$  for an urban plot that is informally held. Let us denote  $\mathcal{I}_t$  the set of informal dwellers in the city during the first half period (t, t + 0.5) before the land grab opportunity shocks happen. These are households who choose to live in the city at the beginning of the period  $(d_t^{U,i}=1)$ , who did not hold a formal property right at the beginning of the period  $(x_t^{F,i}=0)$ , and who did not become formal during the period  $(d_t^{F,i}=0)$ . By definition,  $\mathcal{I}_t = \left\{i | d_t^{U,i} \cdot (1 - x_t^{F,i}) \cdot (1 - d_t^{F,i}) = 1\right\}$  or  $\mathcal{I}_t = \left\{i | d_t^{U,i} \cdot (1 - x_{t+1}^{F,i}) = 1\right\}$ . The land grab opportunity shocks are drawn at a time in (t, t + 0.5), defining a subset  $\mathcal{I}_t^R \subseteq \mathcal{I}_t$  of informal residents at risk of being grabbed, with  $\mathcal{I}_t^R = \left\{i | \epsilon_t^{G,i} \cdot d_t^{U,i} \cdot (1 - x_{t+1}^{F,i}) = 1\right\}$ . At time t + 0.5, if a plot  $i \in \mathcal{I}_t^R$ , is grabbed, grabbers can immediately sell off the plot on the land market (to absentee landlords) at the prevailing market land price  $R_t$ . The set of informal dwellers who get grabbed  $\mathcal{I}_t^G \subseteq \mathcal{I}_t^R$  is defined by

$$\mathcal{I}_{t}^{G} = \begin{cases}
\mathcal{I}_{t}^{R}, & \text{if } \mathcal{I}_{t}^{R} \neq \mathcal{H}_{t} \\
\varnothing, & \text{if } \mathcal{I}_{t}^{R} = \mathcal{H}_{t}
\end{cases}$$
(3)

where  $\mathcal{H}_t = \left\{ i | d_t^{U,i} = 1 \right\}$  is the set of city dwellers over (t, t + 0.5].<sup>16</sup> The aggregate profit from land grabbing in period t is

 $<sup>{}^{16}\</sup>mathcal{I}_t^R = \mathcal{H}_t$  is the pathological case where all individuals should be grabbed but no one would be left in the city to be a grabber, which cannot be possible. In this (unlikely case), we simply assume that no one gets grabbed in the period.

$$\mathcal{P}_{t}^{G} = \sum_{i \in \mathcal{I}_{t}^{G}} R_{t} = \sum_{i=1}^{N} R_{t} \cdot \epsilon_{t}^{G,i} \cdot d_{t}^{U,i} \cdot (1 - x_{t+1}^{F,i})$$
(4)

We assume that the land grabbing profit is redistributed to all remaining city-dwellers  $i \in \mathcal{J}_t$ .<sup>17</sup> Because richer (and more powerful) households are more likely to exert grabbing, we assume that the share of the grabbing profit redistributed to each individual is proportional to that individual's wage  $w_t^{i}$ .<sup>18</sup> Each individual remaining in the city after t + 0.5  $(i \in \mathcal{J}_t)$  thus obtains an additional income from grabbing activities:

$$\mathcal{G}_t^i = \mathcal{P}_t^G \frac{w_t^i}{\sum_{i \in \mathcal{J}_t} w_t^i} \tag{5}$$

#### 2.6Agglomeration and congestion

Considering that an individual resides in the city during time sub-interval (t, t + 0.5] if and only if  $d_t^{U,i} = 1$ , and during time sub-interval (t + 0.5, t + 1] if and only if  $x_{t+1}^{U,i} = 1$ , the population size in the city for those two time intervals can be expressed by the formula

$$N_s = \begin{cases} \sum_{i=1}^{N} d_t^{U,i}, & \text{for } s \in (t, t+0.5] \\ \sum_{i=1}^{N} x_{t+1}^{U,i}, & \text{for } s \in (t+0.5, t+1] \end{cases}$$
(6)

There are benefits and costs associated with an increasing urban population, which we present sequentially. Benefits are captured through agglomeration effects, where the productivity (and thus the wage) of each individual in the city depends on the size and composition of the urban labor force (see Duranton, 2013) as well as on land tenure. The latter assumption reflects the fact that informal plot owners have a reduced labor supply as shown for example by Field (2007) in the case of Lima, Peru. Assuming that each individual is characterized by an exogenous ability  $a_i > 0$  and contributes  $a_i$  units of labor to production when residing formally in the city and  $(1-\kappa)a_i$  with  $0 < \kappa < 1$  when residing informally in the city, we can further define the total efficient labor in the city as

$$L_{s} = \begin{cases} L_{t,1} = \sum_{i=1}^{N} a_{i} \cdot \left(1 - \kappa \cdot (1 - x_{t+1}^{F,i})\right) \cdot d_{t}^{U,i} & \text{for } s \in (t, t+0.5] \\ L_{t,2} = \sum_{i=1}^{N} a_{i} \cdot \left(1 - \kappa \cdot (1 - x_{t+1}^{F,i})\right) \cdot x_{t+1}^{U,i} & \text{for } s \in (t+0.5, t+1] \end{cases}$$
(7)

If residing in the urban area, the wage of individual i can then be specified as

<sup>&</sup>lt;sup>17</sup>The set of non-grabbed dwellers is  $\mathcal{J}_t = \mathcal{H}_t \setminus \mathcal{I}_t^G$ . It includes all urban households who were not grabbed in period t. It is easy to see that  $\mathcal{J}_t = \left\{ i | d_t^{U,i} \cdot \left( 1 - \epsilon_t^{G,i} \cdot (1 - x_{t+1}^{F,i}) \right) = 1 \right\}$  or  $\mathcal{J}_t = \left\{ i | x_{t+1}^{U,i} = 1 \right\}$ . <sup>18</sup>Alternatively, we could have considered that redistribution occurs with equal shares  $\frac{1}{|\mathcal{J}_t|}$  or that it reflects

an idiosyncratic ability or willingness to exert corruption.

$$w_s^{U,i} = \begin{cases} W_{t,1}^{U,i} \equiv a_i . \sigma. \left[1 + L_{t,1}\right]^{1/\gamma} & \text{for } s \in (t, t + 0.5] \\ W_{t,2}^{U,i} \equiv a_i . \sigma. \left[1 + L_{t,2}\right]^{1/\gamma} & \text{for } s \in (t + 0.5, t + 1] \end{cases}$$
(8)

where  $\sigma > 0$ , and  $\gamma > 0$ .<sup>19</sup>

Let us now turn to congestion. For simplicity, we assume that congestion translates into a monetary cost borne by city dwellers and is expressed in monetary units. It is measured by a congestion function which depends on the size of the city.<sup>20</sup> We have

$$c_{s} = b. \left[N_{s}\right]^{\delta} = \begin{cases} C_{t,1} \equiv b. \left[\sum_{i=1}^{N} d_{t}^{U,i}\right]^{\delta} & \text{for } s \in (t, t+0.5] \\ C_{t,2} \equiv b. \left[\sum_{i=1}^{N} x_{t+1}^{U,i}\right]^{\delta} & \text{for } s \in (t+0.5, t+1] \end{cases}$$
(9)

where  $N_s$  is defined by (6), for  $s \in (t, t+1]$ . Here,  $w_s^i$ ,  $c_s$ ,  $W_{t,1}^i$ ,  $W_{t,2}^i$ ,  $C_{t,1}$ ,  $C_{t,2}$  are measured per period. Because of the existence of possible shocks, both  $W_{t,2}^i$  and  $C_{t,2}$  are random.

Equation (9) captures the negative externalities associated with agglomeration.<sup>21</sup>

### 2.7 Land prices

As for land costs, they are only incurred upon arrival in the city (when the individuals need to purchase a land plot). We assume that each individual consumes one unit of land and that there is a unique price for land in the city at any given point in time.<sup>22</sup> We assume that the ratio of the land price to the average income is constant. This long-term relation has been established at the city level both theoretically and empirically in the literature (see Ried and Uhlig, 2009, Malpezzi, 1999, and Leung, 2014). Since transactions only occur during the first half of the period (households purchase or sell land at the beginning of the period, and grabbers sell off grabbed land at time t + 0.5), the price is a function of the population and wage that prevail during (t, t + 0.5], so we have

$$R_t = \lambda \cdot \frac{\sum_{i=1}^{N} W_{t,i}^{U,i} \cdot d_t^{U,i}}{\sum_{i=1}^{N} d_t^{U,i}}$$
(10)

$$Y = \frac{\sigma . [1+L]^{1/\gamma + 1}}{1/\gamma + 1}$$

with  $w_t^i = a_i \frac{dY}{dL}$ .

<sup>&</sup>lt;sup>19</sup>The formula can be derived by assuming a production function

<sup>&</sup>lt;sup>20</sup>Congestion here reflects the various externalities associated with city size, including travel distance and time (Izraeli and McCarthy, 1985), pollution (Lamsal *et al.*, 2013) or criminality (Glaeser and Sacerdote, 1999).

 $<sup>^{21}</sup>$ The formula can be derived as the average transport cost in a mono-centric city with convex transport costs (see Fujita, 1989).

 $<sup>^{22}</sup>$ This can be viewed as the average price of land in the city. We could adopt a more sophisticated representation of land with prices that vary depending on within-city location as in Selod and Tobin (2015) but this would make the model more complex without affecting the main results.

where  $0 < \lambda < 1$ .<sup>23</sup>

### 2.8 Land transactions

Land is transferred whenever there are population movements between the city and the rural area or when land is grabbed (and immediately sold off).

Migrants to the city only purchase land upon arrival. We can thus define a variable that measures land purchases as  $P_t^i = R_t$  if individual *i* arrives in the city shortly after time *t* and  $P_t^i = 0$ otherwise. This is modeled using the formula

$$P_t^i = R_t . d_t^{U,i} . (1 - x_t^{U,i}) \tag{11}$$

Conversely, individuals who voluntarily decide to leave the city shortly after time t sell their land back upon departure at a price  $R_t$ . We can define a variable that measures land sales as  $S_t^i = R_t$ if individual *i voluntarily* leaves the city during period (t, t + 1] and  $S_t^i = 0$  otherwise.<sup>24</sup> This is obtained for<sup>25</sup>

$$S_t^i = R_t (1 - d_t^{U,i}) x_t^{U,i}$$
(12)

### 2.9 Location and land tenure transitions

We now turn to the general definition of transitions, which are defined by the correspondence  $\Gamma : \mathbf{x}_t^i \mapsto \mathbf{x}_{t+1}^i$  as a function of  $\mathbf{x}_t^i$ ,  $\mathbf{d}_t^i$  and  $\epsilon_t^i$  where  $\mathbf{x}_t^i \in \{0,1\}^2$ ,  $\mathbf{d}_t^i \in \{0,1\}^2$  and  $\epsilon_t^i \in \{0,1\}^2$ . This correspondence completely defines what happens between time t and time t + 1 to the location and tenure (state variables) of an individual in all possible states and facing all possible combinations of shocks.

We can now infer the laws of motion that fully characterize the transitions between t and t + 1 as functions of states at time t and decisions and shocks between time t and time t + 1. We have

$$x_{t+1}^{U,i} = d_t^{U,i} \cdot \max\left\{x_t^{F,i}, d_t^{F,i}, 1 - \epsilon_t^{G,i}\right\}$$
(13)

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Although the land price fluctuates within each period because of involuntary population movements between the first and the second half of each period, transactions only occur at the beginning of the first half of the period following voluntary location decisions. We also assume that sales of grabbed land occur at the current land market price, which can be justified by stickiness.

<sup>&</sup>lt;sup>24</sup>Individuals who are victim of a land grab must leave the city and cannot recoup their land investment. <sup>25</sup>Note that in each period the total net payment received by absentee landlords is  $\Pi_t = \sum_{i=1}^{N} (P_i^i - S_i^i) - \sum_{i \in \mathcal{I}_t^G} R_t$ , which can be positive or negative. In the long run, when the population of the city and the share of informal dwellers stabilize, this is expected to be zero as there will be as many sales as purchases.

$$x_{t+1}^{F,i} = d_t^{U,i} \cdot \max\left\{x_t^{F,i}, d_t^{F,i}\right\}$$
(14)

Transition formula (13) states that in order to reside in the city at time t + 1, individual *i* must have decided to remain in or to move to the city between time *t* and t+1 and either already held a property right for his urban plot at time *t*, decided to formalize between time *t* and time t + 1, or did not face a land grab shock between time *t* and t + 1. Transition formula (14) recognizes that to have a property right at time t + 1, the individual must have decided to remain in or to move to the city between time *t* and t + 1 and either already had a property right at time *t* or acquired one between time *t* and t + 1.

### 3 Stochastic game and social planner solution

We will now determine how the system evolves under two different optimization problems and associated solution concepts (stochastic game and social planner optimum). This involves determining how states at the beginning of one period are followed by policy functions during the period (decisions in our framework) that determine states at the beginning of the following period. To do this, let us define the *strategy* for individual *i* as the function from the vector of states  $\mathbf{x}_t = \left\{ (x_t^{U,i}, x_t^{F,i})_{i=1,...,N} \right\}$  into individual decisions  $\mathbf{d}_t^i = (d_t^{U,i}, d_t^{F,i})$ , which we simply denote  $D_t^i(\mathbf{x}_t)$ .

To understand how strategies are determined, we now need to understand how individuals are affected by decisions. To do that, observe that at time t, when individual i decides to live in the rural area during the period (t, t + 1] (i.e.  $d_t^{U,i} = 0$ ), he will receive  $(W_{t,1}^R + W_{t,2}^R)/2 + S_t^i$  in the period. When individual i decides to live in the urban area during the period, he will pay  $d_t^{F,i}.f_t + P_t^i$  at the beginning of the period, receive wage  $W_{t,1}^{U,i}/2$  and incur the congestion cost  $C_{t,1}/2$  during the first half period. During the second half period, if the individual is forced to leave the city because he faced a land grab opportunity at t + 0.5 (i.e.  $\epsilon_t^{G,i} = 1$ ) and did not have a property right (i.e.,  $x_{t+1}^{F,i} = 0$ ), then he will receive  $W_{t,2}^R/2$ ; otherwise, he will receive a wage  $W_{t,2}^{U,i}/2$ , incur a congestion cost  $C_{t,2}/2$ , and receive his fraction of the land grab proceeds  $\mathcal{G}_t^i$ . The net income of the individual who decides to reside in the city in (t, t + 1) is thus

$$y_{t} = \begin{cases} \frac{1}{2} \left( W_{t,1}^{U,i} - C_{t,1} + W_{t,2}^{R} \right) - P_{t}^{i} & \text{if } \epsilon_{t}^{G,i} = 1, x_{t+1}^{F,i} = 0, \\ \frac{1}{2} \left( W_{t,1}^{U,i} - C_{t,1} + W_{t,2}^{U,i} - C_{t,2} \right) + \mathcal{G}_{t}^{i} - d_{t}^{F,i} \cdot f_{t} - P_{t}^{i} & \text{otherwise.} \end{cases}$$

Thus, we have the utility of individual i over the period (t, t+1]

 $<sup>^{26}</sup>$ Note that because decisions are made before shocks occur in each period, they are only functions of the current states but not of the realization of the shocks.

$$u_t^i = u^i(\mathbf{x}_t, \mathbf{d}_t) = \begin{cases} \frac{\left( \left( W_{t,1}^R + W_{t,2}^R \right)/2 + S_t^i \right)^{1-\alpha}}{1-\alpha} & \text{if } d_t^{U,i} = 0, \\ \frac{y_t^{1-\alpha}}{1-\alpha} & \text{otherwise.} \end{cases}$$
(15)

The relevant part of the expression when the individual decides to reside in the rural area does not include the term  $d_t^{F,i} f_t$  because, by definition, a household will not simultaneously decide to formalize and migrate to the rural area. The specification reflects risk-aversion through the parameter  $\alpha$ .

With the above framework, we can now solve the two different optimization problems that respectively correspond to the social planner solution or the stochastic game solution that results from individual choices.

### 3.1 Social planner solution

At the beginning of each period t, the planner assigns to individuals a sequence of location and formalization decisions so as to maximize the expected value of the sum of discounted stream of aggregated utilities and profits, considering the exogenous shock probabilities (and likelihood of transitions between states). The social planner's objective function at time t is

$$\max_{\{\mathbf{d}_t, \mathbf{d}_{t+1}, \dots\}} \mathbb{E}\left[ U(\mathbf{x}_t, \mathbf{d}_t) + \sum_{\tau=t+1}^{\infty} \beta^{\tau-t} . U(\mathbf{x}_{\tau}, \mathbf{d}_{\tau}) \right]$$
(16)

where  $U(\mathbf{x}_t, \mathbf{d}_t) = \sum_{i=1}^{N} u_t^i(\mathbf{x}_t, \mathbf{d}_t)$  aggregates individual preferences and  $\mathbb{E}$  is the expectation operator<sup>27</sup> and  $\beta \in (0, 1)$  is the discount factor and the expectation is taken over the random productivity and land grab opportunity shocks. Note that the shocks enter in (16) through  $\mathbf{x}_{\tau}$ which, as we have seen, is a function of  $\mathbf{x}_{\tau-1}$ ,  $\mathbf{d}_{\tau-1}$  and  $\epsilon_{\tau-1}$ . The transition laws of  $\mathbf{x}_t$  are given by (13) and (14) for each individual. For simplicity, we denote the transition laws as  $\mathbf{x}_t = g(\mathbf{x}_{t-1}, \mathbf{d}_{t-1}, \epsilon_{t-1})$ .

Because it is an infinite-horizon problem, the decision depends only on the current state and we can write the corresponding Bellman equation (Bellman, 1957) as

$$V^{s}(\mathbf{x}) = \max_{\mathbf{d}} \mathbb{E} \left\{ U(\mathbf{x}, \mathbf{d}) + \beta . V^{s}(\mathbf{x}_{+}) \right\}$$
(17)

where  $\mathbf{x}$  is the current-period state, and  $\mathbf{x}_+$  is next-period state dependent on  $\mathbf{x}$ , decision  $\mathbf{d}$ , and the shocks  $\epsilon$ , i.e.,  $\mathbf{x}_+ = g(\mathbf{x}, \mathbf{d}, \epsilon)$ . The optimal policy function is  $D^i(\mathbf{x})$  for individual *i*.

Definition of social planner solution: We define the social planner solution as the value function  $V^{s}(\mathbf{x})$  and the set of individual policy functions  $\mathbf{D}(\mathbf{x}) = \{D^{i}(\mathbf{x}) : i = 1, ..., N\}$  that solve the Bellman equation (17) given the Social Welfare Function U.

 $<sup>^{27}\</sup>mathrm{We}$  consider a utilitarian social welfare function but any other social welfare function can be used.

The right-hand side of the Bellman equation (17) can be expressed as  $\Gamma(V^s)(\mathbf{x})$  where  $\Gamma$  is the Bellman operator. We see that the value function  $V^s(\mathbf{x})$  is a fixed point of the Bellman operator, so we can use an iterative method to find  $V^s(\mathbf{x})$ . We apply the value function iteration, that is, we first choose an initial guess of  $V^s(\mathbf{x})$ , denoted as  $V_0^s(\mathbf{x})$ , and then compute  $V_t^s(\mathbf{x}) = \Gamma(V_{t-1}^s)(\mathbf{x})$  for  $t \geq 1$  until the iteration converges. A detailed discussion of value function iteration is available in Judd (1998).

### 3.2 Stochastic game

Here we are trying to solve the stochastic game problem where every individual wants to maximize the present value of his own expected stream of utilities. Mathematically, instead of (16), we now have the multi-objective optimization problem:

$$\max_{\{\mathbf{d}_t^i, \mathbf{d}_{t+1}^i, \mathbf{d}_{t+2}^i, \dots\}} \mathbb{E}\left[ u^i(\mathbf{x}_t, \mathbf{d}_t) + \sum_{\tau=t+1}^{\infty} \beta^{\tau-t} u^i(\mathbf{x}_{\tau}, \mathbf{d}_t) \right] \quad \text{for } i = 1, \dots, N$$
(18)

Note that  $\mathbf{x}_t$  and  $\mathbf{d}_t$  are still states and decision vectors for all individuals in the economy.

Since every individual has his own value function  $V^i(\mathbf{x})$  and policy function  $D^i(\mathbf{x})$  which depend on the states of all individuals, we also need to replace (17) with the following set of Bellman equations (one per individual):

$$V^{i}(\mathbf{x}) = \max_{\mathbf{d}^{i}} \mathbb{E}\left\{u^{i}(\mathbf{x}, \mathbf{d}) + \beta V^{i}(\mathbf{x}_{+})\right\} \quad \text{for } i = 1, ..., N$$
(19)

where  $\mathbf{x}_{+} = g(\mathbf{x}, \mathbf{d}, \epsilon)$ .

In this context, our concept of equilibrium is the stationary Markov-perfect equilibrium as in Maskin and Tirole (1987, 1989a, and 1989b).<sup>28</sup> It is a natural equilibrium concept to adopt in a dynamic setting such as ours where individuals optimize their own discounted utility taking into account other individuals' decisions.

Definition of equilibrium: We define a stationary Markov-perfect equilibrium as the set of value functions  $\mathbf{V}^{all}(\mathbf{x}) = \{V^i(\mathbf{x}) : i = 1, ..., N\}$  and the set of individual policy functions  $\mathbf{D}(\mathbf{x}) = \{D^i(\mathbf{x}) : i = 1, ..., N\}$  such that for any individual i = 1, ..., N and for any vector of states  $\mathbf{x}$ and other players' actions  $\mathbf{d}^{-i} = (\mathbf{d}^1, ..., \mathbf{d}^{i-1}, \mathbf{d}^i, ..., \mathbf{d}^N)$  with  $\mathbf{d}^j = D^j(\mathbf{x})$  for  $j \neq i$ , the value function  $V^i(\mathbf{x})$  solves the Bellman equation in (19), and the individual strategy  $D^i(\mathbf{x})$  solves the right-hand side of the equation (19).

We denote the right-hand side of the system of Bellman equations  $\mathcal{F}(\mathbf{V}^{all})(\mathbf{x})$ , where  $\mathcal{F}$  is the Bellman operator vector.  $\mathbf{V}^{all}(\mathbf{x})$  is the fixed point of  $\mathcal{F}$ . Thus, as for the social

 $<sup>^{28}</sup>$ The same equilibrium concept has been widely applied in the literature on industry dynamics, see e.g., Ericson and Pakes (1995), Maskin and Tirole (2001), and Doraszelski and Satterthwaite (2010).

planner problem, we can also solve for  $\mathbf{V}^{all}(\mathbf{x})$  by applying an iterative method. However, it is time consuming to compute  $\mathcal{F}$  for problems with large N, because of three levels of "curseof-dimensionality", whereby computational cost increases exponentially in the number of state variables, the number of decision variables, and the number of shock variables for computing expectation. To address this issue Pakes and Mcguire (1994) introduced a computational method for computing Markov-perfect Nash equilibria for stochastic games with continuous choices. In a related work, Doraszelski and Judd (2012) analyze continuous-time stochastic games to avoid the curse of dimensionality in computing expectations. In this paper, we use a variant of the method of Pakes and Mcguire (1994) to find a stationary Markov-perfect equilibrium for our discrete-time, infinite-horizon stochastic game with discrete states and discrete choices. That is, we choose the optimal policy functions of the social planner problem as our initial guess of  $\mathbf{D}(\mathbf{x})$  for the stochastic game, denoted as  $\mathbf{D}_0(\mathbf{x}) = \{D_0^i(\mathbf{x}) : i = 1, ..., N\}$ . We then let the initial guess of  $\mathbf{V}^{all}(\mathbf{x})$  be  $\mathbf{V}_0^{all}(\mathbf{x}) = \mathbb{E}\{u^i(\mathbf{x}, \mathbf{D}_0(\mathbf{x}))\}/(1-\beta)$ . Denoting  $(\mathbf{D}_t^{-i}(\mathbf{x}), \mathbf{d}^i, D_t^{i+1}(\mathbf{x}), ..., D_t^N(\mathbf{x}))$ , we compute

$$V_t^i(\mathbf{x}) = \max_{\mathbf{d}^i} \mathbb{E}\left\{ u^i(\mathbf{x}, \mathbf{D}_{t-1}^{-i}(\mathbf{x}), \mathbf{d}^i) + \beta . V_{t-1}^i(\mathbf{x}_+) \right\},\tag{20}$$

for each i = 1, ..., N, and let  $D_t^i(\mathbf{x})$  be the optimizer for individual i at the t-th iteration for  $t \ge 1$ . At iteration t, we know the value function and policy functions at the previous iteration t - 1 for every individual. Each individual determines his own optimal decision under the assumption that the other individuals make their decisions at t that replicate their policy functions at t - 1. Note that although the  $\mathcal{F}$  operator has to be solved jointly for all individuals, equation (20) can be solved separately for each individual i. This makes equation (20) much easier and faster to solve. We iterate over t until both  $\mathbf{V}_t^{all}$  and  $\mathbf{D}_t(\mathbf{x})$  converges. The converged value and policy functions are the solution to the stochastic game.

From Maskin and Tirole (2001), we know that there exists a Markov-perfect equilibrium for our stochastic games with finite action spaces. However, our stochastic games may still have multiple equilibria, although Maskin and Tirole (2001) point out that the Markov-perfect equilibrium concept, a refinement of the Nash equilibrium, can be applied to eliminate or reduce the multiplicity of equilibria in dynamic games. Recently, Borkovsky et al. (2010) applied the homotopy approach to detect equilibrium multiplicity for games with continuous strategies, and Judd et al. (2012) developed all-solution homotopy methods to find all equilibria of static and dynamic games with continuous strategies. Yeltekin et al. (2015) provide a numerical method for computing all subgame-perfect equilibria of dynamic games with both discrete and continuous strategies, but their examples consist of only two or three-player dynamic games even with massive parallelization. As our examples are stochastic games and have a large number of players (in our example N = 5 players and 2N = 10 dimensions of states), it is still challenging to find all equilibria for such a large-dimensional problem, so we leave this for future research.

### 4 Model calibration

We choose values for the model parameters based on econometric estimates in the economic literature on urbanization and development. When econometric estimates are not available, we calibrate the remaining model parameters to match observed patterns of urbanization in developing countries. For most significant model parameters, we conduct a sensitivity analysis over the range of their plausible values. Table 1 lists the model's parameters and shows the chosen values.

We set the number of economic agents to 5 in order to balance the model's computational feasibility with tractability. We interpret the number of agents as population quantiles. We consider a uniform distribution of abilities over (0,1] with  $a_i = i/N$  for i = 1, ..., N. Agent N is thus the individual of highest ability  $a_N = 1$ . We normalize the before-productivity-shock rural wage  $w^R$  to 1. We set the informal residency penalty on productivity  $\kappa$  equal to .2, consistently with Field (2007). We choose a value of 3 for  $\sigma$ . In developed economies for which state-ofthe-art studies control for sorting according to ability, an increase in city size of 10 percent causes productivity to increase by between .3 and .8 percent (Duranton, 2009). We thus choose a benchmark value of  $\gamma$  of 11, which yields productivity increases of .4 to .7 percent depending on city size.<sup>29</sup> We choose a value of .2 for the rural wage elasticity to adverse shocks,  $\eta$ , based on Jayachandran (2006) who estimated an rural wage elasticity of 17 percent to a weather shock. Wet set the probability of adverse income shock in rural area,  $\pi^P$ , to .3 based on Damberg and AghaKouchak (2013), who report 12 episodes between 1979 and 2013 where more than 20 percent of the land in the Southern Hemisphere was under moderate to severe drought. This corresponds to a drought every three years or a yearly probability of a drought of approximately  $1/3.^{30}$ 

As regards the congestion cost parameters, we choose a value of 1 for b and .3 for  $\delta$ . These numbers are based on the average of Kahn (2010) estimates, who reports city-size elasticities of .14, .25 and .49 for commute times, carbon monoxide pollution and for violent crime respectively. Our choice of  $\lambda$  is based on Malpezzi (1999), who reports a median housing price-to-income ratio in 133 US MSAs of 4.5. Assuming that land represent two-thirds of total housing costs and considering that our period is 10 years, this leaves us with a value of .3.

For the formalization cost parameter,  $\mu$ , we choose a value of .3. There is a wide variety of situations in terms of formalization contexts, with costs ranging from a few percentages of land value to up to 100 percent or more of the value of the land (see Durand-Lasserve et al., 2015). For  $\pi^G$  we assume a value of .1 which is consistent with the high prevalence of conflicts in the cities of developing countries.

<sup>&</sup>lt;sup>29</sup>In our model, wage elasticity with respect to urban labor force size is  $\frac{L}{\gamma \cdot (1+L)}$ . Since L is comprised between 1 and 5, a value of  $\gamma$  comprised between 10.4 and 16.6 ensures that wage elasticities are comprised between 0.03 and 0.08 in any state of the economy.

 $<sup>^{30}</sup>$ .3 is a conservative estimate as other shocks affecting incomes such as conflicts, natural disasters or health crises can also occur (see Zceleczky and Yosef, 2014).

Parameter	Description	Value
Ι	Number of economic agents	5
$a_i$	Agents' ability	$\{0.2, 0.4, 0.6, 0.8, 1\}$
$\kappa$	Informal residency productivity penalty	0.2
$\sigma$	Agglomeration scaling factor	3
$\gamma$	Income effect of agglomeration	5, 11, 100
$\eta$	Rural wage elasticity of adverse shocks	0.2
b	Congestion scaling factor	1
$\delta$	Congestion elasticity of agglomeration	0.3
$\lambda$	Land price to rent ratio	0.3
$\mu$	Cost of land tenure formalization	0.3,  0.9
$\pi^P$	Probability of adverse shock in rural area	0.3
$\pi^G$	Probability of land grab attempt / eviction enforcement	0.05,0.1,0.5
$\alpha$	Risk aversion parameter	2
β	Discount rate (10 year period)	0.86

Table 1: Parameter Values of Calibrated Model

We set the value of the risk aversion parameter,  $\alpha$ , to 2, which is consistent with reported estimates in the meta-analysis conducted by Havranek et al. (2015). We use an annual discount rate of .985, which is consistent with the number adopted by long run dynamic computational forward-looking economic models, e.g., Nordhaus' DICE model (Nordhaus, 2008). Given that a period spans over 10 years in our model, this translates to (.985)<sup>10</sup> = .86.

Given a significant range of heterogeneity for some model parameters, we conduct a sensitivity analysis to demonstrate the model's robustness to chosen parameter values. Specifically, we analyze our results' sensitivity to variations in following model parameters: (a) income effect of agglomeration,  $\gamma$ , of 5 (high agglomeration potential) and 100 (low agglomeration potential); (b) cost of land tenure formalization,  $\mu$ , of .9 (high formalization cost); and (c) probability of land "grab",  $\pi^{G}$  of .05 (low chance of eviction) and .5 (high chance of eviction).

### 5 Simulation Results

We solve equations (17) and (19) as explained in section 3 for a set of parameter values described in section 4 to obtain the value functions that can be used to infer stationary states and corresponding optimal decision rules. We then simulate dynamic urbanization paths corresponding to the social optimum and the Markov perfect equilibrium based on the realization of randomly drawn shocks  $\epsilon_t^P$  and  $\epsilon_t^{G,i}$ .

Figure 4 illustrates one of such simulated paths that corresponds to solving for a Markov-perfect equilibrium under a low formalization cost, low agglomeration potential and low risk of eviction. For all simulations we start with an empty set of the city with no residents.<sup>31</sup> We see that

<sup>&</sup>lt;sup>31</sup>We have also run simulations for an alternative assumption of one, the most productive, informal urban



Figure 4: Example of Urbanization Path, Markov-perfect Equilibrium

Note. Simulated path assumes the following parameter values:  $\gamma = 100, \mu = 0.3, \pi^G = 0.05$ .

in the second period the most productive agent moves into the city, and stays informal. Next period, this agent faces an increase in wage income and purchases a title for his plot. In period 4, another, less productive, agent moves into the city, and chooses to stay informal. The wage incomes of both agents 4 and 5 increase thanks to the agglomeration effect and agent 4 chooses to formalize. The stationary state is obtained in period 5 as agents 1, 2, and 3 do not find it optimal to move into the city as the agglomeration potential is low. In this stationary state the urbanization rate is 40 percent and the rate of informality is 0 percent (all urban residents eventually choose to formalize their land plots). We can also see that welfare (defined as the sum of agent's discounted utilities  $\sum V^i$  in the stationary state and normalized to 100 in period 1 for illustration purposes) increases as agents move in the city and become formal. This result is consistent with earlier theoretical and empirical evidence of the welfare improving aspects of urbanization (Bertinelli and Black 2004) and secure property rights (Feder and Feeny 1991).

While Figure 4 is illustrative of the urbanization dynamics in our model, it is not generalizable as each simulation path results in a different stationary state given initial states and the history of productivity and land grab shocks. To obtain generalizable results, we simulate dynamic urbanization and formalization paths 100,000 times for each initial state and parameter values,

resident in the initial state. The results were very similar.

and calculate the expected urbanization and land formality rates.

Figures 5 and 6 show expected urbanization and land formality rates that correspond to the simulated Markov-perfect stationary equilibria (panel a) and social optima (panel b).<sup>32</sup> Figure 5 illustrates the variations in urbanization and land formality outcomes given different sizes of agglomeration potential and probabilities of land eviction when the land formalization cost is low ( $\mu = 0.3$ ). Figure 6 shows the same simulation results when the land formalization cost is high ( $\mu = 0.9$ ).

Beginning with Figure 5 (panel a), we see that when agglomeration potential is high and eviction probabilities are low to moderate, the Markov-perfect stationary equilibria is consistent with an expected urbanization rate of 60 percent. When the agglomeration potential is low or moderate and eviction probabilities are high, the expected urbanization rate declines to 40 percent. Figure 6 (panel a), shows a similar pattern. These results lead to the following proposition:

Proposition 1a: The urbanization rate in the Markov-perfect stationary equilibrium increases when (a) eviction enforcement is weak, and (b) agglomeration potential is high.

The underlying intuition behind Proposition 1a is as follows. The urbanization dynamics in our model are driven by the realized benefits of moving to the city. Agents with lower abilities can only find it individually optimal to move to the city when agglomeration potential is high enough to compensate for the urban rent and congestion costs. Even in these situations the decision to move to the city is not warranted. As their income is not sufficient to pay for formalization costs, agents choose to stay informal for some time before they can afford paying for land titles. When the probability of land eviction is high, low productive and risk-averse agents will find it suboptimal to move to the city.

Now, let us turn to Figure 5 (panel b), which represents simulated results for the social optimum, and let us compare these results to those from panel (a). We see that irrespective of variations in model parameters, the expected urbanization rate is 60 percent. The expected urbanization rates are the same for the social optimum and the Markov-perfect stationary equilibrium when agglomeration potential is high and eviction probabilities are low to moderate. The expected urbanization rates are, however, higher for the social optimum that for the Markov-perfect stationary equilibrium for low or moderate agglomeration potential and high eviction probabilities. A similar pattern is observed when we compare panels (a) and (b) of Figure 6, although the expected urbanization rate of 60 percent is not always sustained when land tenure formalization costs are higher. These results lead to the following proposition:

Proposition 1b: The urbanization rate under the Markov-perfect stationary equilibrium is lower than in the social optimum when (a) agglomeration potential is low, and (b) eviction enforcement is strong.

 $<sup>^{32}</sup>$ The numerical values of expected urbanization and land formalization rates that correspond to the model simulations are shown in appendix Table A.1.



### Figure 5: Expected Urbanization and Informality Rates, $\mu=0.3$

(a) Markov Perfect Equilibrium

Note. Shaded areas correspond to the share of informal residents.



Figure 6: Expected Urbanization and Informality Rates,  $\mu=0.9$ 

(a) Markov Perfect Equilibrium

Agglomeration Potential, 1/y

Probability of land grab,  $\pi^{g}$ 

Note. Shaded areas correspond to the share of informal residents.

To understand the logic behind Proposition 1b, it is important to recall the important distinction between the allocation of urban residents under the social optimum and the Markov-perfect equilibrium. In the Markov-perfect equilibrium, all agents move sequentially and make their land formalization decisions simultaneously. In the social optimum all decisions are made by the joint welfare-maximizing social planner, who has discretion over the timing of individuals moving into the city. The social planner may then choose to move less productive agents into the city first and allow them to obtain land titles before they can be evicted by more productive agents entering the city. Proposition 1b makes an important claim that the path of urbanization itself matters for final urbanization outcomes - an issue completely overlooked in static models of urbanization.

Combining propositions 1a and 1b yields the following corollary:

Corollary 1: In cities that have low agglomeration potential and strong eviction enforcement, the urbanization rate is low and lower than the social optimum.

This finding resonates well with the observed over-enforcement of evictions in the developing countries. The model suggests that, in some contexts, local governments may have done more harm than good by checking migration to cities through eviction of informal settlements (see Lall et al., 2006, on the causes of over-restrictive internal migration policies and Durand-Lasserve and Selod, 2009, on eviction policies). Over-enforcement of evictions may have caused some cities to be undersized (i.e., overlooking the potential benefits of further agglomeration) in a way that is similar to the enforcement of migration restrictions (see Au and Henderson, 2006, on the case of Chinese cities).

The next important issue to investigate is that of land tenure formalization. We see from Figure 5 (panel a) that when land tenure formalization costs are low, all agents that choose to move to the city also choose to formalize. This does not always happen when formalization costs are high. Figure 6 shows that informal residency can be sustained in the Markov-perfect stationary equilibrium when the eviction probability is low. If the city exhibits medium to high agglomeration potential, the observed informality rate is two-thirds. When the city's agglomeration potential is low, all residents are informal. These observations constitute the basis for the next proposition:

Proposition 2a: Informality can be sustained in the long run in the Markov-perfect stationary equilibrium. Informality is all the more likely to prevail as formalization costs are higher, eviction enforcement is weak, and agglomeration potential is low. For low land formalization costs, informality is resorbed.

The underlying explanation for Proposition 2a is fairly straightforward. Agents' decisions to formalize are determined by the difference between the expected marginal benefits of avoided eviction and potential gains from evicting other informal residents, and the realized marginal cost of formalizing land tenure. As the probability of land eviction declines, the latter effect tends to dominate and no one formalizes. When the city's agglomeration potential is low, the city is smaller (Proposition 1a), and the expected gain from evicting other informal residents diminishes. This, in turn, leads to an even higher share of informal residents in the city.

Figure 5 (panel b) shows that even when formalization costs are low, informality is desirable in the social optimum when both the city's agglomeration potential and the probability of eviction are low. In this case, the resulting urbanization rate (59 percent) is higher compared to that observed in the Markov-perfect equilibrium (40 percent). We observe a similar phenomenon when the formalization cost is high. Figure 6 (panel b) shows that for low to medium values of the city's agglomeration potential and the eviction probability, informality is more prevalent under the social optimum, and the expected urbanization rate is higher (56 percent) compared to that observed in the Markov-perfect equilibrium (40 percent). This finding leads to the following proposition:

### Proposition 2b: The social optimum does not necessarily require a fully formal city.

To understand this proposition it is important to point out that our model considers an utilitarian social optimum defined as the discounted sum of of expected utilities of all economic agents. Under this utilitarian social optimum, the social planner may choose to relocate an individual to the city even if it is individually optimal for that agent not to migrate into the city. In this case, the social planner's choice is driven by the positive agglomeration externalities this agent imposes on other city residents. If the expected utility gain from agglomeration externalities for other city residents exceeds the utility loss for that individual, the social planner will find it optimal to relocate the agent to the city. However, in view of the high formalization costs, the social planner may not find it optimal to require that individual to formalize, leading to greater informality.

$\gamma$	$\mu$	$\pi^G$	$V^1$	$V^2$	$V^3$	$V^4$	$V^5$	$\sum V^i$	$V^s$
5	0.3	0.05	-7.38	-7.38	-2.93	-1.92	-1.43	-21.04	-21.04
5	0.3	0.1	-7.38	-7.38	-2.93	-1.92	-1.43	-21.04	-21.04
5	0.3	0.5	-7.38	-7.38	-2.93	-1.92	-1.43	-21.04	-21.04
5	0.9	0.05	-7.38	-7.38	-3.41	-2.09	-1.44	-21.70	-21.50
5	0.9	0.1	-7.38	-7.38	-2.93	-1.92	-1.43	-21.04	-21.04
5	0.9	0.5	-7.38	-7.38	-7.38	-1.94	-1.45	-25.54	-21.04
11	0.3	0.05	-7.38	-7.38	-3.64	-2.32	-1.70	-22.42	-22.42
11	0.3	0.1	-7.38	-7.38	-3.64	-2.32	-1.70	-22.42	-22.42
11	0.3	0.5	-7.38	-7.38	-7.38	-2.26	-1.68	-26.08	-22.42
11	0.9	0.05	-7.38	-7.38	-4.31	-2.49	-1.69	-23.25	-23.16
11	0.9	0.1	-7.38	-7.38	-3.64	-2.32	-1.70	-22.42	-22.42
11	0.9	0.5	-7.38	-7.38	-7.38	-2.26	-1.68	-26.08	-24.25
100	0.3	0.05	-7.38	-7.38	-7.38	-2.54	-1.87	-26.55	-23.77
100	0.3	0.1	-7.38	-7.38	-7.38	-2.54	-1.87	-26.55	-23.73
100	0.3	0.5	-7.38	-7.38	-7.38	-2.54	-1.87	-26.55	-23.73
100	0.9	0.05	-7.38	-7.38	-7.38	-2.70	-1.96	-26.81	-24.35
100	0.9	0.1	-7.38	-7.38	-7.38	-2.54	-1.87	-26.55	-24.08
100	0.9	0.5	-7.38	-7.38	-7.38	-2.54	-1.87	-26.55	-25.85

Table 2: Simulated Value Functions

Once we have established how urbanization and informality rates respond to the model parameters under different Markov-perfect equilibria and social optima, we can turn our attention to the welfare analysis. Table 2 shows the values of the simulated value functions of the five economic agents under Markov-perfect equilibria (columns 4-8), the sum of their value functions (column 9), and the value function corresponding to the social optimum (column 10). We see from Table 2 that the sum of agents' utilities is highest in cities with the highest agglomeration potential ( $\gamma = 5$ ) and the lowest formalization cost ( $\mu = 0.3$ ) irrespective of the values of the eviction probability. In this case the sum of agents' expected utilities is the same as the expected sum of utilities, which implies that the Markov-perfect equilibria are also the social optima. This result leads to the following proposition:

Proposition 3: Simulated Markov-perfect stationary equilibria Pareto dominate other equilibria and are socially optimal under (a) high agglomeration potential and (b) low formalization costs.

Proposition 3 implies that the equilibria observed in developed countries, where the agglomeration potential is high and formalization costs are low, are likely to be socially optimal. Urbanization can thus be left to the market when the parameters of the economy are favorable. The proposition also highlights that in the absence of effective policies to improve those parameters in developing countries (e.g., making formalization more affordable), urbanization will likely be inefficient. Careful examination of Table 2 shows that other equilibria may not be ranked unanimously as economic agents rank them differently. The expected agents' utilities are non-monotonous functions of (a) agglomeration potential, (b) eviction enforcement and (c) formalization costs. More productive agents that choose to reside in the city may face a trade-off between maximizing their wages (which depend on the city's agglomeration potential and agent's abilities) and increasing their gains from potential land grabs of informal residents' land plots as these two effects may or may not go in the same direction.

To further elaborate on this point, consider a city with medium agglomeration potential ( $\gamma = 11$ ). We can see from Table 2 that, regardless of formalization costs, the social optimum is reached for low to medium probabilities of eviction. Strict eviction enforcement deters in-migration of less productive agents who cannot afford to pay for land tenure formalization before they can establish themselves in the city. However, by looking at individual payoffs under different land eviction regimes, we see that more productive agents (4 and 5) achieve higher levels of expected utility when the eviction probability is high. For these agents, the marginal costs exceed the marginal gains of having an additional agent migrate to the city. As these agents are likely to be economic and political elites that establish themselves earlier in the city, their preferred eviction regime may not necessarily reflect the socially optimal outcome. These observations combined yield the following proposition:

Proposition 4: Strict eviction policies can be welfare reducing. It can be in the interest of the society but not necessarily in the interest of city elites to accept some level of informality.

In line with Corollary 1, our model provides a theoretical insight into the political economy of over-eviction policies. Although evictions remain widespread in many developing countries, it is interesting to note that some countries have moved away from strictly enforced evictions and modified their legal frameworks to provide protection against eviction (Durand-Lasserve 2007). Proposition 4 suggests that more democratic contexts are favorable to such changes.

### 6 Conclusion

We analyze the interplay between urbanization and evolution of land property rights, two features of economic development that interact in a very important way. Understanding this interaction is crucial for developing countries as dysfunctional urban land property rights systems continue to prevail in many parts of the developing world, and their implications for the path of urbanization in the long run are not well understood. The model we develop provides a novel analytical framework to study this issue. It is a dynamic stochastic model of a representative city that jointly determines urbanization and evolution of land property rights. Each period, heterogeneous households decide whether to live in the city or in a rural area, and whether to pay for land property rights that will protect them from future eviction attempts. Holders of informal plots are randomly exposed to land seizure by other city dwellers, and seized plots can be resold on the land market. Population movements in and out of the city are thus affected both by land grabbing and productivity shocks. Agglomeration and congestion effects are endogenous to migration, affecting wages and land prices.

Our main result is that land property rights institutions, which are very difficult to reform, have a significant effect on the dynamics of urbanization in the long run. Contrary to the developed world experience, leaving urbanization to the market may be suboptimal because of the constraints imposed by dysfunctional property rights systems in developing countries. We also demonstrate that, under certain conditions, informality can be socially optimal, as it makes it possible for low-income residents to contribute to the urban economy. In these situations, strict urban eviction policies can be welfare reducing.

It is important to note that our major insights are conditional on structural fundamentals of prevailing land property rights systems. While our approach is justified given the persistence of land property rights institutions and apparent difficulties in reforming them, our comparative dynamics provides further insights into the political economy of changing land property rights systems. In future research it would be interesting to understand how the parameters of land property rights systems themselves evolve endogenously with urbanization and possibly shed light on the "institutional trap" that seems to be plaguing much of the developing world.

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## Appendix

Parameters			Social Optimum		MPE	
$\gamma$	$\mu$	$\pi^G$	$x^u$	$x^f$	$x^u$	$x^f$
5	0.3	0.05	0.6	0.6	0.6	0.6
5	0.3	0.1	0.6	0.6	0.6	0.6
5	0.3	0.5	0.6	0.6	0.6	0.6
5	0.9	0.05	0.59	0.4	0.58	0.2
5	0.9	0.1	0.6	0.6	0.6	0.6
5	0.9	0.5	0.6	0.6	0.4	0.4
11	0.3	0.05	0.6	0.6	0.6	0.6
11	0.3	0.1	0.6	0.6	0.6	0.6
11	0.3	0.5	0.6	0.6	0.4	0.4
11	0.9	0.05	0.56	0	0.58	0.2
11	0.9	0.1	0.6	0.6	0.6	0.6
11	0.9	0.5	0.5	0.5	0.4	0.4
100	0.3	0.05	0.59	0.4	0.4	0.4
100	0.3	0.1	0.6	0.6	0.4	0.4
100	0.3	0.5	0.6	0.6	0.4	0.4
100	0.9	0.05	0.56	0	0.38	0
100	0.9	0.1	0.56	0.2	0.4	0.4
100	0.9	0.5	0.45	0.45	0.4	0.4

Table A.1: Expected Urbanization and Informality Rates

Note. MPE corresponds to Markov-perfect stationary equilibrium.