Informal Settlements and Urban Development*
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Abstract. This paper examines how informal settlements affect urban land use patterns. Whether formed by squatters or consensual illegal conveyances, informal settlements are most likely to persist in fringe locations with low expected future formal sector land rents. Using a unique dataset from Cochabamba, Bolivia, we test whether observed land use patterns are consistent with the model. The results are consistent with the predicted effects of ownership risk. Informal settlements tend to arise closer to the urban fringe. Development densities are greatest for squatter settlements, less for other informal settlements, and least for residential development undertaken in the formal sector.

Keywords: Squatters, informal settlements, slums, property rights

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1. Introduction

Ninety eight percent of the urban population growth in sub-Saharan Africa over the past 15 years took place in slums. Slums also accounted for 60% of the urban population growth in Latin America and 76% in southern Asia.[1] This pervasive growth in slum communities emphasizes the need to better understand the slum formation process and its effects on urban development, social inclusion and poverty.

This paper examines the impact of an informal urban housing sector on urban land development. Most slums in developing countries originate as illegal settlements, established through squatting or consensual informal sales. Informal transactions and squatting, however, give rise to differing land title quality and ownership risk for occupants. Differences in title quality, especially when land is not formally conveyed, can have profound effects on economic development in general (Alchian and Demsetz 1973, Alston, et al. 1996, Besley 1995, Bohn and Deacon 2000, De Soto 2000) and urban development in particular (Miceli, et al. 2003, Turnbull 2008). The question addressed here is whether observed land use patterns are consistent with the patterns implied by ownership risk.

Although the literature on informal property markets is large and varied, there has been to date no formal empirical test of the predicted ties between the initial legality of an urban settlement and the subsequent land use and property value. As a result, the nature of the squatting-urban development nexus remains an open empirical question. In order to begin filling this gap in the literature, this paper uses block level data for Cochabamba, Bolivia, to examine the squatting-land use relationships implied by theory. Cochabamba embraces a variety of informal settlements (both nonconsensual squatting and illegal consensual sales) as well as a range of current legal status, and therefore offers a particularly useful case for empirical study.

The discussion is organized as follows. The second section briefly reviews the relevant literature. The third section presents a stylized model tying current land use patterns and land values to the ownership regime at the time of settlement. The fourth

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[1] Obtained using the “Millennium Development Goals Indicators” official data of 108 middle and low income countries.

section of the paper describes the history of informal settlement in Cochabamba, Bolivia, the subject of our empirical study. The fifth section presents the data, empirical model, and empirical estimates. The final section concludes.

2. Squatting and Urban Development

The property rights-urban land development nexus has been the focus of growing attention in the field of urban economics in recent years. Part of this literature concentrates on the dynamic effects of insecure property rights arising from public sources like land use regulations and takings by governments, or private sources like squatters and adverse possession.[2] In this view ownership risks arising from private sources (like squatters) tend to hasten the pace of land development at the city level more than ownership risks arising from government regulatory takings to the extent that private source risks affect all land in an urban area while government policies typically target a narrower range of plots. Ownership risk arising from private sources also affects developers' choices of structural density. Whether it leads to higher or lower structural density depends on the relative growth in the demands for alternative land uses over time; greater ownership risk increases (decreases) structural density when the demand for land uses with greater structural density is growing more slowly (more rapidly) than the demand for land uses with less structural density over time.

One broader implication is that, ceteris paribus, locales with disorganized or corrupt titling systems and/or where squatting is pervasive will have less undeveloped land remaining in the urban interior than comparable cities with secure property rights. When applied to ownership risk from private sources, these models are useful for comparisons across different urban areas but they may not be as useful for empirical studies of land development patterns within a single urban area.[3] In any case, at the

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[2] See Turnbull (2005) for an overview of this literature.

[3] This is because the literature has not yet identified how (or whether) these ownership risks might vary across locations within a particular urban area. Note that this is not necessarily true for ownership risk arising from public regulation when different regulations target specific parts of the urban area.

moment there are no empirical tests of models explaining the effects of squatter settlements on urban land use patterns.[4]

Jimenez (1985) offers another approach, focusing directly on the behavior of organized squatter communities invading government owned lands. In his model, the squatter community decides on the number of squatters to settle as a community. Additional members in the squatting community increase government's costs of land clearing and therefore decrease the probability of eviction. At the same time, however, additional members in the squatting community increase the cost of providing public services and property upgrading once the community is settled. Jimenez (1985) concludes that, greater government efforts to reduce squatter settlements will actually result in more populated squatter communities.

A third type of model that appears in the urban economics literature concerning urban development and squatter settlements views the squatting process as an interaction between unorganized squatters or organized squatter communities and private landowners in the dynamic context of a two-period environment (Jimenez and Hoy 1991, Turnbull 2008). The landowner holds undeveloped land in the first period, land that has an expected future value once it is developed for the formal sector in the second period. The greater the future expected value of the land, the more resources the owner will expend to secure eviction when he is ready to develop it. The squatters, however, invade the land in the first period while taking into account that the landowner may evict them in the second period. The squatters' investments in housing capital therefore reflect their anticipation of the likelihood of future eviction by the landowner.

Jimenez and Hoy (1991) model assume that squatters respond to the eviction plans announced by the landowner in the first period, regardless of whether or not the announced strategy represents a credible threat by the landowner. In this setting, the landowner's inability to legally collect rent from squatters prompts more frequent eviction than is efficient. Because squatters' housing demands are negatively related to the perceived probability of eviction, the inefficiently frequent eviction by the landowner leads to lower than efficient levels of investment in housing by squatters. Turnbull

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[4] Miceli, et al. (2002) study the effects of private source ownership risk from encroachment, conveyance errors, and fraud on property values in Chicago. As such, it does not address the level of ownership risk commonly associated with squatting or other forms of illegal settlement.

(2008), on the other hand, assumes that squatters will believe the landowner's eviction threat only if it is credible, that is, only if the owner's benefits from evicting the squatters in the second period exceed the costs. Excluding the possibility of non-credible threats by the landowner in the first period of the model leads to fundamentally different conclusions. In this case squatters have an incentive to over-invest in housing capital, making it more costly for the landowner to implement the eviction strategy. This leads to greater than efficient structural densities in squatter settlements.

Nonetheless, Jimenez (1985) and Turnbull (2008) both predict that the density of a squatter settlement is related to the vigor of the landowner's eviction strategy, whether the owner is a private party or government. These predictions, however, have not been tested empirically. The empirical question of whether squatter settlements present greater structural densities than comparable non-squatter settlements remains unsettled. In order to answer this question empirically, the next section introduces a key missing element in the Turnbull (2008) model—the spatial component in the demand for land in the formal sector—in order to facilitate the empirical implementation of the framework.[5]

3. The Model

A. The squatting model

The Turnbull (2008) two-period model assumes a representative squatter who makes the decision on how much capital, h, to invest on a single plot of land owned by the landlord. The landlord then decides whether to develop the land for formal sector use in taking into consideration the capital investment made by the squatter in the first period. Her decision takes into account the value of the developed land in the formal property market, $V(s)$, where the state of the formal property market is indexed by s with $V_s > 0$. The index s is distributed over [0,1] with a cumulative density F.

Before developing the land for the formal land market, the landowner must first evict the squatter and clear the structures h from the land at the cost $C(h)$ where $C_h > 0$. The landowner will develop the land in the formal land market only if the present value of the net rent in the realized state is greater than or equal to the cost of clearing the land:

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[5] See the recent working paper by Brueckner and Selod (2008) for an alternative approach to that taken here.

$V(s) \geq C(h)$. The land owner evicts the squatters and develops the land for formal sector use whenever the realized state of demand, s, in the formal land market is greater than the critical value θ satisfying

$$V(\theta) = C(h) \qquad (1)$$

Thus, the landowner's credible eviction strategy is summarized by θ implicitly defined by (1). Solving (1) implicitly yields the owner's reaction function

$$\theta = \varphi(h) \qquad (2)$$

The representative squatter knows the landowner's eviction policy at the outset and includes it in his decision as a probability of eviction given by the function

$$\pi(\theta) = \int_{\theta}^{1} dF(s) \qquad (3)$$

To find the squatter's best response to the landowner's credible strategy, maximize his utility $u(x,h)$—a function of housing capital h and non-housing consuming goods x—subject to the budget constraint

$$I = px + rh \qquad (4)$$

where I is monetary income, and r and p represent the prices of capital and non-housing goods respectively. Eviction occurs (if at all) after the squatter has invested in housing capital h. If the squatter is evicted he enjoys the opportunity utility $u(x,0)$ and if the squatter is not evicted he enjoys utility $u(x,h)$. The squatter's best response to the landowner's eviction policy is to maximize expected utility

$$Eu = [1 - \pi(\theta)]\, u(x,h) + \pi(\theta)\, u(x,0) \qquad (5)$$

subject to (4). Doing so, the squatter's optimal strategy conditional on the landowner's behavior can be expressed as the implicit solution to the appropriate necessary conditions as

$$h = \psi(\theta, I, p, r) \qquad (6)$$

where it can be shown that income normality or neutrality ($\psi_I \geq 0$) ensure $\psi_\theta > 0$.

The squatter's optimal level of housing capital and the landowner's critical demand state for eviction are strategic complements. Therefore, the private market equilibrium is given by the Nash solution $\{\theta^*, h^*\}$ satisfying (2) and (6) and the usual stability conditions.

B. The intra-urban spatial component

Squatter settlements are mostly an urban phenomenon; yet, the models surveyed earlier explain squatting behavior and urban development without an explicit spatial element. The model described above is easily modified to introduce a spatial component to better understand the manner in which squatter settlements shape urban areas.

In the canonical monocentric urban land market model land located near the central business district (CBD) garners higher rents in the formal sector than land located at the periphery. Assuming that residents employed in the formal sector in the city commute to the central business district (CBD), bid rents hence land value decreases with distance k from the CBD, approaching the agricultural land rent at the city limit. Thus, k enters the land owner's net return function increasing the demand for developed property as a shift parameter that varies with distance from the CBD, $V(s,k)$ where $V_k < 0$. The equilibrium critical value θ^* satisfying (2) and (6) is now an increasing function of distance k as well as the squatter's structural density h.

In order to incorporate the spatial dimension of the urban land market into the squatter's housing demand, note that, whether employed in the CBD or locally, the squatter's income net of commuting costs generally declines with greater distance. Replacing income I in (6) with net income net $I(k)$ where $I_k < 0$ suitably modifies the squatter's modified housing demand.[6]

As demonstrated in the appendix, totally differentiating (2) and (6) and solving for the comparative static predictions in the usual manner implies that the equilibrium θ^* generally increases while the equilibrium h^* generally decreases with greater distance from the CBD. Intuitively, greater distance from the CBD decreases the demand for developed land in the formal sector and therefore diminishes the range of second period demand states that make clearing the land of squatters worthwhile to the landowner. The resultant increase in the critical value θ^* with greater distance reduces the range of states in which land will be formally developed, so we expect to empirically observe that *squatting will be more likely to persist closer to the city fringe than near the CBD*.

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[6] The squatters are employed in the informal sector. If some are employed in the CBD while others are employed locally and so do not have to commute then the local employment income will be the same as the CBD employment income net of commuting cost. See, e.g., Muth (1969, 42-45) or Turnbull (1995, 26-27).

Regarding structural density, whether employed in the CBD or locally, when income net of commuting costs declines with distance, the squatter's demand for housing capital declines as well. While the less vigorous eviction policy increases the demand for housing, the first effect tends to dominate so that we expect empirically observe that *the equilibrium structural density in squatter developments to declines with distance*.

C. Illegal subdivisions

Squatting is one option that is open to poor urban residents. Another common strategy found in Latin America is that of urbanizing land despite prohibition by municipal land development regulations (Abramo 2003). This practice of illegal land subdivision is commonly referred to as loteos in Latin America, where land owners of agricultural land (usually with the help of professional loteadores) divide their land and informally sell it as developable land to individuals or communities who then construct their own dwellings on these plots.

Turnbull (2008) also presents a model of an informal land market, interpreted here as the market for illegal subdivisions or loteos. The key difference between the informal market and the squatting situation is that the landowner can collect rent, R, from the informal settlers occupying the land in question in the former while no rent is collected in the latter. This is an informal transaction, that is, the transaction is not recognized under law. Therefore, the landlord remains free to clear the land in the second period and develop it for the formal sector if the gains from doing so exceed the costs, in forgone informal rent plus the clearing cost. Preserving the notation, the landowner's decision rule to develop in the formal sector is now given by:

$$V(\theta) - C(h) \geq R \qquad (7)$$

which yields a new optimal strategy function for the landowner:

$$\theta = \tilde{\varphi}(h,R) \qquad (8)$$

The informal settler's expected utility function remains the same as in the squatter's case (4), except that now the expected utility function is maximized subject to budget constraint (9) that includes the payment R in the first period:

$$I = px + rh + R \qquad (9)$$

The necessary conditions for the informal settler's problem lead to a new housing demand function

$$h = \tilde{\psi}(p, r, I, R) \qquad (10)$$

The Nash equilibrium for the informal land market $\{\tilde{h}, \tilde{\theta}, \tilde{R}\}$ can be compared with the equilibrium $\{\theta^*, h^*\}$ for the squatter case. In general, the rent R entering the landowner's function in the illegal subdivision case increases the legal land owner's opportunity cost of developing the land for the formal sector. In other words, it reduces the range of demand states for which it would be profitable to clear the land and develop it for the formal sector. On the settler's side, the extra payment R reduces his equilibrium utility level and therefore the demand for housing capital, h. Comparing illegal subdivisions to squatting settlements, equilibrium eviction rates and structural densities are generally lower in illegal subdivisions ($\tilde{\theta} > \theta^*$ and $\tilde{h} < h^*$).[7]

The model does not make any explicit predictions about rent gradients in informal settlements beyond what we expect from location equilibrium. It does, however, make predictions about density gradients. The previous result is straightforward: illegal subdivision generally leads to a lower density than does squatting. But more can be said. Because formal sector land rents tend to decline with distance from the CBD, structural density in the formal sector similarly declines with distance from the CBD. But what do we observe in an informal market comprising both squatters and illegal subdivisions? Informal market participants make decisions under the same economic incentives as their formal sector counterparts. Thus, sites near employment centers or amenities will tend to be more highly valued than locations not so fortunately situated. So, it is not surprising that we will observe negative rent and density gradients in informal settlements, too.

This yields a pattern of urban land use according to legal status of the original settlement. Refer to the linear city in figure 1. The density curves for the informal sector (squatters and illegal subdivisions) lie above the corresponding formal sector density curve for equivalent distances from the CBD, as depicted for the outlying locations in the figure (recall that informal land development is more likely in the outlying locations than closer to the CBD). The figure depicts steeper density gradients for the informal sector

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[7] There may be cases in which the informal subdivision development will exhibit higher eviction rates or greater housing capital than comparable squatter developments, but never both at the same time (Turnbull 2008, 12-13).

than in the formal market. We expect the density gradients to differ across sectors in part because, even though proximity to the CBD increases structural density in both sectors through the usual commuting cost trade-offs, the change in eviction probability with CBD proximity in the informal sector has an additional effect on the capital/land ratio. In figure 1, formal sector development takes place nearest the CBD, informal subdivisions occupy the city from k_a to k_b and squatters occupy the city from k_b to the city limit k_c.

D. Community squatting

The model above focuses on a representative squatter and an individual landowner and is meant to depict situations in the population of atomistic individualistic squatters confront landowners. There are, however, cases in which squatters organize as communities with governing committees that present a coordinated united front when interacting with landowners. The Jimenez (1985) model describes the behavior of a squatter community invading public lands. Recall that the community's problem in this model is to determine the optimal number of squatters. Additional squatters lower the probability of eviction as they increase the costs of land clearing the landowner faces (there is a community level decision on the settlement's structural density). But additional members in the community also increase the costs of future public service provision and property upgrading once the community is settled. The formal model used above does not include the infrastructure and community service complications arising from community squatting, but it arrives at the same implication regarding density.

4. Land Settlement in Cochabamba

The city of Cochabamba was founded in 1574 as a center of food production and shipment for the booming colonial mining industry in what is today the western part of Bolivia. Situated at 8,360 feet (2,550 meters) above sea level on the fertile lands of the low valley region of the state of Cochabamba, the city is currently the third largest in the country.

Referring to table 1, Cochabamba's first significant urban expansion occurred during 1900-1950 as the city began accommodating a large wave of rural migrants. This rapid growth prompted the local government to institute a comprehensive plan to regulate the pace of development. By 1946, municipal authorities responded with a plan to regulate development over the next 50 years (Goldstein 2004). But the plan could not contain the city's rapid population growth and the pressure this growth put on the land available for formal development. Thus, by 1951 the city experienced its first wave of squatters on land in the south-eastern part of the city. Municipal authorities responded with forceful evictions, but the squatter settlements persisted. Soon, other land invasions took place in other parts of the city with varying degrees of success. Between 1945 and 1976, about 10 percent of the land being developed in Cochabamba was occupied by illegal means either through land invasions or illegal subdivision of rural land.

The central government and its housing ministry tried to ease the city's housing problem by enacting public programs providing land for the poor at affordable prices since the 1970s. These programs, however, have been highly ineffective and extremely costly due, in part, to their corrupt administration (Solares and Bustamate 1986). In most cases, these programs were reduced to simple regularization actions of previously illegally settled plots of land (Goldstein 2004).

Between 1976 and 1992 the city experienced its highest population growth rates from a second wave of rural urban migration taking place in the country as a whole. During this period, the city grew by about 2780 hectares; 30 percent of those were developed in the informal sector. Most of the illegal growth taking place in this period can be attributed to loteadores (illegal land brokers) subdividing agricultural or protected forest land and selling it against municipal regulations as urban land. The municipal government's first reaction to this practice was to bulldoze this illegal housing, but the persistence of these illegal developments made the policy costly in terms of both economic resources and political capital (Solares 1999).

To this day, illegal land subdivision remains one of the main ways that land is developed in Cochabamba. Between 1992 and 2001, about 70 percent of urban land was developed under this modality. A large portion of old illegal land subdivisions and virtually all of the squatter settlements have been legalized trough many title regularization programs over time. In 2002 a new land titling program was enacted to regularize the situation of newly created illegal settlements. Following the same lines as previous formalized title programs, the central government promised that this would be the last such effort. However, as previously, this announcement has not slowed the rapid pace of illegal growth (Farfan 2004).

Recall that the squatting theory predicts that the legal origin of a settlement affects its development pattern as settlers respond to the risk of eviction. In the case of Cochabamba, we identify different types of settlements according to their legal origin: (1) Legal settlements, which include settlements developed in accordance to all existing laws and regulations. (2) Squatter settlements, which encompass settlements that originated as land invasions by breaking the laws of property and municipal laws or land use regulations. (3) Illegal land subdivisions, which involve settlements in which the land was purchased consensually but developed in violation of municipal laws of urbanism. And (4) Government supported settlements, which constitute settlements that developed, in most cases, in violation of municipal laws but had the support of the (national) housing ministry for the land purchase.

5. Empirical Analysis

This section examines the relationship between settlement type and land use characteristics, using city blocks as the unit of analysis. The data is drawn from the 1992 and 2001 censuses collected by the Bolivian National Institute of Statistics (INE in Spanish) for the entire city. Land prices are obtained from the municipality's cadastre system, which was updated in 2002. In order to classify the settlements by legal origin, we used municipality maps reflecting the city's master plans in 1945, 1961, 1977, and 1998.[8] Table 2 presents the variables used in the empirical analysis.

A. Population and structural density models

We use several common rent and density gradient specifications to test the relationship between a settlement's legal origin and its characteristics in the year 2001. Our simplest model uses a basic negative exponential function where density follows an exponential function (Clark, 1951; Mills, 1972; Muth, 1969),

$$D = D_0 e^{-\gamma k + \beta x}$$

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[8] We are grateful for the expert advice of urban historian Professor Humberto Solares of San Simon University which was essential for classifying the city blocks according to their legal origin.

where D is a measure of density, D_0 is the density at the CBD, k distance from the CBD, and γ denotes the density gradient. The vector **x** includes other variables thought to influence population density. These variables are defined in table 2 and include distance to a major road, households' income,[9] provision of public services (measured as percentage of homes connected to a sewer system), percent of homes occupied by owner, a set of dummy variables indicating geographical orientation in the city (direction from the CBD in octants), A set of dummy variables indicating time period when the neighborhood was settled or consolidated, and a set of binary variables indicating the legal status of the block when settled. The different types of developments in the sample are formal sector development, squatter settlements, loteos (illegal subdivisions) that are still illegal, older loteos that have been since legalized, government supported subdivisions, and illegal subdivisions on protected land.[10]

To check robustness, we also consider an alternative functional form using a third degree polynomial specification (Frankena 1978)

$$D = D_0 e^{(\gamma_1 k + \gamma_2 k^2 + \gamma_3 k^3 + \beta x)}$$

while a third variant allows for different functional forms by using the flexible Box-Cox transformation (Kau and Lee 1976)

$$\frac{D(k)^{\lambda} - 1}{\lambda} = \gamma_0 + \gamma_1 k + \beta x$$

It is well known that structural density and population density are vertical translations of each other in standard urban land use theory assuming formal market transactions (Mills 1972, Muth 1969). Therefore, we use two alternative measures of development density, total population per hectare and total number of homes per hectare,

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[9] No direct income measure is available, so apply factor analysis to construct an income scale at the block level using indirect information related to living standards that is available in the census. The variables included in the analysis are: percent of households in the block that own a TV set, percent of households in the block that own a car, percent of households in the block that own a refrigerator in the kitchen, and percent of households in the block that own a telephone line. These variables yield a highly reliable index of city block income (Cronbach Alpha = .88) that explains 75 % of the combined variance of the variables used. The appendix provides additional details pertaining to the construction of this variable.

[10] We classify land development on national park (reserve) areas adjacent to the city as "Illegal subdivisions on protected land". This classification represents a special case of illegal subdivisions because it takes place on privately owned plots that can only be used as forest land in accordance to Law No. 253 enacted by The Bolivian Congress and President Paz Estensoro in November 4th, 1963. The Law did not expropriate land owned by indigenous communities. It merely restricted its use to low impact agriculture and forests.

to test whether the same relationship holds for development undertaken through squatting or informal transactions.

Tables 3 and 4 report the density gradient estimates for population density and structural density, respectively. Given the high correlation between population destiny and structural density implied by the theory the similarity between the results using these indicators is not surprising.[11] In both tables, column 1 shows the simple negative exponential specification and column 2 allows for differences in gradients across legal origin types. Column 3 shows the cubic function estimates and columns 4 and 5 present the Box- Cox transformation estimates in both tables. In the simple negative exponential specification (column 1 in both tables), all of the coefficients on legal origin binary indicators using formal development as the reference group are positive and statistically significant. This shows that development in the informal sector occurs at higher density than development in the formal sector as the theoretical model presented in the paper suggests. City blocks that had originated as squatter settlements, sometimes through violent invasions of land, exhibit greater densities than other types of informal development. On the other hand, city blocks that originated as informal subdivisions during 1976-1992, when municipal authorities passively allowed this type of development to occur, exhibit the lowest structural density compared to other types of informal development. Furthermore, the models show that there are systematic differences in density gradients across the different types of informal development as evidenced by the statistically significant coefficients on the interaction terms between the legal origin indicators and distance from CBD. Figure 2 depicts these differences in density gradients across legal status using the Box-Cox estimates. As illustrated in the figure, squatter settlements, illegal subdivisions on protected land and recent illegal subdivisions have steeper density gradients than formal sector development while government supported subdivisions and the first illegal subdivisions in the city have flatter density gradients than formal sector development. These comparisons are calculated for non-central locations (e.g., between k_1 and k_2 in figure 1), the part of the

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[11] In our sample the Pearson correlation coefficient between the population per hectare and number of houses per hectare is 0.94.

urban area where informal development is most likely to take place.[12] In this area of the city, the structural density for a given distance is most dense for squatter settlements, less dense for recent illegal subdivisions, followed by government supported subdivisions, illegal subdivisions on protected land, old illegal subdivisions and formal sector development.

B. Land price models

We also estimate land price gradients, using analogues to the density gradient models described above. Land prices are measured in 2002 US dollars per hectare. Our interest in the land price gradient is driven by the rent relationship implied by the underling density gradient and the degree to which the legal status of the settlement confers secure title to land occupiers.

The price gradient estimates in table 5 reveal some interesting results. City blocks that originated as squatter settlements tend to have lower rents and steeper rent gradients than comparable city blocks that originated in the formal sector. Given that squatter settlements were regularized and formally titled in the 1980s, this result suggests that former squatter settlements have a legacy effect of sub-optimal land use at present time. City blocks in recent illegal subdivisions and illegal subdivisions on protected land also present lower and steeper price gradients than comparable city blocks that originated in the formal sector. Since these types of settlements are not yet regularized, these lower rents may be capturing an eviction threat risk premium. Interestingly, old informal subdivisions that were regularized during the 1990s have a flatter price gradient than that of formal subdivisions. Consequently, old informal subdivisions have higher rents than comparable formal development as distance from the CBD increases. This difference may be capturing the land regulation effects in development that originated in the formal sector. This result can be observed in figure 3 which depicts the price gradient estimates from the Box -Cox estimates in column 5. In the region of the urban area between k_1 and k_2, old illegal subdivisions tend to have the highest land rents followed by legal development and government supported subdivisions, which have similar rent gradients.

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[12] In Cochabamba $k_1$and k_2 are approximately 3 and 10 km from the CBD, respectively.

Below legal development land rents lay illegal subdivisions on protected land, followed by recent illegal subdivisions and squatters, in that order.

Perhaps one of the most interesting findings is that, for settlements originated in the informal sector, structural density does not necessarily follow land prices in the way standard urban economics theory predicts. In standard urban economic theory, which ignores differences in property rights or ownership risk, land prices are positively related to structural density. Thus, sectors of the urban area where the land is relatively cheap tend to have lower structural densities than other sectors where land rents are greater. Squatter settlements, which, ceteris paribus, have lower land rent than any other type of development, also tend to exhibit the highest density. This reflects the importance of a settlement's legal origin. The legal origin determines the settlement's original occupation pattern, which in turn exhibits a legacy effect of persistent high density.

6. Conclusion

Illegal settlements constitute an important component of urban land markets in many developing countries. A large percentage of urban growth in many regions of the world takes place in the form of illegal settlements of one type or another, the bulk of which are identified as slums. The effects of this type of growth on overall urban development, however, are poorly understood. Further, the empirical literature dealing with these questions has been hampered by the limited availability of data relevant to the underlying theoretical models.

This paper applied a simple model of the squatter settlement process to investigate the spatial land use implications of illegal settlements. It also provided a new empirical look at the slum formation process using unique data from Cochabamba, Bolivia, a city with long experience with a wide variety of informal urban settlements.

The empirical results indicate, as suggested by the theory, that neighborhoods originating as squatter settlements exhibit greater density than comparable illegal subdivisions. In turn, illegal settlements of all forms exhibit greater density than comparable legal settlements. At the same time, the land rent analysis reveals that squatter settlements are not the best and highest use for the land; land rents tend to be significantly lower than rents in comparable legal settlements even long after title regularization. In the case of illegal subdivisions, land rents tend to mimic those of the legal market more closely, as expected.

The paper presents a novel empirical study of the relationship between property rights, property title quality, and urban land use in developing countries. The need to understand the future consequences of current slum formation is increasingly important as this development mode accounts for a growing proportion of new development. This is essential for effective housing and land use policy in an era in which poverty is becoming an increasingly urban phenomenon in many emerging economies. De Soto (2000) and others effectively argue that we need to understand the channels through which property rights institutions affect urban development before establishing the micro foundations for broader economic development questions. This study represents a modest step in that direction.

References

Abramo, P. (2003). *A Cidade Da Informalidade : O Desafio Das Cidades Latino-Americanas*. Rio de Janeiro, Lincoln Institute, Livraria Sette Letras, FAPERJ.

Alchian, A. and H. Demsetz (1973). "The Property Rights Paradigm." *Journal of Economic History* 33(1): 16-27.

Alston, L., G. Libecap, et al. (1996). "The Determinants and Impact of Property Rights: Land Title on the Brazilian Frontier." *Journal of Law, Economics, and Organization* 12(1): 25-61.

Besley, T. (1995). "Property Rights and Investments Incentives: Theory and Evidence from Ghana." *Journal of Political Economy* 103: 903-937.

Bohn, H. and R. J. Deacon (2000). "Ownership Risk, Investment, and the Use of Natural Resources." *American Economic Review* 90: 526-549.

Brueckner, J. K. and H. Selod (2008). A Theory of Urban Squatting and Land-Tenure Formalization in Developing Countries. *Working Paper*, http://www.socsci.uci.edu/~jkbrueck/squatting.pdf. Accessed March 2008

Clark, C. (1951). "Urban population densities." *Journal of the Royal Statistical Society* 114: 490-496.

De Soto, H.(2000). *The mystery of capital : why captitalism triumphs in the West and fails everywhere else*. New York, Basic Books.

Farfan, F. (2004). "Formal and Customary Housing Tenure Initiatives in Bolivia." *Habitat International* 28(2): 221-230.

Frankena, M. (1978). "A bias in estimating urban population density functions." *Journal of Urban Economics* 5: 35-45.

Goldstein, D. M. (2004). *The spectacular city: violence and performance in urban Bolivia*. Durham, Duke University Press.

Jimenez, E. (1985). "Urban Squatting and Community Organization in Developing Countries." *Journal of Public Economics* 27: 69-92.

Jimenez, E. and M. Hoy (1991). "Squatter's Rights and Urban Development." *Economica* 58(229): 79-92.

Kau, J. B. and C. F. Lee (1976). "The functional form in estimating the density gradient: An empirical investigation." *Journal of the American Statistical Association* 71: 326-327.

Miceli, T. J., H. Munneke, et al. (2002). "Title Systems and Land Value." *Journal of Law and Economics* 45(565-582).

Miceli, T. J., C. F. Sirmans, et al. (2003). "Land Ownership Risk and Urban Development." *Journal of Regional Science* 43: 73-54.

Mills, E. S. (1972). *Urban Economics*. Glenview, IL, Scott Foresman and Company.

Muth, R. (1969). *Cities and Housing*. Chicago, University of Chicago Press.

Solares, H. (1999). *Vivienda y Estado: Politicas Habitacionales y Produccion del Habitat Popular en America Latina*. Cochabamba, Bolivia, Editorial Serrano.

Solares, H. and Rodriguez-Ostria (1990). *Historia, Espacio, y Sociedad: Cochabamba 1550-1950: Formación, Crisis y Desarrollo de su Proceso Urbano*. Cochabamba, Centro de Investigacion y Desarrollo Regional (CIDRE).

Solares, H. and F. Bustamante, Eds. (1986). *Crisis Urbana y Barrios Populares: El Caso de Alalay, Ticiti, y Valle Hermoso*. Cochabamba, Editorial Universitaria.

Turnbull, G. K. (1995). *Urban consumer theory*. Washington, D.C. Urban Institute Press

Turnbull, G. K. (2005). "The Investment Incentive Effects of Land Use Regulations." *The Journal of Real State Finance and Economics* 31(4): 357-396.

Turnbull, G. K. (2008). "Squatting, Eviction, and Development." *Regional Science and Urban Economics* 38 (1) 1-15

Table 1 Cochabamba's Urban Growth 1574-2001

Time period	1574-1812	1812-1900	1900-1945	1945-1976	1976-1992	1992-2001
Growth in Urbanized Area (Hectares)	77	110	1,110	2,049	2,778	957
Growth in Legal Urbanized Area (Hectares)	77	110	1,110	1,870	1,956	285
% Legal Growth (Area)	100	100	100	91	70	30
Informally originated development as % of urban area	0	0	0	5	16	24

Source: National Institute of Statistics Cartographic Data 1976, 1992, 2001, Solares and Rodriguez (1990)

Table 2 Descriptive Statistics

Block's Legal Origin	**City Blocks N**	**Percent**	**Cum.**
Illegal Subdivision (protected area)	334	5.06	5.06
Squatter Settlement	304	4.61	9.67
Public Supported Subdivision	221	3.35	13.01
Illegal Subdivision (Still Illegal)	581	8.8	21.81
Illegal Subdivision (Now legal)	818	12.39	34.21
Legal	4,343	65.79	100
Consolidation Time Period (block age)	**City Blocks N**	**Percent**	**Cum.**
1574-1812	74	1.12	1.12
1812-1900	91	1.38	2.5
1900-1945	584	8.85	11.35
1945-1976	2,171	32.89	44.24
1976-1992	2,656	40.24	84.47
1992-2001	1,025	15.53	100
Octant (Origin =CBD)	**City Blocks N**	**Percent**	**Cum.**
1. N-NE	611	9.26	9.26
2. NE-E	533	8.07	17.33
3. E-SE	228	3.45	20.78
4. SE-S	1,987	30.1	50.89
5. S-SW	802	12.15	63.04
6. SW-W	431	6.53	69.57
7. W-NW	727	11.01	80.58
8. NW-N	1,282	19.42	100
Block characteristics	**City Blocks N**	**Mean**[a]	**Std. Dev**[a]**.**
Population Density (Pop/Ha)	5896	115.4	80.59
Homes Density (Homes/Ha)	5949	27.27	19.68
Land Price ($US/Sq m)	6601	79.37	74.54
Distance from the CBD (Km)	6601	4.47	2.23
Distance to a major road (m)	6601	855.56	1266.08
% Homes connected to sewer system	5880	52.65	45.14
% Homes occupied by owner	5880	54.31	21.6
Income (Factor)	5787	0	2.03

a. Calculated using the number of city blocks observed for each variable

Table 3. Population density models

Model	1	2	3	4	5
Dependent variable	Log(pop/Ha)	Log(pop/Ha)	Log(pop/Ha)	(Pop/Ha)$^{\lambda}$	(Pop/Ha)$^{\lambda}$
Box-Cox transformation estimate λ	-	-	-	0.5092	0.5223
Distance to CBD (Km)	-0.08	-0.0895	-0.3031	-0.7926	-0.9562
	[0.0138]***	[0.0165]***	[0.0643]***	[0.1008]***	[0.1282]***
(Distance to CBD (Km))^2			0.0597		
			[0.0138]***		
(Distance to CBD (Km))^3			-0.0041		
			[0.0009]***		
Distance to a major Road (m)	0.0001	0.0001	0.0001	0.0007	0.0009
	[0.0000]***	[0.0000]***	[0.0000]***	[0.0001]***	[0.0002]***
% Homes connected to sewer system	0.0067	0.0067	0.0071	0.0623	0.0656
	[0.0005]***	[0.0005]***	[0.0005]***	[0.0038]***	[0.0042]***
% Homes occupied by owner	0.0008	0.0009	0.0007	0.0026	0.0054
	[0.0009]	[0.0009]	[0.0009]	[0.0060]	[0.0064]
Neighborhood Income (factor)	-0.0347	-0.035	-0.0316	-0.5862	-0.6139
	[0.0130]***	[0.0131]***	[0.0131]**	[0.0894]***	[0.0946]***
Illegal Subdivision (Protected Area)	0.1501	1.3519	0.0981	1.5681	10.7532
	[0.0828]*	[0.3483]***	[0.0852]	[0.6052]***	[2.1518]***
Squatter (Invasion)	0.5698	0.6731	0.6182	6.7052	16.4291
	[0.0550]***	[0.1755]***	[0.0555]***	[0.5407]***	[2.2341]***
Government supported subdivision	0.3353	-1.4128	0.2918	2.8237	-13.6172
	[0.0573]***	[0.2835]***	[0.0584]***	[0.5182]***	[2.7523]***
Illegal Subdivision (New: Still Illegal)	0.6246	0.5713	0.5702	3.3686	4.7916
	[0.0837]***	[0.2751]**	[0.0869]***	[0.6108]***	[2.2611]**
Illegal Subdivision (Old: Now legal)	0.3064	-0.0952	0.2756	1.2592	-3.4945
	[0.0529]***	[0.1566]	[0.0543]***	[0.3966]***	[1.3032]***
Illegal Subdivision (protected area) *CBD dist		-0.0002			-0.0016
		[0.0001]***			[0.0004]***
Squatter (Invasion) *CBD dist		0			-0.0032
		[0.0001]			[0.0007]***
Government supported subdivision*CBD dist		0.0004			0.0035
		[0.0001]***			[0.0005]***
Illegal Subdivision (New: still Illegal) *CBD dist		0			-0.0002
		[0.0000]			[0.0003]
Illegal Subdivision (Old: Now legal) *CBD dist		0.0001			0.0007
		[0.0000]**			[0.0002]***
Constant	3.6498	3.6061	3.6922	11.0886	11.0667
	[0.1062]***	[0.1085]***	[0.1106]***	[1.0104]***	[1.0868]***
Observations	5787	5787	5787	5787	5787
R-squared	0.24	0.25	0.24	0.32	0.33

Robust standard errors in brackets

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

(1) For brevity coefficients on direction (octants) and time of consolidation variables are not shown in this table.

Table 4. Structural Density Models

Model	1	2	3	4	5
Dependent variable	Log(Houses/Ha)	Log(Houses/Ha)	Log(Houses/Ha)	(Houses/Ha)$^{\lambda}$	(Houses/Ha)$^{\lambda}$
Box-Cox transformation estimate λ	-	-	-	0.5118965	0.5231251
Distance to CBD (Km)	-0.08	-0.0984	-0.3849	-0.8025	-0.9601
	[0.0143]***	[0.0172]***	[0.0689]***	[0.1019]***	[0.1287]***
(Distance to CBD (Km))^{2}			0.0733		
			[0.0145]***		
(Distance to CBD (Km))^{3}			-0.0048		
			[0.0009]***		
Distance to a major Road (m)	0.0001	0.0001	0.0001	0.0007	0.0009
	[0.0000]***	[0.0000]***	[0.0000]***	[0.0001]***	[0.0002]***
% Homes connected to sewer system	0.0072	0.0072	0.0076	0.0631	0.0658
	[0.0005]***	[0.0006]***	[0.0006]***	[0.0038]***	[0.0042]***
% Homes occupied by owner	-0.0011	-0.001	-0.0012	0.0027	0.0054
	[0.0009]	[0.0009]	[0.0009]	[0.0061]	[0.0064]
Neighborhood Income (factor)	-0.0285	-0.0288	-0.026	-0.5944	-0.6166
	[0.0141]**	[0.0141]**	[0.0142]*	[0.0904]***	[0.0949]***
Illegal Subdivision (Protected Area)	0.1234	1.2905	0.0772	1.5879	10.7924
	[0.0839]	[0.3461]***	[0.0862]	[0.6120]***	[2.1589]***
Squatter (Invasion)	0.5716	0.5287	0.6228	6.7943	16.5118
	[0.0556]***	[0.1930]***	[0.0565]***	[0.5477]***	[2.2442]***
Government supported subdivision	0.315	-1.5729	0.2853	2.8564	-13.6692
	[0.0598]***	[0.2993]***	[0.0609]***	[0.5245]***	[2.7631]***
Illegal Subdivision (New: Still Illegal)	0.6233	0.3626	0.5721	3.3987	4.8076
	[0.0840]***	[0.2745]	[0.0871]***	[0.6176]***	[2.2695]**
Illegal Subdivision (Old: Now legal)	0.3317	-0.2168	0.2945	1.268	-3.512
	[0.0545]***	[0.1658]	[0.0560]***	[0.4011]***	[1.3080]***
Illegal Subdivision (protected area) *CBD dist	[0.1431]	[0.1494]	[0.1574]	[1.1568]	[1.2603]
		-0.0002			-0.0016
Squatter (Invasion) *CBD dist		[0.0001]***			[0.0004]***
		0			-0.0032
Government supported subdivision*CBD dist		[0.0001]			[0.0007]***
		0.0004			0.0035
Illegal Subdivision (New: still Illegal) *CBD dist		[0.0001]***			[0.0006]***
		0			-0.0002
Illegal Subdivision (Old: Now legal) *CBD dist		[0.0000]			[0.0003]
		0.0001			0.0007
		[0.0000]***			[0.0002]***
Constant	2.2038	2.1737	2.2853	11.1602	11.0892
	[0.1234]***	[0.1257]***	[0.1278]***	[1.0230]***	[1.0912]***
Observations	5787	5787	5787	5787	5787
R-squared	0.24	0.25	0.25	0.32	0.33

Robust standard errors in brackets

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

(1) For brevity coefficients on direction (octants) and time of consolidation variables are not shown in this table.

Table 5 Land Price Models

Model	1	2	3	4	5
Dependent variable	Log($ /sqm)	Log($ /sqm)	Log($ /sqm)	($ /sqm)$^{\lambda}$	($ /sqm)$^{\lambda}$
Box-Cox transformation estimate λ				-2.146	-2.192
Distance to CBD (Km)	-0.1272	-0.1828	-1.0963	-0.000009	-0.000013
	[0.0060]***	[0.0087]***	[0.0283]***	[0.000000412]***	[0.000000497]***
(Distance to CBD (Km))^2			0.1634		
			[0.0050]***		
(Distance to CBD (Km))^3			-0.0078		
			[0.0003]***		
Distance to a major Road (m)	0.0001	0.0001	0	0	0
	[0.0000]***	[0.0000]***	[0.0000]***	[0.000000000]***	[0.000000001]***
% Homes connected to sewer system	0.0011	0.0004	0.0006	0	0
	[0.0002]***	[0.0002]**	[0.0002]***	[0.000000013]***	[0.000000011]***
% Homes occupied by owner	0.0008	0.0005	0.0006	0	0
	[0.0002]***	[0.0002]**	[0.0002]***	[0.000000016]	[0.000000013]
Illegal Subdivision (Protected Area)	-0.1416	-1.2594	-0.0709	-0.00001	-0.000094
	[0.0331]***	[0.0691]***	[0.0299]**	[0.000002391]***	[0.000004192]***
Squatter (Invasion)	-0.3298	-0.4301	-0.2834	-0.000036	0.000003
	[0.0195]***	[0.0744]***	[0.0193]***	[0.000001815]***	[0.000003969]
Government supported subdivision	0.0251	-0.5607	0.1812	0.000002	-0.000048
	[0.0161]	[0.0492]***	[0.0114]***	[0.000001702]	[0.000006750]***
Illegal Subdivision (New: Still Illegal)	-0.0421	-0.5602	-0.0167	-0.000016	-0.00007
	[0.0185]**	[0.0695]***	[0.0161]	[0.000001520]***	[0.000004459]***
Illegal Subdivision (Old: Now legal)	0.1585	-0.7824	0.0793	0.000014	-0.00007
	[0.0150]***	[0.0469]***	[0.0088]***	[0.000001405]***	[0.000004303]***
Illegal Subdivision (protected area) *CBD dist		0.0002			0
		[0.0000]***			[0.000000001]***
Squatter (Invasion) *CBD dist		0			0
		[0.0000]			[0.000000001]***
Government supported subdivision*CBD dist		0.0001			0
		[0.0000]***			[0.000000001]***
Illegal Subdivision (New: still Illegal) *CBD dist		0.0001			0
		[0.0000]***			[0.000000001]***
Illegal Subdivision (Old: Now legal) *CBD dist		0.0002			0
		[0.0000]***			[0.000000001]***
Constant	5.9271	6.0288	6.3713	0.465997	0.456306
	[0.0348]***	[0.0360]***	[0.0353]***	[0.000002803]***	[0.000002325]***
Observations	5880	5880	5880	5880	5880
R-squared	0.69	0.71	0.78	0.72	0.76

Robust standard errors in brackets

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

(1) For brevity coefficients on direction (octants) and time of consolidation variables are not shown in this table.

Figure 1
Density function of linear city with informal settlements

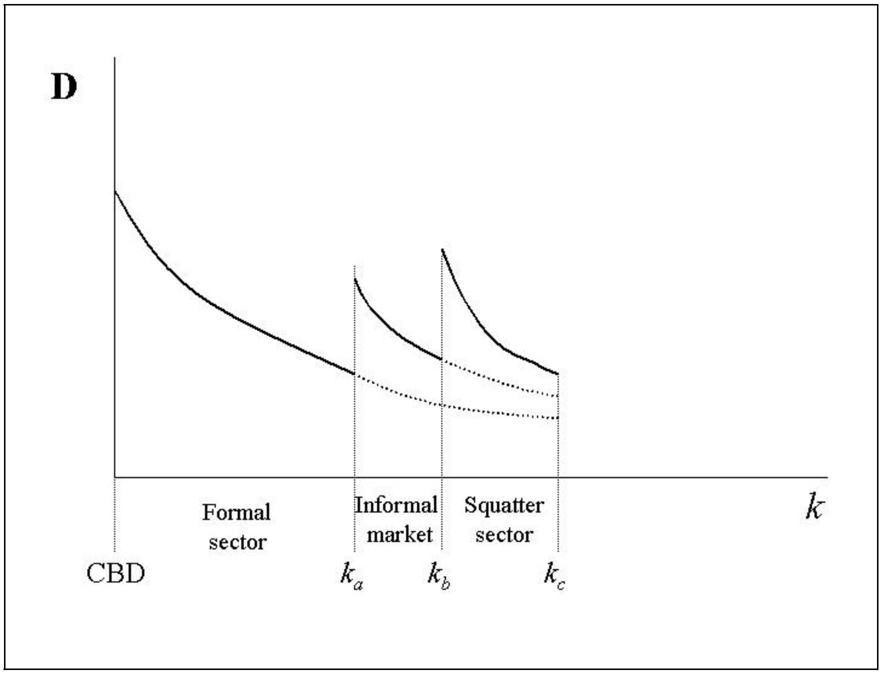


Figure 2
Estimated density gradients by settlement type

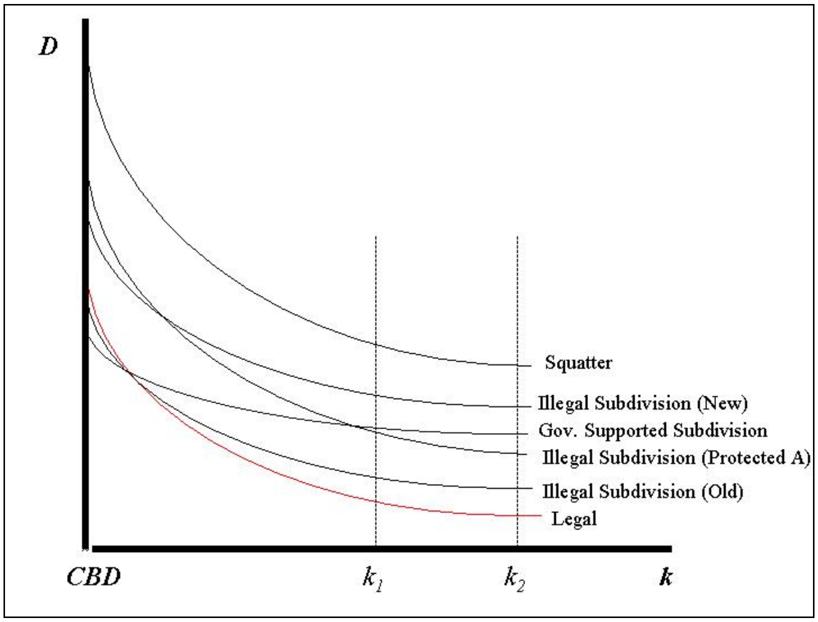
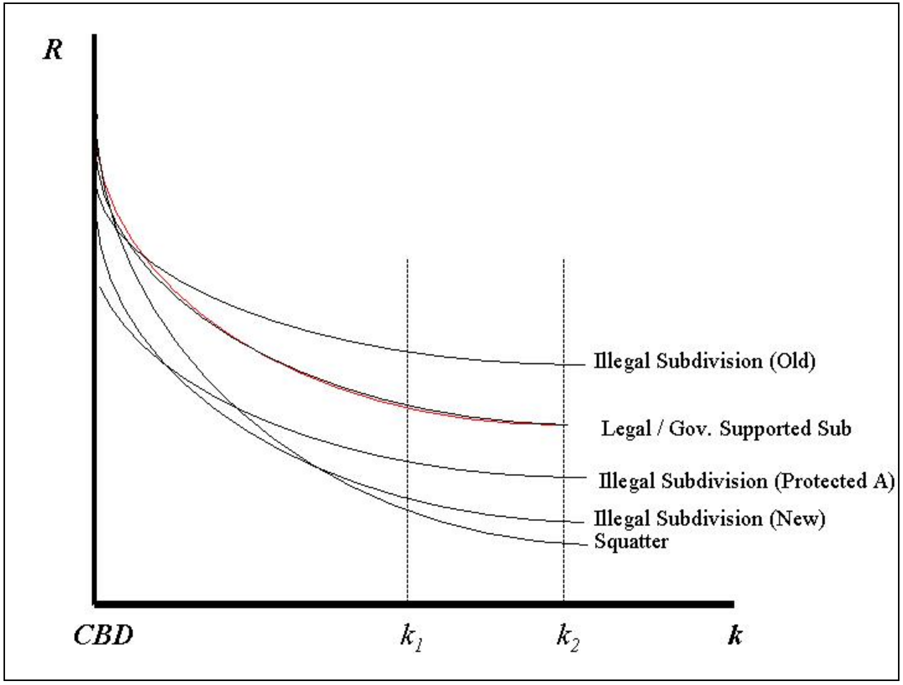


Figure 3
Estimated price gradients by settlement type



Appendix

1. Proof

This appendix demonstrates the claim that the likelihood of squatting is generally greater for locations further away from the CBD and that structural density of squatter settlements generally declines with greater distance from the CBD. These results are general in the sense that, while a non-increasing likelihood of squatting with distance and a non-decreasing density cannot be ruled out, they both cannot hold at the same time. Introduce *k* into the model as described in the text to yield the Nash equilibrium conditions:

$$\theta^* = \phi(h, k)$$
$$h^* = \psi(\theta^*, I(k), p, r)$$

with the Lipschitz condition $J = 1 - \psi_\theta \phi_h > 0$. Totally differentiate and solve in the normal manner to find the comparative static predictions:

$$\frac{\partial \theta^*}{\partial k} = \frac{\phi_k + \phi_h \psi_I I_k}{J} \tag{A.1}$$

$$\frac{\partial h^*}{\partial k} = \frac{\psi_I I_k + \phi_k \psi_\theta}{J} \tag{A.2}$$

Show that $\frac{\partial \theta^*}{\partial k} \le 0$ and $\frac{\partial h^*}{\partial k} \ge 0$ cannot both be true. At the same time, by contradiction, suppose it is true. Then (A.1) and (A.2) imply, respectively, that $\phi_k / \phi_h \le -\psi_I I_k$ and $\phi_k \psi_\theta \ge -\psi_I I_k$ so that $\phi_k \psi_\theta \ge -\psi_I I_k \ge \phi_k / \phi_h$ or $\psi_\theta \phi_h \ge 1$ using $\phi_k > 0$. That is, the supposition implies $J = 1 - \psi_\theta \phi_h \le 0$ which contradicts the Lipschitz condition $J>0$ assumed at the outset. Therefore, the supposition cannot be true.

2. Construction of the Block income Index

Bolivia's last population census (2001) did not ask respondents to provide their level of income. However, the survey included a series of questions concerning home appliances, household equipment, and household education choices, among others. A group of these indicators was used to construct an income index at the census block level using exploratory and confirmatory factor analysis.

The variables used to construct the index using a principal component extraction method of factor analysis were:

A) % of households in the block that own a TV set.
B) % of households in the block that own a car.
C) % of households in the block that own a refrigerator at home.
D) % of households in the block that own a telephone line.

The correlation matrix for these variables is presented below in table A.1

Table A.1
Correlation matrix of variables used to construct
block income index

	Tvpnt	Carpnt	Refripnt	Phonepnt
Tvpnt	1.00			
Carpnt	0.45	1.00		
Refripnt	0.69	0.67	1.00	
Phonepnt	0.59	0.73	0.84	1.00

A principal component analysis used on the 4 variables produced a set of factors of which the first one explained about 75% of the variance in the 4 variables combined (Eigen value = 2.98). The second factor explained only 14 % of the variance in the 4 variables combined (eigen value =.58). Using the Kaiser-Guttman rule we confidently conclude that these 4 variables produce only 1 principal component (i.e. block income) with a decent degree of reliability[13]. The estimated eigen values for each component are depicted in table A.2.

Table A.2
Estimated eigen values using principal component extraction method
on 4 census indicators of household income

Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	2.98	2.40	0.74	0.74
Component 2	0.58	0.29	0.15	0.89
Component 3	0.29	0.14	0.07	0.96
Component 4	0.15	.	0.04	1.00

Finally, the block income variable was constructed using the estimated eigen vectors (factor loadings) shown in table A.3.

Table A.3
Factor loadings used to estimate block income variable

Variable	Component 1
Tvpnt	0.45
Carpnt	0.47
Refripnt	0.54
Phonepnt	0.53

---

[13] The Cronbach alpha coefficient for these 4 variables was .88. We also applied Confirmatory Factor Analysis to test the one-factor model. The results give ample support for the one-factor model: Model χ^2= 12.96 (df =1); Root Mean Square Error of Approximation (RMSEA)=0.04; 90% confidence interval for the RMSEA = (0.024; 0.066); Comparative Fit Index (CFI) = 0.99