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THE EFFICIENCY OF LAND-USE IN A DEVELOPING CITY: TRADITIONAL VS MODERN TENURE SYSTEMS IN KAMPALA, UGANDA

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JEL Classification: O1, R3, R52

Keywords: urban, land-tenure, land-use, customary, Uganda

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26/2/19

The efficiency of land-use in a developing city: traditional vs modern tenure systems in Kampala, Uganda*

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Land rights and tenure systems are an important factor behind poor housing and inefficient land-use in developing country cities. In Kampala, Uganda, four systems of land tenure coexist, allowing a detailed study of the effects of these on household and firm location decisions. Spatially disaggregated data across the city suggest that the presence of a traditional land tenure system (called mailo) skews land-use towards informal housing and away from productive activities. Using a structural model of the city we show that this due to mailo having a positive value for occupants of informal housing, attributable to mailo-specific amenity benefits and/ or rent caps. We use the model to investigate the effect of converting all mailo land in the city to leasehold. Despite direct loss of amenity experienced by mailo residents, aggregate city income may rise substantially because of more efficient land-use. Manufacturing firms move into formerly mailo areas and form new clusters of activity. This increases urban wages, particularly among the low skilled, and raises aggregate urban real incomes by 2% in the absence of localisation economies and as much as 6.7% in the presence of such economies of scale.

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1. Introduction

Lack of clarity surrounding land titles, and the consequent rights to occupy and to build on land, is frequently cited as a major contributing factor to poor housing conditions, lack of investment, and low productivity in many developing cities (e.g. Brueckner and Lall 2015). Unclear land rights prevent the efficient allocation of land, a city's ultimate scarce factor, and its subsequent development. As a result land-use in many developing cities appears haphazard, with lower density residential neighbourhoods occupying prime land that could be more efficiently used by businesses or higher density apartment buildings. Low density residential areas are often slums, in which more than 60% of Africa's urban population is housed (Marx et al. 2013). As well as preventing development of these areas, tenure systems can support land-use patterns that limit the connectivity between firms and workers and stifle the development of clusters of firms needed to support high productivity.

This paper is a study of the impact of land tenure systems on patterns of land-use in Kampala, Uganda, investigating the extent to which land tenure patterns shape the location of economic activity in the city and hence have consequences for real incomes. The paper shows three main things. First, that there is a strong positive correlation between the presence of a traditional land tenure system (the 'mailo' system) and the location of informal housing within the city, as well as negative links between mailo land and economic activity. Second, using a structural model to control for other factors that could be driving this correlation, we argue that this is a causal effect, with mailo providing amenity to tenants through a combination of below market price land and social or network benefits. Third, we show that there are substantial efficiency gains to be made through land tenure reform in the city.

The overall development of Kampala appears typical of a number of East African cities. It has grown rapidly, from 775,000 in 1990 to around 1.5 million in 2014, and is predicted to more than double in size again by 2030. These high rates of urban population growth have led to a sprawling, low density city, with the wider urban area, the Greater Kampala Metropolitan Area (GKMA), estimated to be home to 4 million people. Buildings are often shacks or at best one or two storey traditional structures, with more than 60% of the city resident in these informal structures (locally termed muzigos). These are spread over a large area, with poor travel conditions across town due to congested low-quality roads and the lack of a public transit system; the Ministry of Transport estimates that 40% of journey times within the city during rush hour are spent at standstill. With such a dispersed and disconnected urban population firms struggle to reap the potential benefits of the city and locate instead near their consumer and labour markets, spreading out throughout the urban area. Many of these are small firms, specialising in providing consumer services, with manufacturing employment representing only about 10% of urban jobs.[1]

Kampala has a unique history with regards to its land tenure system, with four different land tenure types simultaneously present in the urban area. In 1900, the British Government and the Bugandan Kingdom, the historic rulers of the region in which Kampala lies, divided the land in the area between them, with half of the city remaining under a traditional land tenure system, mailo, and half being transferred to leasehold or freehold tenure.[2] Over time, these contrasting land tenure systems have

[1] See Bird, Hierons and Venables (2018) for detailed analysis of the spatial pattern of employment in Kampala.
[2] The history is described in greater detail in section 2 of the paper.

shaped the patterns of urban growth of the city. Under freehold and leasehold tenures land is transferable and can be sold or leased to the highest bidder relatively easily. Under customary tenure, which has developed on formerly public or private land, established groups of settled households have acquired rights to that land over time, although lack of official documentation limits the exchangeability of the land. Under mailo, the traditional land tenure system, both the land-owner (private owners or the Buganda kingdom) and the tenant have claims to the land, making the sale or transfer of land difficult as permission must be sought from more than one party. Tenants who have been on mailo land for at least 12 years cannot be evicted if they pay a minimum annual ground rent, generally well below what would be the market rent. As a result, urban development on mailo land is particularly difficult; the dual-ownership system impedes sale and purchase, particularly as tenants – who can block land transfer – may have below market rents. Simultaneously, a lack of paper records creates an eviction risk for mailo tenants, limiting their incentives to invest in structures on the land they occupy. Together, these factors are likely to provide obstacles to developing land, even that in prime locations, into high value uses.

We analyse the ways in which the land tenure systems influence the patterns of economic activity through three stages. First, in Section 2 we explore how the location of different types of economic activity correlates with the tenure system. This shows clearly that employment, particularly in business services, is less intense on mailo and customary lands, whereas households resident in informal muzigo housing are more densely located in these areas. These differences are suggestive that land tenure systems have an influence on the patterns of activity within the city, and as a result, on the city's output and the residents' well-being. However, correlations between mailo land and employment and population densities could be capturing patterns that result from other features of the city. For example, mailo land may be poorly located, in which case the tenure system may not be the main cause of the observed land-use. We control for this using observable information about the land, such as elevation and ruggedness, and find that the correlations still remain strong. However, to consider other economic factors that are potentially at play, such as connectivity to economically dynamic areas of the city, we need to consider the complete urban system as a whole.

To examine this, in Section 3 we develop a spatial computable general equilibrium (CGE) model of a city. This model is in the tradition of new economic geography and its quantitative application as developed by Ahlfeldt et al. (2016). The development of this literature is reviewed by Redding and Rossi-Hansberg (2017), who describe the menu of features that can be captured in such models. Features of the model developed in the present paper include a fine level of spatial disaggregation, with the city divided into 96 distinct geographical areas, each with a fixed land area and connected to others through a transport network. Travel times around this network determine the costs of moving goods and services, costs of commuting, and the spatial range of productivity spillovers. Firms in different sectors choose where and how much to produce, using a technology that involves input-output linkages and (in some of our experiments) productivity spillovers. Households choose where to live, where to work, and what to consume depending on land rents, access to jobs, and commuting costs.

Our model is innovative in that it includes developing-country features designed to capture both formal and informal employment and housing. Thus, firms differ across sectors (manufacturing, business services, and consumer services) and we separate out one-person small firms. Each of these enterprise types varies by their input mix (including land-use), goods and services produced, and by the tradability of their output. This sectoral heterogeneity is essential to capture the varying patterns of land-use that we observe across the city, and in particular informal sector employment. Nearly one quarter of employment in Kampala is in one-person enterprises, typically producing goods traded only within the city or neighbourhood.[3]

We distinguish between high and low-skilled households and also between formal and informal sector (muzigo) housing. Decisions on which type of housing is built in each place are endogenous, and so too is the density of housing constructed. In the formal sector housing can deliver density by building tall (at increasing unit cost) while in the informal sector density is achieved by 'crowding' which decreases the quality and value of the housing offered (see also Gechter and Tsivanidis 2018, Henderson et al. 2018 for models of formal and informal housing). At equilibrium, the labour, goods, services, land and housing markets all clear, producing a set of endogenous wages, prices and rents for every location in the city, as well as the numbers and types of people and firms who locate in different neighbourhoods. The ensuing pattern of land-use is the focus of our attention.

In Section 4 we introduce the data used to apply this model to Kampala, and calibrate the model so that the equilibrium pattern of household and firm location exactly matches the patterns observed. Kampala is unusual in having highly spatially disaggregated data on firms and households which allow us to analyse how the tenure systems shape the location of different types of residential and commercial activity. The population census provides household numbers by skill level and housing type in each of the 96 parishes in the city, and a census of business establishments provides employment numbers by sector and establishment size in the same set of locations. The calibration produces a set of location specific productivity and amenity parameters which shape the location decisions of firms and workers, over and above those factors captured in the model. For example, if there is a higher density of manufacturing employment in a particular location in the data than that suggested by the model, then the manufacturing productivity parameter for this location is increased, representing some unobserved factors which makes manufacturing employment in this area more attractive.

The calibrated productivity and amenity parameters capture variations in the urban landscape not otherwise captured in the model. Since land tenure is not explicitly modelled, its effects are included in these parameters.[4] In Section 5 we recover the effect of different land tenure systems by regressing these parameters on, amongst other things, the share of land in different parishes under each type of tenure. This shows that the low densities of employment in mailo areas are attributable not to low productivities in these areas, but to residential uses 'crowding-out' firms. Areas with high shares of mailo land have significantly higher amenity parameters for those living in informal housing. We control for geographical features of the city, including elevation and ruggedness of the land, as well as access to schools, hospitals and roads. The positive relationship between mailo land and the amenity

[3] Multiple sectors and factors of production are standard in quantitative spatial models at the international level and some intra-country models (e.g. Fajgelbaum and Redding 2014), but intra-urban models commonly assume a single final good and single type of labour. Exceptions are Redding and Sturm (2016) whose London model has multiple occupations, and Gechter and Tsivanidis (2018) who have one final good and two skill levels.

[4] A priori, we do not know the effects of tenure variation. It is therefore natural to capture them in fixed effects, and these are precisely what are captured in the amenity and productivity parameters.

parameters remains strong. This could be signalling two things: either that these areas provide amenity benefits such as dense community networks and other social benefits, or that rent caps create financial benefits. Without rent data we cannot distinguish the two any further, however the literature provides some evidence that rent caps are a feature of mailo land.

It is important to note what data is, and is *not* available for Kampala. We are restricted to work with a single population census (2002), that for 2012 having not been released because of reservations about its accuracy. There are two business establishment censuses, but that for 2011 (which we use) is deemed considerably more reliable than that for 2002. There is little reliable rent data, and none that covers areas of traditional tenure systems and would enable a direct comparison of rents or land values in different parishes. The absence of times-series variation and rent data means that we place heavy dependence on the structural model. Estimates of some parameters, including some key elasticities, come from elsewhere in the economic literature, and are not structurally estimated.

Finally, in Section 6, we use the calibrated model to illustrate and quantify possible effects of replacing mailo land tenure in the city with the more modern leasehold tenure system. We simulate an experiment in which all the mailo land in the city is converted to leasehold, using the predicted productivity and amenity parameters derived from regressing calibrated productivity and amenity on tenure type. The change reduces the amenity benefits of these areas to informal households; this may be direct amenity value (for example loss of networks) or benefit derived from a rent-cap. We calculate real income effects in both cases; the former is a real cost, whereas the latter is a transfer, with tenants losing and land-owners gaining. In addition to these direct effects, there is a change in the pattern of land-use, as households and firms adjust their locations in the city. The reduction in demand for muzigo housing in areas that were previously mailo allows other households and firms to move in. The consequence is a large spatial redistribution of activity in the city. The relatively land intensive manufacturing sector benefits the most, moving into areas that have become cheaper, forming new clusters and expanding production. This boosts the wages of the low-skilled, some of whom move out of jobs in consumer services and small firms and into manufacturing. The net effect is a more efficient spatial organisation of the city, increasing aggregate welfare by 2.0-6.7% depending on whether or not additional scale economies are present. These gains are equivalent to 24% of average rent per directly affected household (households on mailo land) under no scale economies, rising to 80% with returns to scale of 6%. Capitalising this flow benefit (at 5% discount rate) the value of the reform ranges from 4 times average city rent to 16 times average city rent per directly affected household.

2. Land-use in Kampala

City Context

Kampala, like many other developing cities, is a rapidly growing and sprawling city. Land in the central business district (CBD) is densely built-up with tall tower blocks while adjacent neighbourhoods are packed with one-storey traditional dwellings. Other well-connected plots of land are completely undeveloped, despite proximity to some of the most valuable land in the city. Our study is of an area of 182 km^2, containing 96 parishes (the spatial unit for our data and modelling) which come under the administration of the Kampala Capital City Authority (KCCA), which has significant local regulatory, fiscal and planning powers. The city is bounded to the South East by Lake Victoria, while the neighbouring districts (Mukono to the east, Wakiso to the west) contain some further urban areas as well as agricultural land.

The 2002 population census (Uganda Bureau of Statistics) provides a detailed report of population across the urban area, including not only their location but also data on their skills and housing conditions. Figure 1 shows the population density of each parish in the city, with the average parish home to 9,800 people per square kilometre. The great majority of households in Kampala are headed by low-skilled workers[5]. The share of such workers tends to be lower nearer the city centre (CBD), as shown in Figure 2. The census also gives housing type, and the majority of households in Kampala, 61%, live in informal housing (locally known as muzigo tenements), with the rest living in other types of building that we describe collectively as formal[6]. Muzigo housing is traditional one or two-roomed structures, simple low-quality housing that is frequently densely packed into neighbourhoods with little in the way of access routes and provision of services such as piped water and electricity. Figure 3 shows the distribution of this housing across the urban space: traditional housing is more prevalent to the East of the centre and on the fringes of the city. These patterns correlate with the areas of higher population density.

On the production side, the broad picture is given in Figure 4 that maps urban employment from the 2011 Census of Business Establishments established by the Ugandan Bureau of Statistics (UBOS). This census captures information on every fixed-location establishment, including precise geographical coordinates and employment numbers as well as four-digit ISIC codes. The establishment level information is then aggregated to the parish level, providing employment numbers by sector for all the parishes in Kampala.[7] Spatially, employment is highly concentrated in the area surrounding the CBD.

Table 1 gives summary statistics of population, skills and housing, and the central block of the table gives a detailed breakdown of employment: 317,499 jobs are captured by the establishment census. For purposes of analysis, we group these into four categories, manufacturing, business services, consumer services and one-person enterprises. Consumer services is the largest group, covering 39% of all jobs, including retail, hairdressing and food services. Business services, which includes banking and legal firms as well as wholesale providers, represent 23% of all jobs, with 9% of jobs in manufacturing. Firms in Kampala are particularly small, with 22% of jobs in one-person firms, most of which constitute 'informal' employment; we group these together, separating them out from their business activity. Remaining jobs are in agriculture and government.

[5] Using a typology close to the International Standard Classification of Occupations, high-skilled workers include the major occupational groups 1 to 4 (Managers, Professionals, Technicians and associate professionals and Clerical support workers) while the low-skilled include groups 5 to 9 (Service and sales workers, Skilled agricultural, forestry and fishery workers, Craft and related trades workers, Plant and machine operators, and assemblers and Elementary occupations).

[6] The other categories present in the data area detached house, semi-detached house, flat and other.

[7] The establishment census is unusual in that it involved knocking on every door within the city, aiming to capture all employment. In all they managed to record the jobs of 42% of the working population. In the simulation and calibration of the model, the number of households is scaled to match the number of jobs available in the city.

Figure 1: Population density

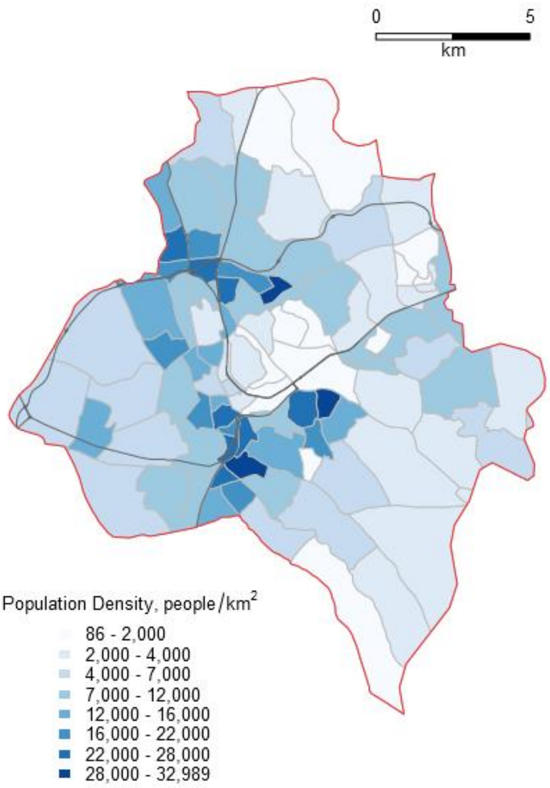


Figure 2: Share of population who are low-skilled

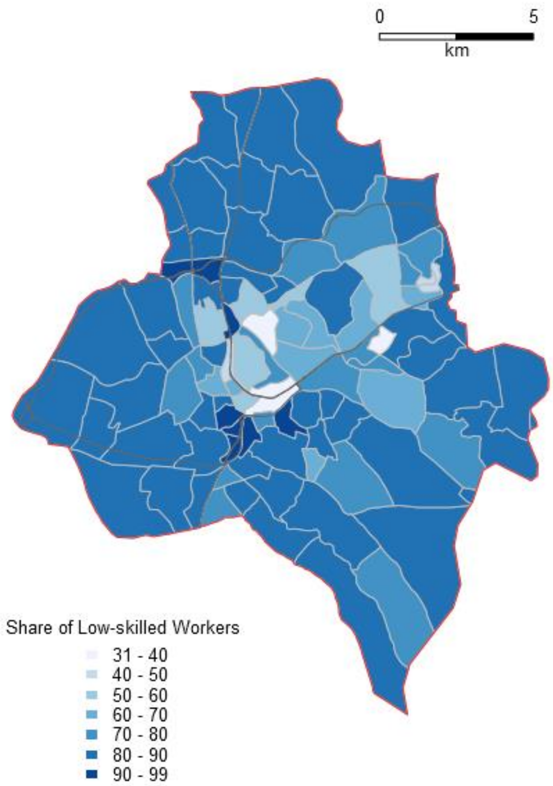


Figure 3: Share of informal housing

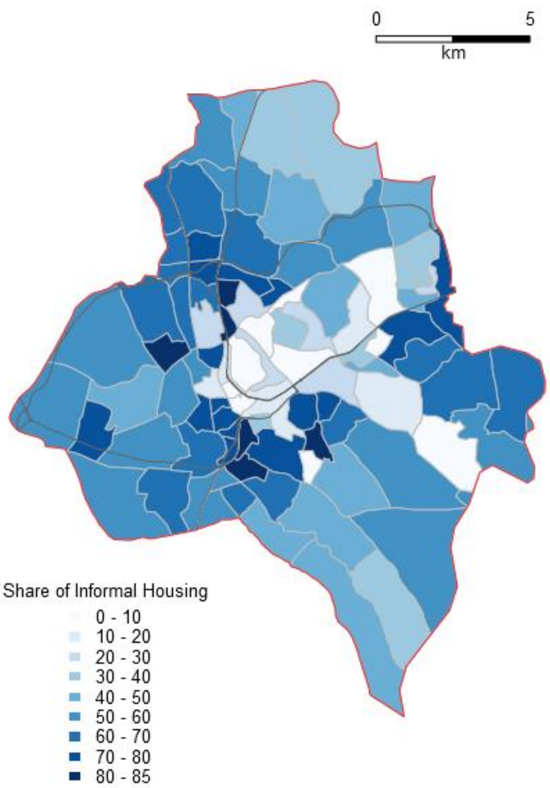


Figure 4: Employment Density

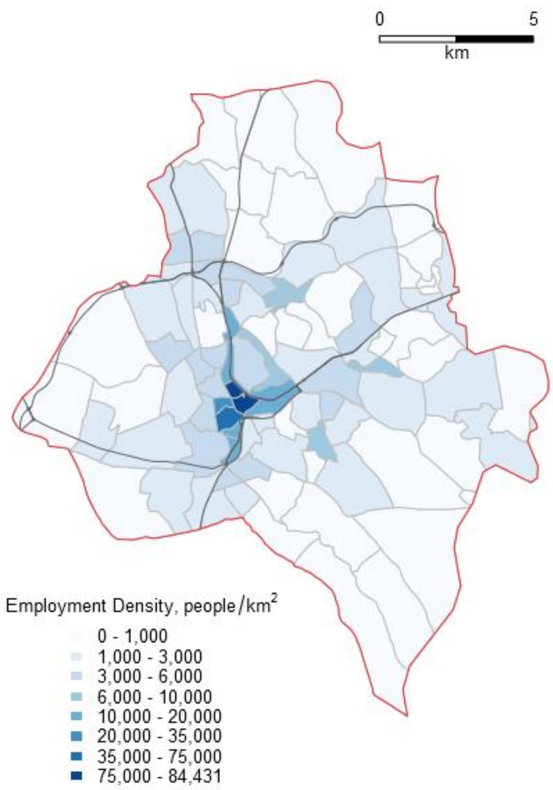


Table 1: Summary statistics; population, employment and land tenure

96 Parishes	**Total**	**Mean**	**Minimum**	**Maximum**
Population	**1219735**	**12706**	**32**	**44786**
Low Skill Households	222491	2318	1	9352
High Skill Households	41829	436	2	1361
Low Skill Informal "Muzigo" Households	142482	1484	0	5913
Low Skill Formal Households	80009	833	1	3439
High Skill Informal "Muzigo" Households	18573	193	0	770
High Skill Formal Households	23256	242	2	657
Employment	**317499**	**3307**	**7**	**26439**
Manufacturing Employment	28913	301	0	2584
Business Services Employment	74304	774	0	8172
Consumer Services Employment	123814	1290	2	13671
One-person Firm Employment	71922	749	5	8638
Agricultural Employment	877	9	0	177
Government Employment	17669	184	0	843
Area (km2)	**179.3**	**1.9**	**0.1**	**7.9**
Mailo Share	32%	29%	0%	100%
Customary Share	20%	18%	0%	54%
Freehold Share	27%	27%	0%	83%
Leasehold Share	22%	26%	0%	93%

Land Tenure System

The 1998 Uganda Land Act enshrined in law the existence of four different types of land tenure system, freehold, leasehold, customary and mailo in the country. The co-existence of these different land tenure systems dates back to the arrival of the British in the region in the later 19th century, culminating in the 1900 Uganda Agreement between the Buganda Kingdom, the historic rules of the region, and the British Protectorate Government. This effectively split the city of Kampala into two areas, one of mailo land under traditional pre-colonial tenure structures, and another of leasehold and freehold land. The mailo land was controlled by the Bugandan Kingdom, and the rights to this land were either owned by the king (the Kabaka) or other royalty, local chiefs and other powerful individuals. The areas allocated to this were predominantly in the pre-existing parts of the city, particularly the areas around the royal palace in Mengo in the western half of modern Kampala. The British protectorate was assigned, according to the agreement, approximately half of the land of Uganda. Article 15 of the agreement specifies that of the approximate 19,600 square miles of land in Uganda, 9,000 square miles were to be allocated to the British, and this was expressly listed as the unoccupied land of the day, "Waste and uncultivated land to be vested in Her Majesty's Government, and to be controlled by the Uganda Administration" (Uganda Agreement, Mengo, 10th March 1900, Article 15, as reported in West 1965).

The land under the control of the British Protectorate Government was managed as leasehold and freehold.

Early on, the sale of mailo land to non-Africans was apparently encouraged, partly so that owners of mailo land could raise enough capital to develop other parts of their property. These sales were carefully controlled, however, and did not prove popular. As a result they were prohibited in 1916, by which time only 118 square miles of land (out of more than 9000) had changed hands, and much of this transferred land was reacquired by the Buganda Kingdom (West, 1965). As a result of this prohibition the pattern of mailo land seen in Kampala today is very similar to that which existed in the city more than a century ago. It is noteworthy that mailo land was historically seen as more valuable, (therefore occupied prior to the Uganda Agreement), and owned by elite landowners and the Bugandan Kingdom. Over the decades, bonafide occupants of this land were given increased rights, including the right not be evicted given the payment of a minimum annual ground rent which was established in law in 1928.

The era of Idi Amin saw all land decreed public land, and these different tenure systems disappeared for a period of 20 years until the 1995 Constitution and 1998 Land Act. This re-established the four tenure types that exist in the city today, transferring land back into its original tenure system. Firstly, there is freehold land, under which the owner has full perpetual rights to the land, and can sell or develop the land according to their own will. The land allocated to schools and religious institutions is all freehold, as is some land that was previously under customary use. Secondly, there is leasehold land, under which a leaseholder has the rights to the land for a long period, most often 49 years. This land is managed by the Kampala District Land Board (KDLB), and leaseholders have full rights to the land for use, transfer and development, subject to the KDLB's approval.

The two traditional tenure systems are customary land and mailo land. Tenants on customary land are long term residents on public land who have acquired some rights through their presence there. This land can potentially be converted by the tenant to leasehold or freehold, however the procedure occurs only infrequently. The land and their rights to it therefore cannot be used for formal collateral, and redevelopment of the land is constrained by the cost of formalising the plots. Establishing who holds customary rights to this land is complicated by the lack of formal titles.

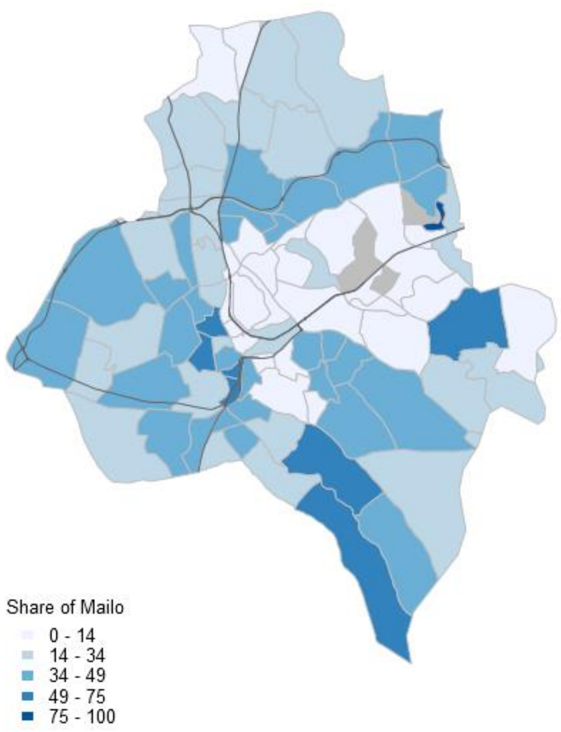
Mailo land reverted to what is today essentially is a dual land ownership system, under which the tenant owns the structures on each plot, and the mailo landowner the underlying land itself, managed by the Buganda Land Board (BLB). In order to sell a plot of mailo land, the landowner requires their tenants' consent, and must compensate them. The tenant, if they have occupied the land for at least 12 years, only need pay a minimal annual ground rent, the Busuulu, to the land owner in order to be unable to be evicted. This ground rent was set at just 1,000 UGX in the 1998 Land Act, irrespective of what economic activity occurs on the land, the size of the plot (up to an acre) or where it is located. In 2010 this was amended to allow land boards to set new ground rents in agreement with the Ministry of Lands, and the current urban annual ground rent per plot is 50,000 UGX, little more than 13 USD a year. This can include prime land in the heart of the city.

This rent is clearly below the market rent for a plot in the city, and so tenants have little by way of incentive to allow the sale of this land (Jones et al. 2015, Giddings 2009). However, tenants do often lack paper records of their occupancy, which needs to exceed 12 years for eviction restrictions to come into force, and so landowners of mailo land have been reported to engage in illegal evictions, reducing tenure security.

Importantly for our research strategy, conversion of land between mailo and freehold or leasehold is near non-existent, and has not been allowed historically. Land has remained under its original tenure system for most of the last century, bar a period of political upheaval in the 1970s and 1980s, and has remained under this system throughout the high periods of urban growth in the 1990s and 2000s. Additionally mailo land is not the low-quality land that has little in the way of value to its holders; historically, this land was the prime urban land, that occupied by the Bugandan Kingdom prior to colonialization.

Each of the four types correspond to between 20% and 30% of household tenure types within the city, although the shares vary considerably between parishes. The share of land under mailo tenure is shown in Figure 5; detailed maps of land tenure systems within the city do not exist, and so we have to rely on shares derived from the population census.

Figure 5: Land Tenure – Percentage of land under mailo.



Revealed Impact of the Land Tenure System

These varying land tenure systems are likely to have different effects on the pattern of land-use in Kampala. We begin analysis by examining correlations between the share of land in a parish under mailo tenure, and the population and employment densities in that parish. Each of figures 6-15 have the share of land under mailo on the horizontal, and population or employment on the vertical axis. They also plot the relationship from an OLS regression between the respective variables, with a band showing a 95% confidence interval.

Figure 6 indicates that parish population density increases with the share of land under mailo tenures. Figures 8 to 11 details the shares of population by skill and housing type: the greater population densities in parishes with a high share of land under mailo tenure are made-up of a high share of households in informal housing, particularly low-skilled households. Meanwhile, households in formal housing are relatively less important in areas with mailo land.

Employment density varies negatively with the share of land under mailo tenure as shown in Figure 7; however the main driver of this is a few highly dense cells near the city centre. When we separate employment into different sectors, we observe a negative correlation between the share of land under mailo and the share of jobs in business services, alongside a positive correlation with the share of jobs in one-person firms and in consumer services. The relationship with manufacturing is weak.

Figure 6 Population Density, people per square kilometre

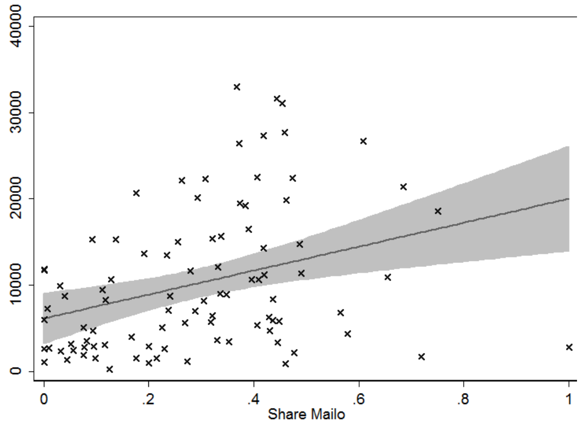


Figure 7. Employment Density, jobs per square kilometre

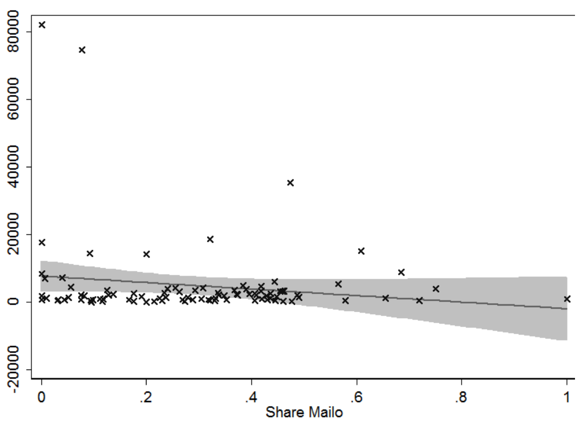


Figure 8. Share of Households – High Skilled, Formal Housing

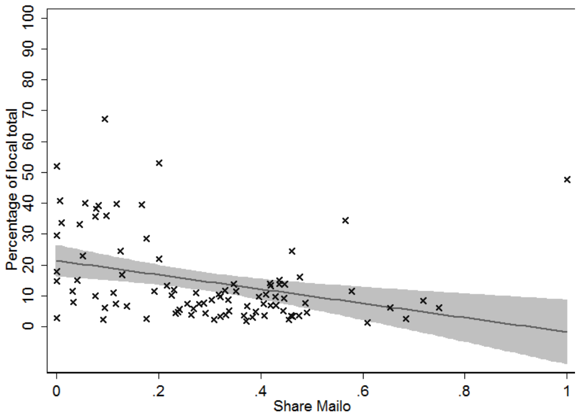


Figure 9. Share of Households – High Skilled, Informal Housing

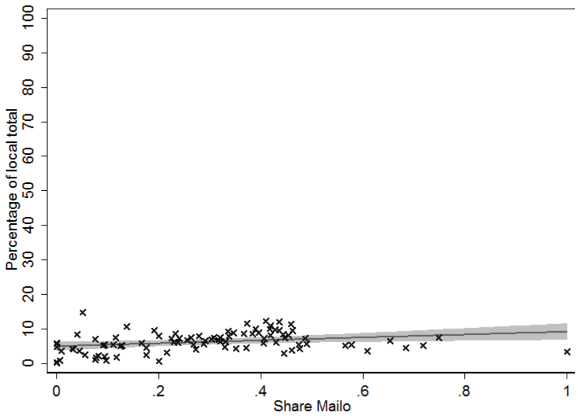


Figure 10. Share of Households – Low Skilled, Formal Housing

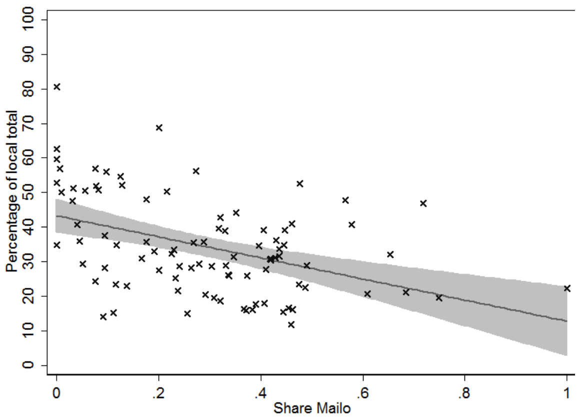


Figure 11. Share of Households – Low Skilled, Informal Housing

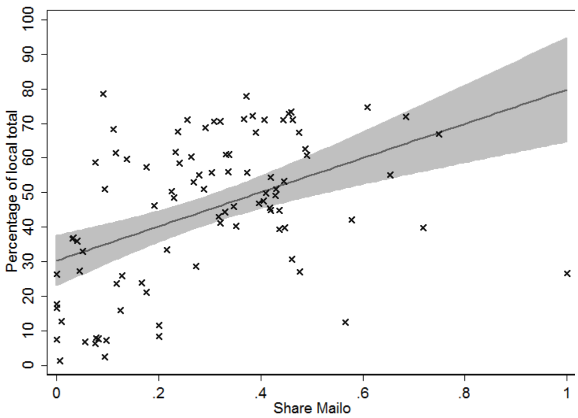


Figure 12. Share of Employment - Manufacturing

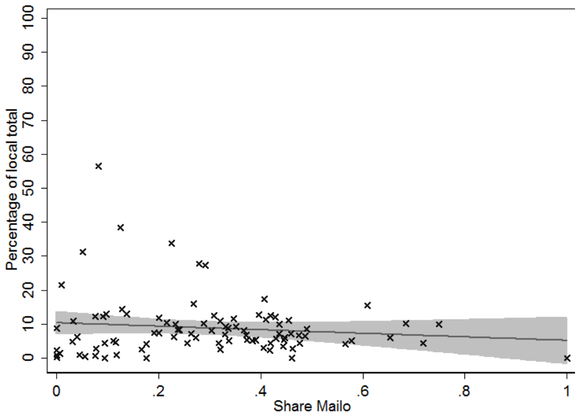


Figure 13. Share of Employment – Business Services

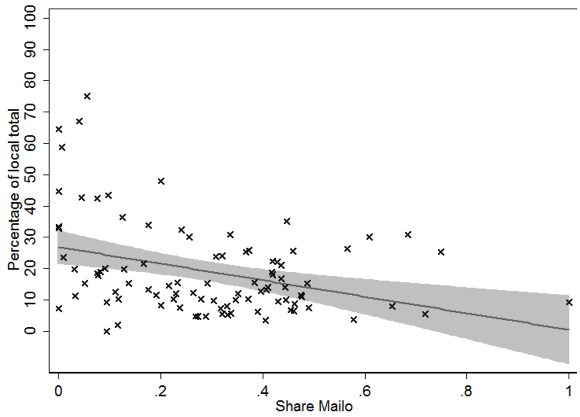


Figure 14. Share of Employment – Consumer Services

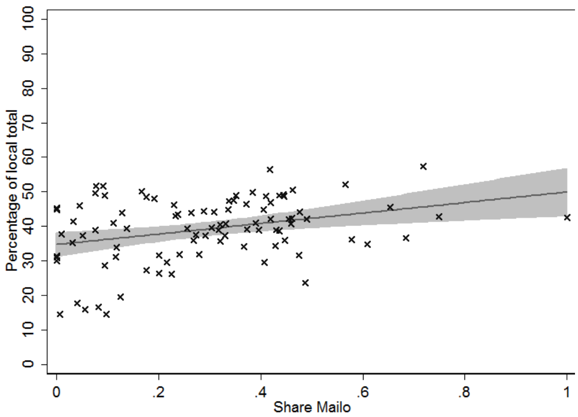
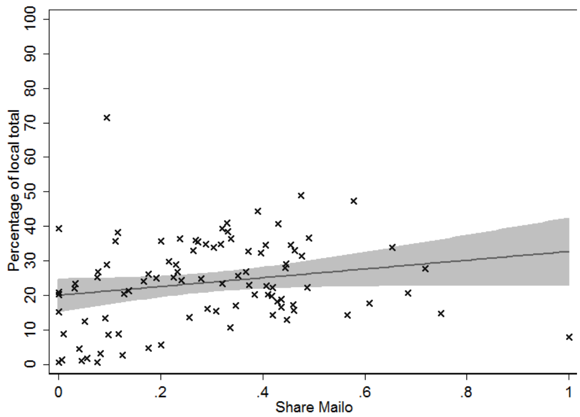


Figure 15. Share of Employment – One-person firms



The results are supported by OLS regression analysis, reported in Table 2. The share of jobs by sector, and the share of households by type, are regressed on the proportion of land within the parish that is under mailo, customary, or freehold tenure, together with additional geographical controls. These controls include the elevation of land, ruggedness, the distance to the central business district (CBD), the area of the parish, as well as access to main amenities in the city including distance to the nearest school, hospital and major road. The results show significant relationships between the presence of mailo and the type of activity in the parish, even when we control for some of the additional features of that land.

As shown in the figures, there is no significant relationship between the share of employment in manufacturing and the location of mailo land. For all other sectors of employment, however, there are clear and significant correlations. A parish that is fully mailo versus one that is fully leasehold has 24 percentage points less of its employment in business services, relative to a parish that is fully leasehold; on customary land business services are 37 percentage points less prevalent than on leasehold. Consumer services and single person firms have the opposite pattern, with the former 21 percentage points more prevalent on mailo land and 27 percentage points more on customary, and the latter 11 percentage points more prevalent on mailo land and 37 percentage points on customary. Looking at residential occupation by skill level and housing type, informal muzigo housing, occupied by both low and high-skilled workers, is more concentrated in areas with mailo land. A parish that is fully mailo versus one that is fully leasehold would have 4 percentage points more of its housing for high-skilled informal households, and 58 percentage points more of its housing for low skilled informal households. This is offset by a 22 percentage point lower share of high-skilled formal housing and a 40 percentage point lower share of low skilled formal housing. Customary land also has strong significant correlations with the tenure type: it has far greater shares of low-skilled informal housing, and lower shares of high-skilled and, to a lesser extent, low-skilled formal housing. Finally, we observe significantly greater shares of informal housing for both high and low skilled on freehold land relative to leasehold land, and lower shares of formal housing for low skilled. Much of freehold land is owned by public organisations, such as government offices and schools, or also religious organisations, including churches and mosques.

These correlations are shaped by many factors, and the task in the remainder of the paper is to disentangle the effect of land tenure from that of other place specific factors. In the regressions, we control for additional geographical characteristics. However, there are further economic factors that may be at play. For example, we control for distance to the city centre, capturing to a degree access to economic activity. However, economic activity is not all located at one point in space, and mailo land might just be in areas of the city that are unattractive for business services because it is more distant from clusters of economic activity. To factor out these more general considerations we construct and calibrate a structural general equilibrium model of the city. Equilibrium land-use is generated by the model, and this is fitted to the city data by calibration of productivity and amenity parameters for each parish. These calibrated parameters capture effects over and above those explicitly described in the model. As we will see in the next section, the model captures many of the economic geography interactions that take place in the city, but does not control directly for the effects of land-tenure. Any such effects are therefore captured in the calibrated amenity and productivity. If these parameters are correlated with the presence of mailo land it suggests that this tenure system is having a direct impact on the location of firms and households within the city.

Our focus in doing this analysis is on mailo land. Customary land is potentially endogenous, in so far as settlers are able to acquire customary land rights if they occupy any freehold or leasehold land over time; locations where informal housing is built may therefore be more likely to become customary with time. The location of mailo land is different in that, as argued above, it is determined not by patterns of settlement but by historical allocations of land at the time of colonisation. Therefore, the location of present households cannot be said to be driving the location of mailo land, the relationship must be from mailo land to the location of households.

Table 2. Share of employment, by sector & share of residential population, by skill and house type.

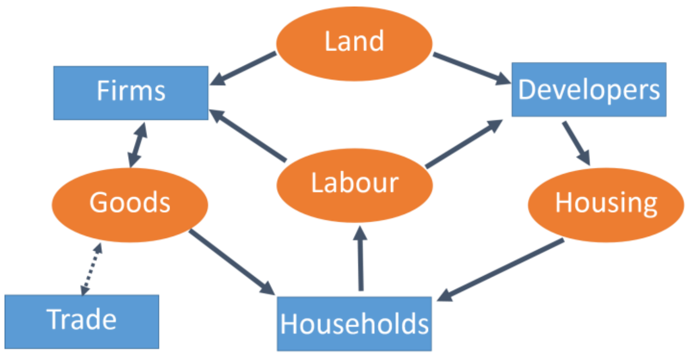
	Share of sector employment in cell employment				Share of skill/housing type in cell residential population			
	Manufacturing	Business services	Consumer services	Single person	High skilled formal	High skilled informal	Low skilled formal	Low skilled informal
Customary (share)-	-0.138	-0.367***	0.269***	0.369***	-0.701***	0.0303	-0.205	0.875***
	(0.116)	(0.116)	(0.0957)	(0.0911)	(0.0934)	(0.0287)	(0.151)	(0.185)
Freehold (share)	-0.00200	-0.130	0.104	0.106	-0.0970	0.0534*	-0.320***	0.364**
	(0.0803)	(0.106)	(0.0821)	(0.0780)	(0.109)	(0.0292)	(0.0866)	(0.141)
Mailo land (share)	-0.109	-0.237***	0.212***	0.114*	-0.221***	0.0439**	-0.400***	0.577***
	(0.0763)	(0.0735)	(0.0581)	(0.0638)	(0.0769)	(0.0172)	(0.0664)	(0.0964)
Area	-0.00305	-0.00765	0.00662	0.0155**	-0.00357	-0.00114	0.0235**	-0.0188
	(0.00645)	(0.00812)	(0.00654)	(0.00730)	(0.00864)	(0.00239)	(0.0112)	(0.0142)
Distance to Centre	0.0114*	-0.00966	-0.00379	-0.00854	0.00838	-0.000541	0.00327	-0.0111
	(0.00670)	(0.00877)	(0.00625)	(0.00763)	(0.00664)	(0.00221)	(0.0109)	(0.0132)
Elevation	0.251	-0.202	-0.0557	-0.957	0.941	0.414	-0.789	-0.567
	(0.986)	(0.798)	(0.690)	(0.759)	(0.838)	(0.262)	(1.287)	(1.573)
Ruggedness	-5.567*	1.191	2.502	1.604	1.897	-1.249*	1.822	-2.470
	(3.328)	(2.175)	(2.099)	(2.523)	(2.541)	(0.672)	(3.739)	(4.987)
Constant	-0.0530	0.595	0.274	1.251	-0.880	-0.412	1.407	0.885
	(1.071)	(0.904)	(0.772)	(0.857)	(0.940)	(0.294)	(1.466)	(1.772)
Other Controls	YES	YES	YES	YES	YES	YES	YES	YES
Observations	92	92	92	92	92	92	92	92
Adjusted R^2	0.085	0.431	0.163	0.257	0.526	0.195	0.339	0.494

OLS regressions on the share of employment in each sector, on the share of parish land under different land tenure systems. Area measured in square kilometers, and distances, elevation and ruggedness in kilometers. Additional controls include distance from nearest school, hospital, major road, and road density. All shares are between 0 and 1. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

3. The model

The model covers the 96 parishes of Kampala, each of which is a spatial cell in the model. Each can contain productive and residential activity. We work with four production sectors, as given in Table 1, plus a locally fixed labour demand from the public sector and urban agriculture. Firms in each of the sectors choose whether and where to enter and how much to produce and sell to each parish. Households are classified into two skill types and may occupy two alternative types of housing, formal and informal (Table 1). They choose where to live, where to work (incurring commuting costs), what sort of housing to occupy (formal or informal), and how much housing and other goods and services to consume. Housing 'developers' chose the quantity and quality of housing offered at each location, with formal and informal sectors using different building technologies. The equilibrium solves for prices and the ensuing choices of firms, households and developers such that supply equals demand for labour, goods, services, housing and land. This is illustrated schematically in Figure 16, with types of decision takers given in rectangles and markets in ellipses. The remainder of this section sets out the ingredients of the model in greater detail, concentrating on the innovative parts of the model. The full specification is given in the appendix.

Figure 16: Agents and Markets



Geography: The 96 parishes are labelled by subscripts *i*, *j*, and there is a further geographical cell (denoted 0) representing the rest of the world. They are connected through a matrix of distances, adjusted by road quality (see Section 4). This matrix underpins three distinct sorts of connectivity. First, the costs of shipping goods and services from firms to households, costs which vary across sectors according to the tradability of output. Second, commuting costs; workers travel from place of residence to place of work, this being more costly (and more time consuming) the further the journey and the worse the roads along which they travel; it also depends on transport mode (motorised or walking), which we assume to be a function of income[8]. Third, possible agglomeration economies, i.e. positive productivity spillovers between firms, the strength of which depends on distance between firms.

Firms: Productive sectors are labelled by superscripts s = 1,..4. They are all monopolistically competitive and contain firms producing differentiated products. The number of active firms in sector

[8] In the application in this paper, for simplification, high-skilled workers have access to motorized transport, and low-skilled works can walk, with no cross-over between the two groups.

s at cell i is denoted n_i^s and this is determined by free entry and exit such that equilibrium profits are zero. Each firm ships output from its location, cell i, to cells j, incurring iceberg trade cost factor T_{ij}^s based on the connectivity matrix outlined above and varying by sector. Cells are also supplied by imports (i.e. goods from outside the city) the prices and numbers of varieties of which are assumed constant. As is standard, there is a price index for each sector s in each cell i, P_i^s which is a CES function of numbers of varieties and delivered prices, with elasticity of substitution σ^s .

Costs of production are a CES function of the prices of labour, intermediates, land, and primary goods/food (imported at a fixed price). We distinguish between two levels of labour skill, indexed by superscript l (l = 1 high skill, l = 2 low skill), with cell i wage rates w_i^l. Intermediates are composite goods with price indices P_i^s .[9] The price of land available to sector s in cell i is r_i^s; we allow this to be sector specific as explained below. The productivity of each sector in each cell is denoted a_i^s and is the product of two terms. One is a sector-cell specific shift factor A_i^s which will be calibrated from the data. The other is sector-cell specific agglomeration economies which depend, according to function $\mathrm{f}^s(.)$, on employment in the sector, L_j^s, weighted by a measure of proximity (inverse distance), θ_{ij}^s, so

$$a_i^s = A_i^s \mathrm{f}^s\left(\sum_j \theta_{ij}^s L_j^s\right) \tag{1}$$

Productivity may depend on the land tenure system in place but we do not directly observe this effect. It is captured in the shift factor A_i^s and will be recovered by cross-parish regression in section 5. The location of government and agricultural employment is taken as exogenous, with the former assumed to be high-skilled and the latter low-skilled intensive.

Households: City-wide populations of the two skill types are exogenous and denoted L^l, l = 1,2. Each household is assumed to have one working member, to choose its consumption pattern, and to make discrete choices of where to live, work, and of whether to live in formal or informal housing. The utility of a household of type l living in cell i, working in j and occupying housing of type h, (h = 1, formal, h = 2, informal) is

$$u_{ij}^{lh} = \left(w_j^l + m_{ij}^l\right) b_i^{lh} t_{ij}^l / \left[\left(q_i^h\right)^{\beta^l} \prod_s (P_i^s)^{\beta^{sl}}\right] \tag{2}$$

The first element in the numerator is income, with wage income depending on labour type and place of work, w_j^l, and other income transfers denoted m_{ij}^l. We will assume that these transfers are the total of rents and profits and that they are distributed equally to all households in a lump sum manner. The second term, b_i^{lh}, is the amenity value to an individual of type l of living in housing of type h in location i. The third term, $t_{ij}^l < 1$ represents commuting costs. These impact utility directly and depend on the distance matrix; they vary by worker type, and we assume that high-skilled workers use motorized transport and low-skilled workers walk. The denominator of eqn. (2) is the consumer price index. This is Cobb-Douglas across goods and housing, where the price of a unit of housing space of type h in cell

[9] These include imports of food, which we treat as an intermediate to single person enterprises, consumer services and (to a small extent) manufacturing.

i is q_i^h. Exponents sum to unity, and these expenditure shares to depend on household skill-level (appendix table A1)

The discrete choices of where to live, where to work, and how to be housed are captured by a choice function giving the probability π_{ij}^{lh} that an individual of type l will live in i, work in j and occupy house type h.[10] If the total city population of workers of type l is L^l, then the number living in houses of type h in cell i is $L_i^{lh} = L^l \sum_j \pi_{ij}^{lh}$, and the total number working in cell j is, summing over the two types of housing, $L_j^l = L^l \sum_i (\pi_{ij}^{l1} + \pi_{ij}^{l2})$.

Housing and developers: The distinction between formal and informal housing is important because, as we have seen, the shares of the two vary widely with land-tenure. To capture the distinction we suppose that there are two building technologies. One is formal, where floor-space per unit land can be achieved by building upwards, although this is at increasing marginal cost. The other is informal, where the technology of construction rules out multi-storey building; however, floor space per unit land can be increased by 'crowding', i.e. putting more single storey buildings in a given area, at constant marginal cost but decreasing utility of residents.[11]

To model this, we suppose that, in the formal sector, h = 1, rent per unit land is $r_i^h = q_i^h g_i^h - (g_i^h)^\gamma c_i^h$. The first term is revenue, where g_i^h is floor-space per unit land and q_i^h is the price of floor-space; the second term is construction costs, increasing and convex in space (proportional to height), with and $\gamma > 1$ and depending on construction costs, c_i^h, a Cobb-Douglas function of the prices of labour and intermediates. Developers choose floor-space per unit land to maximise rent, giving $g_i^h = (q_i^h / c_i^h \gamma)^{1/(\gamma-1)}$; the maximised rent (bid-rent) is then, $r_i^h = c_i^h (\gamma - 1)(q_i^h / c_i^h \gamma)^{\gamma/(\gamma-1)}$. This is illustrated on Fig. 17a which gives revenue and construction costs per unit land as a function of floor-space, g_i^h. The difference between these curves is bid-rent (also illustrated as the dashed line); with iso-elastic cost function bid-rent at the optimum is fraction (1-1/γ) of revenue, the remainder being construction costs.

In the informal sector, h = 2, rent per unit land is $r_i^h = g_i^h \left\{ q_i^h (g_i^h)^{(1-\lambda)/\lambda} \right\} - c_i^h g_i^h$. The marginal cost of adding floor space is constant, but willingness to pay and hence the price of floor space is diminishing in quantity because of the disutility of crowding. This is captured by the term in curly brackets, the product of two elements; the price of floor-space at unit quality is q_i^h, and this is multiplied by a quality deflator, decreasing in floor-space per unit land ($\lambda > 1$). Floor space is chosen to maximise rent, taking q_i^h as constant but internalising the negative impact of crowding on price. The rent maximising value is $g_i^h = (q_i^h / c_i^h \lambda)^{\lambda/(\lambda-1)}$ and bid-rent is $r_i^h = c_i^h (\lambda - 1)(q_i^h / c_i^h \lambda)^{\lambda/(\lambda-1)}$. This is illustrated in Fig. 17b. Diminishing returns now come from the disutility of crowding rather than increasing marginal cost of construction, and rent at the optimum is fraction (1-1/λ) of revenue. We set

[10] This takes a CES form, with theoretical underpinnings coming from Frechet distributed individual-place specific heterogeneity, see for example Ahlfeldt et al. (2015).
[11] See Henderson et al (2016) for further development of this approach.

parameters such that λ > γ, so the land-rent share is greater (construction cost share lower) in the informal sector than in the formal.

Figure 17a: Formal sector housing, *h* = 1.

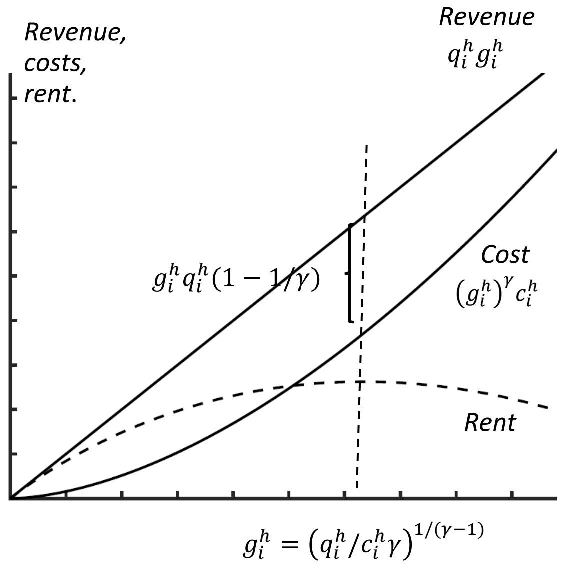
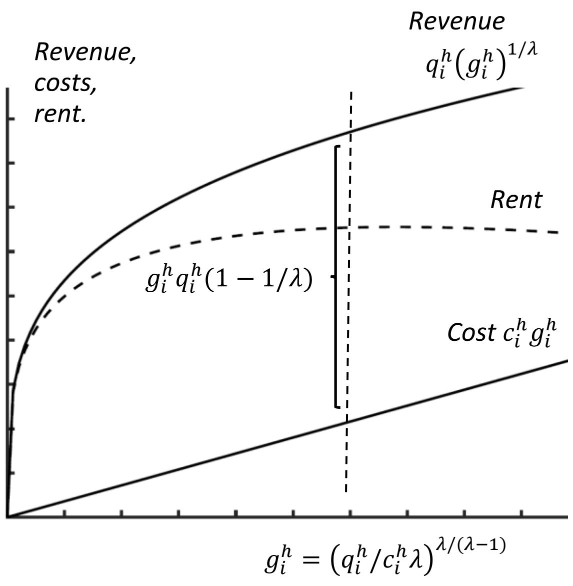


Figure 17b: Informal sector housing, *h* = 2.



Several important points come out of this modelling of housing. First, this approach generates different bid-rents for the two types of housing. It is these rents that determine the allocation of land between different uses, as discussed below. Second, each housing type delivers amenity that enters household preferences (eqn. 2). In the formal sector housing quality is constant, and so therefore is the amenity parameter that enters preferences b_i^{l1}. In the informal sector amenity depends on crowding so is the product of two terms, i.e.

$$b_i^{l2} = B_i^{l2} \left(g_i^2\right)^{\beta^{l2}(1-\lambda)/\lambda} . \qquad (3)$$

The first of these, B_i^{l2} is the parameter to be calibrated, and the second captures endogenous crowding.[12] Amenity may depend on the land tenure system in place but we do not directly observe this effect. It is captured in the shift factors, b_i^{l1}, B_i^{l2} and will be recovered by cross-parish regressions in section 5.

Equilibrium. The model is closed by specifying market clearing, including the market for land and consequent pattern of land-use. Demand for goods, housing, land and labour comes from households, firms, the construction sector and (for goods) also from 'exports'. Supply comes from production, endowments and imports and prices of goods, wages, and house prices. For the land market we take a more flexible approach. There are competing demands for land, represented by bid-rents from commercial use by each sector, r_i^s, residential use from formal and informal sectors, r_i^h, and the outside use, at exogenous rent r_0. A land allocation rule divides the total quantity of land in each cell, $\bar{G}_i$,

[12] This is analogous to the division of the productivity into parts a_i^s and A_i^s in eqn. (1).

between competing uses according to relative bid-rents. We use a CES function, such that land available for use k, G_i^k, is

$$G_i^k/\bar{G}_i = \left(r_i^k\right)^{\varphi}/\left\{r_0^{\varphi} + \sum_k \left(r_i^k\right)^{\varphi}\right\} \tag{3}$$

where superscript *k* runs across alternative commercial and residential uses, $k = s, h$. The parameter φ measures the intensity of competition between different uses, and the larger is this parameter the more responsive is land-use to bid-rents; as φ becomes very large so the land market becomes perfect and all land in a parish goes to the use with highest bid-rent.

4. Data and Calibration

The model is fitted to Kampala using disaggregate data on firm and household location and on the transport network. Geographical data on the city of Kampala comes from shapefiles provided by the Kampala Capital City Authority (KCCA), representing the city in 2013 when collected for the new Kampala Physical Development Plan.

Population and Employment: The population and firm data is discussed in Section 2 above. This is aggregated to the parish level, providing household numbers by skill and housing type, and employment numbers by sector, for all 96 parishes in Kampala.[13] No tenure information exists in four of these parishes, and so the regression analysis in section 5 is restricted to 92 parishes.

Connectivity and transport: Connectivity between parishes in the city is based on the road network extracted from Open Street Maps in October 2015. A network analysis was used to construct the travel cost between all pairs of parishes in the city.[14] Roads are categorized according to their type, and different travel speeds are applied to different roads. For motorized traffic, these speeds are set to 30km/hour along primary roads, 20km/hour along secondary roads, and decreasing speeds for categories of roads beneath these. These speeds reflect the high levels of congestion in Kampala, as documented in recent travel surveys including one by the Ministry of Works and Transport (2012). Travel time calculated this way is the basis for the 'distance' matrix used in shipping goods and services, and for inter-firm productivity spillovers. For commuting, we assume that high-skilled workers have access to motorized transport at these travel speeds. Low-skilled workers travel on foot, with time based on distances in the travel network at a speed of 5km/hour across the whole city. The spatial decay parameter is set so that a 30 minute journey to and from work results in a 5% utility loss.[15]

[13] In the simulation and calibration of the model, the number of households is scaled to match the number of jobs available in the city.

[14] We used the network analysis origin destination matrix from ArcGIS to calculate the fastest travel time between each origin and destination on the network using different travelling methods (walking, baseline driving speed, fast driving speed and congested roads driving speeds). The locations on the network correspond to the centroids of each parish. If the centroids were not located on a road, we added the time to walk to the closest road using the shortest path (the Euclidean distance from the centroid to the closest road) to each distance and duration pairs. See appendix for detailed travel speeds.

[15] With travel times measured in hours, spatial decay parameter for residents is set to 0.1. For goods, the parameter is set to 0.05 for business services, 0.1 for manufacturing, 0.3 for consumer services, and 0.5 for single person firms.

Empirics: The regression analysis includes controls derived from Open Street Maps, including the location of schools, hospitals, major roads, the city centre (defined as the City Square, Kampala) and road density (kilometres of roads per square kilometre). We create the distances by taking the Euclidean distance from the centroid of each parish to the nearest relevant landmark, in kilometers. The mean elevation of land within each parish is also expressed in kilometres, and is calculated using the "Global Multi-resolution Terrain Elevation Data 2010" from the U.S. Geological Survey and NGA, at the 7.5 Arc-second level of precision. Ruggedness is calculated by averaging the slope in all pixels within a parish, with greater values implying more rugged terrain.

Other parameters: Consumption shares across consumer goods and housing space are estimated using data in the Uganda National Housing Survey 2012. Input-output matrices for each of the four production sectors are estimated from an IFPRI social accounting matrix established for the whole of Uganda (Thurlow, 2008). These and other parameters are documented in more detail in appendix B.

The total factor productivity of firms may be subject to agglomeration effects. The calibration process gives productivity parameters a_i^s that can then be divided into a constant parameter A_i^s and an agglomeration element according to equation (1) above. For simulation, we look at cases with and without such productivity spillovers. When present, they are represented by function $f^s\left(\sum_j \theta_{ij}^s L_j^s\right)$ assumed iso-elastic with elasticity of 6% in all sectors[16], and spatial decay parameter θ_{ij}^s exponential in driving time, such that the impact at 30 minutes travel time is just under a quarter of that of immediate proximity.

Goods and services can be imported at a base price of unity, against which all prices, rents and wages within the city are relative. Imports include food, treated as an input to the consumer services sector. The number of varieties available to import is set so that the total value of imports and exports are equal to just under 50% of GVA; around two thirds of the import value is food and primary good imports, while the remainder of imports are predominantly in manufacturing and business services. 35% of the value of manufacturing output is exported, and 45% of the value of business services. These totals include exports to the wider region and elsewhere in Uganda, for example, providing legal services or selling wholesale goods to a shop in neighbouring regions.

Calibration: The application of the model involves two stages, calibration and simulation. The calibration uses the parameters discussed above and calibrates others (productivity and amenity values) such that the model exactly fits the base data across the 96 city parishes. The calibration process solves the model to find productivity and amenity parameters, a_i^s and b_i^{lh} at which values of endogenous variables match the data. In cases in which there are productivity spillovers we use equation 1 to extract spillover effects and derive parameters A_i^s. For households that choose informal housing, we use equation 3 to extract the loss of amenity due to crowding and derive parameters B_i^{l2}.

The productivity parameters for each sector-cell and amenity parameters for each house type-cell are mapped in the appendix. Much of the observed pattern of firm location and household residence is

[16] The choice of 6% corresponds to the estimated values of 3-8% reported in Rosenthal and Strange (2004), and is of a similar magnitude to 7% estimate by Ahlfeldt et al. (2015)

explained by the structure of the model with, for example, the pattern of residence shaped by proximity to jobs. The productivity and amenity parameters can be thought of as residuals, calibrated to fit the model exactly to the data. It is therefore interesting to ask what share of the variance across cells of employment by sector and population by type is explained by these parameters, the remaining share being explained by the structure of the model as it captures the economic geography of the city. OLS regressions of employment by sector in each parish on the calibrated productivity parameters give R^2 of 0.16 for manufacturing, 0.30 for one-person firms, 0.48 for producer services, and 0.55 for consumer services. This indicates that between 84% and 45% of the variation in employment across the city is explained by the geographical structure of the model, rather than the productivity parameters. Across households, there is an R^2 of 0.04 for high-skilled formal and 0.25 for high-skilled informal, 0.16 for low-skilled formal and 0.38 for low-skilled informal; this in turn indicates that between 96% and 62% of the variation in the location patterns of households in the city is accounted for by the structure of the model. In the next section, we ask whether the remaining variance in output and population, captured by these productivity and amenity parameters, is in part explainable by local variation in land tenure systems.

5. Productivity, amenity and land tenure.

The productivity and amenity parameters are essentially residuals from the model: the unexplained benefits to firms and households of locating in specific cells, beyond the factors in the economic geography of the model. Since land tenure is not explicitly contained in the model, the parameters contain information about the impact of tenure on the observed outcomes. They may also capture some other local geographical features that the model does not included, such as the quality of the land, and the presence of local amenities including schools and hospitals.

To extract this information we regress these parameters on land tenure types and further controls, with results reported in Table 3 and Table 4. These are analogous to Table 2 but with dependent variables now the productivity and amenity parameters of different forms of land-use, rather than the observed land-use shares. As the parameters are all estimated from the same system we use a Seemingly Unrelated Regression estimation model (Zellner 1962), which allows for correlation across the error terms between each regression. The regression uses the productivity parameters derived using 6% returns to scale in each sector. Additional results for 0% returns are reported in the appendix, giving qualitatively and quantitatively very similar results.

Columns 1-4 in Table 3 show the link between land tenure and the productivity parameters, controlling for major geographical features of the cells including distance to the centre, elevation and ruggedness of the land. Leasehold tenure is the base system. We find that there is no significant effect of any of the land tenure systems on the productivity parameters, apart from a small negative relationship between customary land and one person firms (which does not exist at lower returns to scale in this sector, see appendix). The model, in factoring in all other determinants of location of employment in the city, has revealed that mailo land in itself is neither a negative determinant of business services productivity nor a positive determinant of productivity in consumer services and one-person firms. In columns 5-8 we additional control for some local amenities that could plausibly influence the productivity of the cells, but which may be argued to have developed as a result of the past economic activity in these areas. The addition of these controls, distance to the nearest school and hospital, major road and local road density, does nothing to change the results on the impact of mailo land on productivity.

In table 4 we repeat the exercise for the amenity parameters. In columns 1-4, we again control for only exogenous geographical features. The presence of mailo land is a strong positive driver of the amenity parameters for informal housing, for occupancy by both high-skilled and low-skilled households. A cell that is completely mailo, compared to one that is completely leasehold, offers 18% higher amenity for high skilled in informal housing, and 19% for low-skilled in informal housing. Ruggedness is the only significant topographical feature, with more rugged land reducing local amenity values.

Since mailo seems to support amenity, what does the amenity represent? There are two possibilities. One is that rents are capped for institutional, legal or historical reasons. We know that tenants on mailo land are subject to rents that are controlled by the Buganda Land Board, that are set at a level of just 13 USD per year, and so we interpret much of this amenity benefit as deriving from households paying rents below the market rate. The other possibility is amenity in kind: better security of tenure, or better access to local services, schools, neighbourhood qualities. In columns 5-8 we control for some of these potential additional amenities, including distance to the nearest school, hospital and major road. Once controlled for, the effect of mailo land on amenity is actually slightly higher for both high and low-skilled in informal housing, with a coefficient of 0.2. In the appendix, we detail in the table A5 the full regression with all the controls, and we observe that amenity decreases with greater distances to schools, and to a lesser extent, hospitals, and well as decreases in areas with lower road density. The higher coefficient on mailo when we include these additional controls suggests that mailo land may actually have worse access to these facilities, and when we control for this worse access, the direct amenity effect of mailo land is even higher. Therefore, we conclude that the amenity effect of mailo land is driven either through the minimal annual rents that occupiers are required to pay or through other tenure specific qualities, such as relatively high security of tenure. Without rent data across the city we are unable to attach weights to these two possibilities. For the simulations of the next section the distinction is unimportant for quantity predictions, but does matter for welfare interpretation, as will be discussed.

Looking at other tenure forms, freehold land no longer has a significant influence on housing choices. Customary land tenure is an even stronger driver of the presence of informal housing, with a cell that is completely customary 35% more amenable for the high-skilled in informal housing, and 45% more amenable for the low-skilled in informal housing. This indicates that the effects we find for mailo land also hold for customary land; however, we hesitate to attach a causal relationship to this, as the share of land in each parish under customary tenure has evolved over recent decades so is less plausibly exogenous. In the experiment of the following section we look only at the reform of mailo, and not of customary lands.

Finally, how do we reconcile the absence of mailo effects on productivity parameters in Table 3 with the significant correlations of mailo on employment in business services and consumer services reported in Table 2? The answer is via the general equilibrium of the urban economy; in particular, employment is crowded out of mailo areas because of their attractiveness to informal settlement.

Table 3. Productivity parameters

	Manufacturing	Business services	Consumer services	Single person	Manufacturing	Business services	Consumer services	Single person
Customary (share)	0.0211	-0.144	-0.0380	-0.0620**	0.0362	-0.117	-0.0344	-0.0602*
	(0.154)	(0.150)	(0.0271)	(0.0312)	(0.142)	(0.140)	(0.0262)	(0.0312)
Freehold (share)	-0.0866	-0.151	-0.0250	-0.0284	0.0342	-0.0554	-0.0124	-0.0213
	(0.132)	(0.129)	(0.0233)	(0.0269)	(0.124)	(0.122)	(0.0228)	(0.0271)
Mailo land (share)	-0.0979	-0.100	-0.0179	-0.0286	-0.0251	-0.0189	-0.00610	-0.0185
	(0.0939)	(0.0917)	(0.0165)	(0.0191)	(0.0880)	(0.0870)	(0.0162)	(0.0193)
Area	-0.00549	-0.00402	0.00482**	0.0103***	-0.00406	-0.00248	0.00500**	0.0101***
	(0.0129)	(0.0126)	(0.00228)	(0.00263)	(0.0123)	(0.0122)	(0.00227)	(0.00270)
Distance to Centre	-0.0423***	-0.0267***	-0.00260	0.00351*	-0.0221**	-0.0108	-0.000549	0.00479**
	(0.0101)	(0.00983)	(0.00177)	(0.00204)	(0.0110)	(0.0109)	(0.00202)	(0.00241)
Elevation	0.280	0.813	-0.0186	-0.325	-0.649	-0.0681	-0.133	-0.396
	(1.437)	(1.404)	(0.253)	(0.292)	(1.326)	(1.310)	(0.244)	(0.291)
Ruggedness	-8.359*	-9.031**	-1.145	-0.347	-5.166	-5.910	-0.687	-0.0222
	(4.357)	(4.258)	(0.767)	(0.885)	(4.015)	(3.969)	(0.740)	(0.880)
Constant	0.943	0.913	0.583**	1.172***	1.824	1.723	0.685**	1.229***
	(1.616)	(1.579)	(0.284)	(0.328)	(1.486)	(1.469)	(0.274)	(0.326)
Other Controls	**No**	**No**	**No**	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	92	92	92	92	92	92	92	92
Adjusted R^2	0.345	0.248	0.139	0.381	0.465	0.372	0.230	0.411

Estimated using a Seemingly Unrelated Regression through the sureg command in stata. Returns to Scale in all sectors of production are set to 6%. Area measured in square kilometers, and distances, elevation and ruggedness in kilometers. Additional controls include distance from nearest school, hospital, major road, and road density. All shares are between 0 and 1. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Amenity parameters

	High skilled formal	High skilled informal	Low skilled formal	Low skilled informal	High skilled formal	High skilled informal	Low skilled formal	Low skilled informal
Customary (share)	-0.0789	0.265*	0.0814	0.367***	-0.0974	0.217*	0.0550	0.316**
	(0.0750)	(0.136)	(0.0794)	(0.140)	(0.0722)	(0.128)	(0.0759)	(0.134)
Freehold (share)	-0.0523	0.0551	-0.0488	0.0666	0.00169	0.161	0.0107	0.166
	(0.0645)	(0.117)	(0.0683)	(0.120)	(0.0629)	(0.112)	(0.0661)	(0.117)
Mailo land (share)	-0.0429	0.184**	-0.0241	0.192**	-0.0284	0.202**	-0.0127	0.206**
	(0.0458)	(0.0829)	(0.0484)	(0.0854)	(0.0447)	(0.0794)	(0.0470)	(0.0832)
Area	0.000983	-0.0138	-0.000662	-0.0172	-0.00103	-0.0178	-0.00344	-0.0218*
	(0.00631)	(0.0114)	(0.00667)	(0.0118)	(0.00625)	(0.0111)	(0.00657)	(0.0116)
Distance to Centre	-0.0153***	-0.0341***	-0.00275	-0.0198**	-0.00515	-0.0149	0.00866	-0.00126
	(0.00490)	(0.00888)	(0.00519)	(0.00916)	(0.00559)	(0.00991)	(0.00587)	(0.0104)
Elevation	1.603**	1.610	1.335*	1.366	1.361**	1.288	1.112	1.086
	(0.701)	(1.269)	(0.741)	(1.308)	(0.674)	(1.196)	(0.708)	(1.253)
Ruggedness	-7.171***	-11.88***	-7.410***	-11.33***	-6.396***	-10.34***	-6.702***	-10.09***
	(2.124)	(3.847)	(2.247)	(3.966)	(2.040)	(3.621)	(2.144)	(3.795)
Constant	-0.664	-0.557	-0.441	-0.341	-0.431	-0.261	-0.223	-0.0781
	(0.788)	(1.427)	(0.833)	(1.471)	(0.755)	(1.340)	(0.794)	(1.405)
Other Controls	**No**	**No**	**No**	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	92	92	92	92	92	92	92	92
Adjusted R^2	0.282	0.397	0.152	0.324	0.363	0.487	0.258	0.405

Estimated using a Seemingly Unrelated Regression through the sureg command in stata. Returns to Scale in all sectors of production are set to 6%. Area measured in square kilometers, and distances, elevation and ruggedness in kilometers. Additional controls include distance from nearest school, hospital, major road, and road density. All shares are between 0 and 1. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6. Land tenure reform

The calibrated model supports the equilibrium observed in the data, and we now use the model for counterfactual analysis. How would city-wide tenure reform – specifically, replacing all mailo tenure with leasehold – change the city, both directly in the parishes most concerned and indirectly as firms and households readjust their location and consumption decisions, forming a new urban equilibrium? The tenure systems are not parameters of the model but we know, from the regression analysis of tables 3 and 4, how land tenure affects model parameters. The mailo land tenure system was shown to have a significant effect only on the amenity parameters for households (both high and low-skilled) in informal housing. We therefore use these estimates to calculate predicted values of these amenity parameters when mailo land in every parish reduced to zero. We re-input these new amenity parameters into the model and solve to find a new equilibrium, which we then compare against the baseline city. There are changes in the pattern of economic activity across the city, and real income changes. Some of the income change is the direct effect of the policy which, as discussed above, can be interpreted either as the direct reduction in amenity benefits to informal households living in these areas, or as the removal of a rent cap, a transfer payment from those in informal housing on mailo land to rent-recipients. The remainder of the income effect arises from a change in the efficiency of land-use, particularly arising as firm location changes

6.1 Aggregate Impacts

Table 5 gives employment by sector, housing choice, and indices of real income (utility). Column 1 is the baseline, matching the actual Kampala data, and column 2 gives the direct effect of converting mailo land to leasehold, holding constant all endogenous variables (so forcing the model out of equilibrium). The following columns give different adjustment scenarios. Column 3 allows prices and quantities to equilibrate, but holds the locations of all firms and households unchanged, while columns 4 and 5 allow relocation in response to profit opportunities and spatial differences in household utility. In column 4 this is done imposing zero economies of scale, and in column 5 localisation economies are set at 6%.

Direct effects have no impact on quantities (by construction), but do change real incomes, as reported in the central block of the table (column 2). Occupants of informal housing on mailo land lose amenity benefit worth 20% of their overall utility, but no other group is directly affected. The predicted parameter changes from the land conversion directly affects that 61% of households that live in informal housing in the base, with the size of this impact varying according to the share of the parishes land under mailo tenure. Expressing the total effect as an average impact for each worker type, this loss of amenity reduces utility by an average of 2.8% for high skilled workers and 4.1% for low skilled (table 5 column 2). If it is this is a loss of real amenity then there is no offsetting transfer to landlords, so the direct effect across the entire population amounts to a 3.7% fall in aggregate welfare (*Amenity; real cost*). If however occupants' amenity is derived from a rent cap, then their loss is landlords' gain. The direct effect is a transfer, increasing total real rental income by 5.6% and leaving aggregate welfare unchanged (*Amenity: transfer*). These two cases provide bounds on the distributional impact of the reform; the following discussion is based around the 'real cost' interpretation, adding comments on how the transfer case differs from this.

Table 5: Conversion of mailo land to leasehold

	1	2	3	4	5
	Base	**Direct effect**	**Fixed location**	**Full adjustment RS = 0%**	**RS = 6%**
Numbers (Thousands)					
Employment Manufacturing	28.9	0.0%	2.6%	11.6%	94.0%
Employment Business Services	74.3	0.0%	0.4%	-1.6%	-24.3%
Employment Consumer Services	123.8	0.0%	-0.5%	-1.6%	-3.8%
Employment One-person	72.0	0.0%	-0.7%	-0.1%	-6.2%
Informal Households	161.0	0.0%	-42.3%	-44.8%	-55.6%
Formal Households	103.3	0.0%	66.0%	69.8%	86.7%
Changes in real income (per capita utility)					
Amenity: real cost					
High Skill	100	97.2	100.3	100.2	89.2
Low Skill	100	95.9	97.9	98.9	108.9
Rental income	100	100.0	98.5	99.4	114.7
Aggregate	100	96.3	97.7	98.4	103.0
Amenity: transfer					
High Skill	100	97.2	100.3	100.2	89.2
Low Skill	100	95.9	97.9	98.9	108.9
Rental income	100	105.6	104.1	105.1	120.3
Aggregate	100	100.0	101.4	102.0	106.7

Column 3 allows partial adjustment, in which households and firms change their consumption patterns, housing choices, and input/output quantities in response to the removal of the rent cap, price and wage adjustment occurs, but all households and firms remain in the same geographical cell of the model. This is quite an artificial situation – we allow the housing stock in each place to change although people cannot relocate - but the direction of change of variables is instructive in building intuition about the full equilibrium changes of columns 4 and 5. Three points are noteworthy.

First, there is a small (1.4%) increase in aggregate welfare, compared to column 2, as firms and households adjust to the direct effects. The adjustment to these effects involves lower demand for housing in the affected areas, so while the utility of both types of workers increases, rents fall somewhat. The aggregate figures mask change at the parish level. Figures 18a-c give changes in nominal rents in each parish as a function of the initial mailo share, and Figure 18a indicates that rents in the most affected areas fall by as much as 20%. Second, the adjustment takes the form of a massive switch from informal to formal housing, as indicated in the top block of table 5. As noted above, the direct amenity loss experienced by a mailo resident amounts to approximately 20% of real income so nearly every affected household switches to formal housing. City-wide, 61% of households live in informal housing (muzigo) in the base, and this share reduces to 35%, while formal housing rises from a 39% share to 65%. Third, there is a small (2.6%) increase in manufacturing employment in response to the fall in rent. While the aggregate decline in real rental income is small, the decline in nominal rents in mailo areas is large (figure 18a) and the increase in manufacturing employment occurs in the most affected areas. Changes in manufacturing employment by parish are given in Figures 19a, and the relationship between the increase in manufacturing and the share of land initially under mailo tenancy is positive and significant.

In column 4, we allow all firms and households to adjust fully, assuming no returns to scale in any of the four sectors of production. As adjustment occurs, so aggregate welfare increases by a further 0.7 percentage points. The main change is the movement of firms into the areas where there was previously mailo land, responding to the lower rents observed in Figure 18a. Manufacturing, as the most land-intensive sector, experiences the largest increase with overall employment rising by 11.4%. This partially reverses the fall in rents (column 3 relative to 2 and Figure 18b compared to Figure 18a). The expansion of manufacturing somewhat crowds out other productive sectors and, since manufacturing is relatively low-skilled labour intensive, low-skilled workers experience a utility increase, while high-skilled experience a small fall.

Column 5 reports results in which there is full adjustment and increasing returns are set at 6% in each of the productive sectors. These are spatially concentrated localisation economies (equation 1), and the spatial decay factor is set such that 40% of the productivity effect is lost within 10 minutes driving time between firms, and 80% is lost within 30 minutes. The effect of the tenure reform is now to trigger quite significant structural change, with city-wide manufacturing employment nearly doubling (96% increase, Table 5 column 5). Manufacturing is most affected because of its land intensity, and other sectors are crowded out. The negative impact is greatest on business services, this because both manufacturing and business services are relatively tradable, so changes in production can be offset by changes in net exports. Aggregate welfare rises to 3.0% above the baseline: utility of low skilled workers rises by an average of 8.9%, although that of high-skilled workers falls by an average 10.8%, since manufacturing is less labour intensive relative to business services. Average rental income rises sharply (14.7% above the base) as some of the productivity benefits of urban agglomeration are captured by rents around the cluster.

Understanding these changes requires looking at the location of activities within the city. Figures 19a-c give changes in manufacturing employment (measured as percentage points of average initial manufacturing employment per unit area). Figure 19b indicates that, with increasing returns to scale set to zero, the change in manufacturing employment is concentrated in relatively few parishes. In particular, these are areas just to the south-west of central Kampala which in the base have a high mailo share, with a couple of these parishes initially more than 75% mailo, and a moderate manufacturing presence. The presence of positive returns to scale – the 6% returns of column 5 and Figure 19c – delivers a spatially concentrated increase in productivity which amplifies these effects, further strengthening manufacturing in the area, increasing productivity and developing a pronounced manufacturing cluster in these parishes. Figure 19c indicates the extent of the spatial reorganisation, with some parishes experiencing very large declines in manufacturing employment, and others large increases.

The geographical concentration of these parishes is indicated by figures 20a-c which map manufacturing employment density. Figures 20a and 20b are the base and full adjustment with zero returns to scale. Adding positive (6%) returns to scale, figure 20c reveals that manufacturing employment becomes more tightly clustered in a few parishes located south-west of the city centre. Initially, each manufacturing job was on average within 20 minutes driving time of 26% of all other manufacturing jobs; with the increased clustering of manufacturing, now 35% of all other manufacturing jobs are within 20 minutes driving time. This amounts to a fall in the average distance between each pair of manufacturing jobs of 0.8-1km. Productivity growth is therefore driven not just by total manufacturing employment, but by its spatial reorganisation. Thus, the mechanism that operates in response to tenure reform is that there is a reorganisation of land-use, part of which is an increased clustering of manufacturing activity within the city. It moves into some parishes which previously had a large share of mailo land, and into other parishes where land is freed up as other firms and households move into previously mailo areas. It is this spatial reorganisation that delivers the large productivity and welfare gains. [17]

The preceding discussion assumed that the amenity benefits of mailo are entirely real benefits, when in fact at least part of them are transfer payments derived from capping of some rents in these areas. Thus, the aggregate gain of 3.0% discussed above rises to 6.7% if the change in amenity is a transfer arising from loss of the rent cap (Table 5, central block, *Amenity; transfer*).[18]

Finally, it is helpful express these numbers per household experiencing the tenure reform. Approximately 30% of the city's households are on mailo land, and so are directly affected by the experiment. Each 1% increase in city-wide real income is equivalent to an income increase for each of these households of an amount equal to 12% of average city rent.[19] The efficiency gain from the policy with zero returns to scale is therefore worth 24% of average rent per directly affected household, this rising to 80% with returns to scale of 6%.[20] These are not small numbers, since it is a one-off reform that can be expected to last in perpetuity. Discounting at 5%, the capital value of the reform per directly affected household ranges from 4.6 times average city rent to 16.4 times average city rent.[21]

[17] Agglomeration gains do not 'cancel out' as they do under some assumptions (e.g. Moretti and Kline 2014) because, at our fine spatial scale, there are spillover effects between parishes.

[18] Transfer payments have no effect on quantity outcome since preferences for goods and services of all agents are identical and homothetic.

[19] 30% of the city's households are on mailo land. Rent (actual and imputed) is 28% of spending. 1% of total city income is therefore 1/(0.3x0.28) = 12% of average city rent per directly affected household..

[20] Respectively 0.12x2.0 and 0.12x6.7.

[21] Using a very different methodology, Henderson et al (2017) estimate the cost of persistent slums in Nairobi at around 20 times current *slum* rent. This is comparable to our estimate expressed as a multiple of *average* city household rent.

Figure 18a: Change in Rents[22]
Fixed location: (column 3)

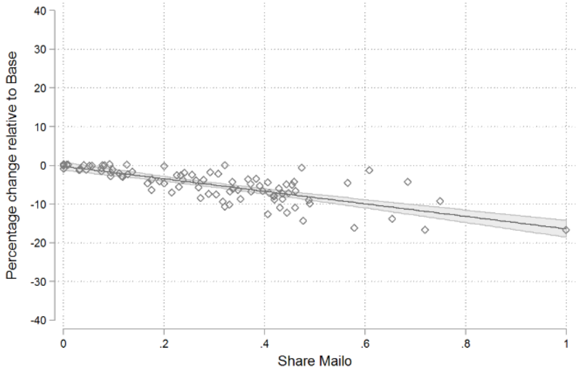


Figure 18b: Change in Rents
Relocation, RS = 0: (column 4)

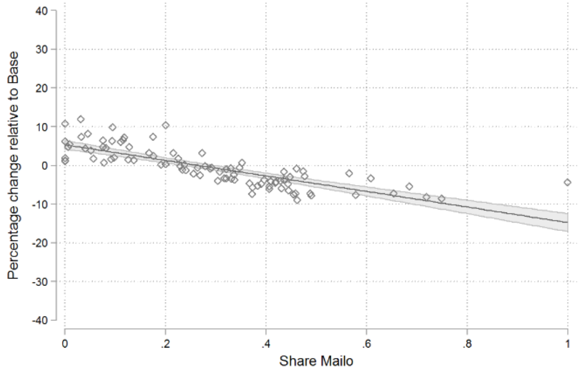


Figure 18c: Change in Rents
Relocation: RS = 6%: (column 5)

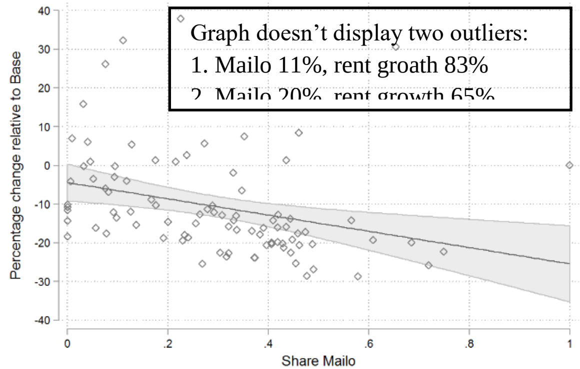


Figure 19a: PP change Manufacturing intensity[23]
Fixed location: (column 3)

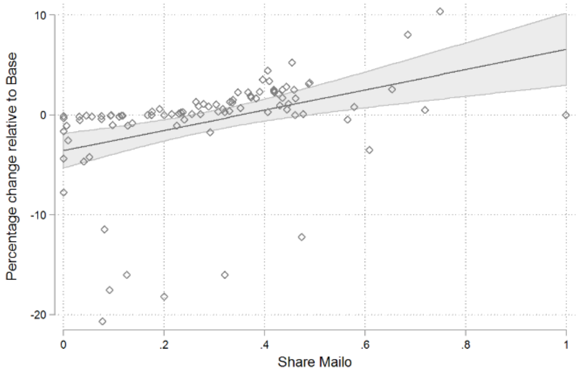


Figure 19b: PP change Manufacturing intensity
Relocation, RS = 0: (column 4)

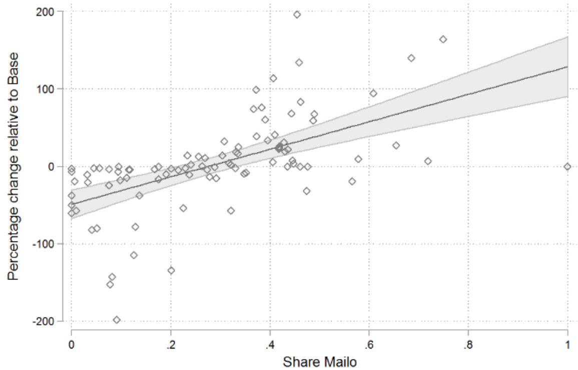
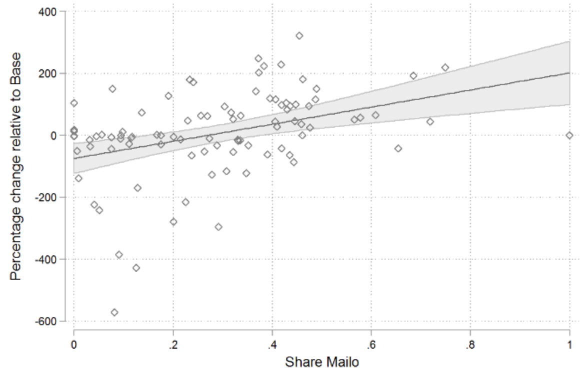


Figure 19c: PP change Manufacturing intensity
Relocation: RS = 6%: (column 5)



[22] Scatter plot of all parishes, and a linear fit of an OLS regression of change in rents against share of land under Mailo, with a band showing the 95% confidence interval.
[23] Percentage Point change in ratio of manufacturing density in cell relative to urban mean. For example, a parish with manufacturing density initially at 200% of the urban mean, increasing to 300% in the scenario, would observe a percentage point change of +100. Note the range of the y axis is much smaller for 19a relative to 19b and 19c.

Figure 20a: Manufacturing Density[24]
(1) Base

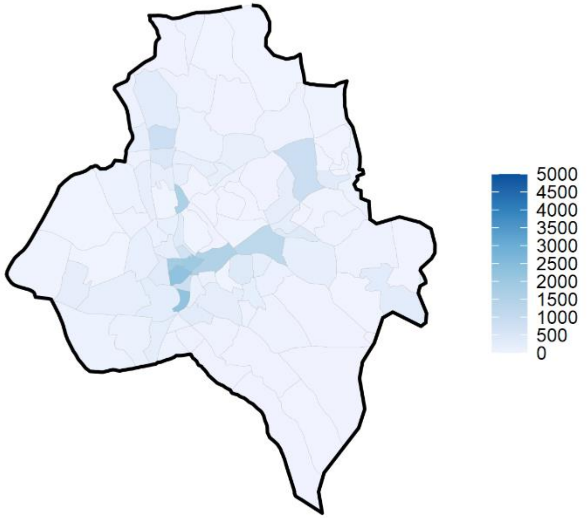


Figure 20b: Manufacturing Density
(4) Relocation, RS = 0

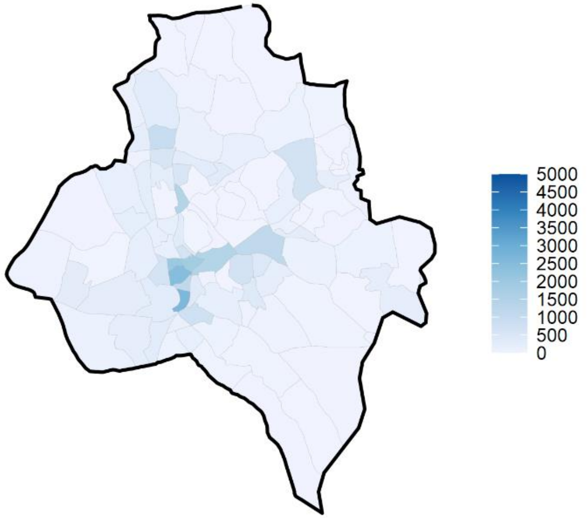
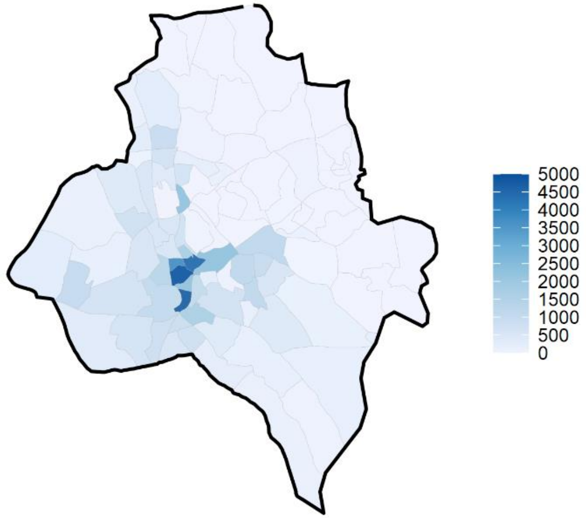


Figure 20c Manufacturing Density
(5) Relocation, RS = 6%



[24] Employment in manufacturing per square kilometer

7. Conclusions

This paper highlight the strong correlations that exist in Kampala, Uganda, between different land tenure systems and the location of formal and informal housing, and employment in different sectors of production. The existence of a complex land tenure system such as mailo is negatively correlated with employment (particularly in business services) and positively correlated with informal housing. Qualitative evidence suggests that this is due to the difficulties in transferring this land, due to the dual-ownership rights, and the rent caps at play that make the land particularly desirable for tenants in informal housing. Historical evidence confirms that the location of mailo is plausibly exogenous, little changed for more than a century.

However, to establish that it is the mailo tenure system that is driving this, and not just an underlying pattern in which mailo land is located in less accessible parishes, we construct a structural model of the city which allows the economic decisions of all firms and households, and their interactions, to be taken into account. This model does not explicitly include the location of different land tenure systems, but the calibration process derives productivity and amenity parameters for each location, parameters which include the impacts of land tenure. Regression analysis on these reveals that mailo is affecting the location of employment and households within the city through its direct effect on informal housing. These households receive an amenity benefit from locating on mailo land, which can either be a direct amenity, or, as the evidence suggests, a rent cap. This direct effect on informal housing means that, in equilibrium, there is little employment in mailo areas.

Having uncovered the direct effect of mailo on parameters of the model, we are able to simulate the long term impacts of reforming mailo land and converting it to leasehold. Reform leads to a re-allocation of households and firms across parishes in the city. The market rents in mailo locations initially fall as they become less attractive for informal housing. In response, employment expands in these areas. The total effects of this are large: manufacturing expands the most, as the land-intensive sector, increasing output by 12% if there are no scale economies, and by 94% with 6% returns to scale. The total impact is then an increase in aggregate welfare of 6.7% (or 3.0% if reform takes the form of a loss of real amenity rather than removal of a rent cap). Gains are more than sufficient to compensate anyone who has lost amenities from the land conversion, and are skewed towards low-skill households. Per directly affected household (i.e. those initially on mailo land), gains are equivalent to 24% of average rent (no scale economies), this rising to 80% with returns to scale of 6%. The capital value of the reform per directly affected household ranges from 4 times average city rent to 16 times average city rent.

These effects are estimated under a long-term time horizon: firms and households can fully re-adjust to the new land tenure system. In reality, the adjustments may be slower or not so complete. However, the results reveal that land reform can lead to large efficiency gains through the relocation of economic activity, and through the induced new cluster patterns, can boost firm productivity, GDP, and individuals' welfare. Thus, the reform of land tenure operates, as it should, by enabling a more efficient use of land and more efficient location of economic activity.

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Appendix Appendix

A. Model Detail

Geography: The city contains I + 1 geographical cells, labelled by subscripts i, j. Of these, I are in the city and one (denoted 0) is the rest of the world. The area of cell i is $\bar{G}_i$.

Production: There are S productive sectors, labelled by superscripts s = 1, 2 ...S. The number of active firms in sector s at cell i is n_i^s, each charging producer price p_i^s and incurring iceberg trade cost factor T_{ij}^s on sales in cell j. Products from the rest of the world arrive at price p_0^s and have n_0^s varieties (both exogenous). The elasticity of substitution between varieties in sector s is σ^s, so the CES price index for sector s products delivered to cell j is

$$P_{ij}^s = \left[\sum_i n_i^s \left(p_i^s T_{ij}^s\right)^{1-\sigma^s} + n_0^s (p_0^s)^{1-\sigma^s}\right]^{1/(1-\sigma^s)} \tag{1}$$

Demand for a single sector s variety produced in i and sold across all cells j is x_i^s, given by

$$x_i^s = \sum_j (p_i^s)^{-\sigma^s} \left(T_{ij}^s\right)^{1-\sigma^s} E_j^s \left(P_j^s\right)^{\sigma^s-1} \tag{2}$$

where E_j^s is cell j expenditure on sector s.

Each cell i sector s firm maximises profits, $\Omega_i^s = p_i^s x_i^s - [x_i^s + F^s]c_i^s$ giving price

$$p_i^s = \sigma^s c_i^s / (\sigma^s - 1) \tag{3}$$

Firms make zero profits if they sell a fixed level of output $\bar{x}^s = (\sigma^s - 1)F^s$. Free entry and exit of firms gives condition:

$$\text{If } n_i^s > 0,\ x_i^s = \bar{x}^s, \text{ else } n_i^s = 0,\ x_i^s < \bar{x}^s, \tag{4}$$

The sector s cost function in cell i is

$$c_i^s = (1/a_i^s)\left[a^{ms}(r_i^s)^{1-\eta^s} + \sum_l a^{ls}\left(w_i^l\right)^{1-\eta^s} + \sum_z a^{zs}(P_i^z)^{1-\eta^s} + a^{fs}\left(p_i^f\right)^{1-\eta^s}\right]^{1/(1-\eta^s)} \tag{5}$$

This is a CES function of the prices of land, r_i^s, labour w_i^l; and intermediates, P_i^z with elasticity of substitution η^s. The final term in this expression is the price of food, p_i^f, which enters the model only as input to the retail and wholesale trade sector. The productivity of each sector in each place is captured by a_i^s. This is a sector-cell specific shift factor A_i^s together with possible sector-specific agglomeration economies which depend, according to function $\mathrm{f}^s(.)$, on employment in the sector, L_j^s, weighted by some measure of proximity, θ_{ij}^s, so

$$a_i^s = A_i^s \mathrm{f}^s\left(\sum_j \theta_{ij}^s L_j^s\right). \tag{6}$$

It follows from this structure that each sector's supply and demands are as follows:

Value of output supplied by cell i: $n_i^s p_i^s x_i^s$

Value of labour type l demanded in cell i:

$$w_i^l L_i^{ls} = n_i^s[x_i^s + F^s] w_i^l \frac{\partial c_i^s}{\partial w_i^l} = n_i^s c_i^s [x_i^s + F^s] a^{ls}\left(w_i^l / c_i^s a_i^s\right)^{1-\eta^s}$$

Value of intermediate from sector z demanded by sector s in cell i:

$$P_i^z I_i^{zs} = n_i^s[x_i^s + F^s] P_i^z \frac{\partial c_i^s}{\partial P_i^z} = n_i^s c_i^s [x_i^s + F^s] a^{zs}(P_i^z / c_i^s a_i^s)^{1-\eta^s}$$

and similarly for food inputs to the non-traded services sector.

Value of land demanded by sector *s* in cell *i*

$$r_i^s G_i^s = n_i^s [x_i^s + F^s] r_i^s \frac{\partial c_i^s}{\partial r_i^s} = n_i^s c_i^s [x_i^s + F^s] a^{ms} (r_i^s / c_i^s a_i^s)^{1-\eta^s}$$

Residential construction: There are two distinct types of housing, formal (h = 1) and informal (h = 2). For the formal sector, h = 1, rent per unit land is $r_i^h = q_i^h g_i^h - \left(g_i^h\right)^\gamma c_i^h$ where γ is the elasticity of costs with respect to density (height). A developer's optimisation problem is to choose g_i^h to maximise this. The rent maximising value of g_i^h and optimised bid rent are:

For h = 1: $$g_i^h = \left(q_i^h / c_i^h \gamma\right)^{1/(\gamma-1)} \quad , r_i^h = c_i^h (\gamma - 1) \left(q_i^h / c_i^h \gamma\right)^{\gamma/(\gamma-1)} . \qquad (7)$$

In the informal sector rent per unit land takes the form is $r_i^h = g_i^h \left\{ q_i^h \left(g_i^h\right)^{(1-\lambda)/\lambda} \right\} - c_i^h g_i^h$. Floor space is chosen to maximise rent, taking q_i^h as constant but internalising the possible negative impact of crowding on price. The rent maximising value of g_i^h and optimised bid rent are:

For h = 2: $$q_i^h \text{ is } g_i^h = \left(q_i^h / c_i^h \lambda\right)^{\lambda/(\lambda-1)} , \quad r_i^h = c_i^h (\lambda - 1) \left(q_i^h / c_i^h \lambda\right)^{\lambda/(\lambda-1)}. \qquad (8)$$

The area of cell that is used by housing of type *h* is denoted G_i^h so the quantity of floor- space of type *h* supplied in cell *i* is $G_i^h g_i^h$. It follows that the values of residential rent and of housing supply of housing in cell *i* are:

Value of residential rent in cell *i*: $\sum_h G_i^h r_i^h$

Value of type *h* housing supplied in cell *i:*

h =1: $G_i^h r_i^h \gamma / (\gamma - 1)$: *h* =2: : $G_i^h r_i^h \lambda / (\lambda - 1)$.

The construction cost of building is Cobb-Douglas, so c_i^h is

$$c_i^h = K_i^h \prod_l \left(w_i^l\right)^{\mu^{lh}} \prod_s (P_i^s)^{\mu^{sh}} \qquad (9)$$

where exponents sum to unity and parameter K_i^h is a cost parameter. Derived demands for inputs used in housing can be expressed, in value terms, as shares of revenue from housing so:

Value of construction demand in cell *i* for inputs from sector *s:*

$$\mu^{s1} G_i^1 r_i^1 \gamma / (\gamma - 1) + \mu^{s2} G_i^2 r_i^2 \lambda / (\lambda - 1):$$

Value of construction demand in cell *i* for labour of type l:

$$\mu^{l1} G_i^1 r_i^1 \gamma / (\gamma - 1) + \mu^{l2} G_i^2 r_i^2 \lambda / (\lambda - 1):$$

Households: There are different types of households (= workers) indexed by l, and the city population of households of type l is L^l taken to be exogenous. These households choose consumption bundles and make discrete choices of where to live, work, and formal or informal housing. The utility of a household of type *l* living in cell *i*, working in *j* and occupying housing of type *h*, (*h* = 1, formal, *h* = 2, informal) is

$$u_{ij}^{lh} = \left(w_j^l + m_{ij}^l\right) b_i^{lh} t_{ij}^l / \left[\left(q_i^h\right)^{\beta^{hl}} \prod_s (P_i^s)^{\beta^{sl}} \right] \qquad (10)$$

These discrete choices are captured by a choice function (with Frechet parameter ζ) giving the probability that an individual of type l will live in i, work in j and occupy house type h, π_{ij}^{lh}.[25] For each l:

$$\pi_{ij}^{lh} = \left(\pi_{ij}^{lh}\right)^{\zeta} / \left\{\sum_h \sum_i \sum_j \left(u_{ij}^{lh}\right)^{\zeta}\right\}, \quad \sum_h \sum_i \sum_j \pi_{ij}^{lh} = 1. \tag{11}$$

The number of workers of type l living in houses of type h in cell i is $L_i^{lh} = L^l \sum_j \pi_{ij}^{lh}$, and the total number working in cell j is, summing over the two types of housing, $L_j^l = L^l \sum_i \left(\pi_{ij}^{l1} + \pi_{ij}^{l2}\right)$.

Given the total number of households of each type, the wages and prices they face, and their location choices, consumer demand for goods and housing and their supply of labour are, for each l:

Value of household demand for sector s in cell i: $L^l \sum_j \left(\pi_{ij}^{l1}\beta^{sl} + \pi_{ij}^{l2}\beta^{sl}\right)\left(w_j^l + m_{ij}^l\right)$

Value of demand for housing type h in cell i: $L^l \sum_j \pi_{ij}^{lh}\beta^{hl}\left(w_j^l + m_{ij}^l\right)$

Value of supply of labour of type l in cell j: $w_j^l L_j^l = w_j^l L^l \sum_i \left(\pi_{ij}^{l1} + \pi_{ij}^{l2}\right)$

Rent, profits, and government: Household income contains a term m_{ij}^l of 'other income'. This is, in aggregate, the total of rents and profits earned by the economy and is distributed to households in an equal lump sum manner,

$$m_{ij}^l = m = \sum_i \left[\sum_s n_i^s \Omega_i^s + \sum_s r_i^s G_i^s + \sum_h r_i^h G_i^h\right] / \sum_l L^l \tag{12}$$

The first term in square brackets is total profits (equal to zero in the full equilibrium), and the other terms are commercial and residential land rents.

*Equilibrium and market clearing***:** Demand for goods, housing, land and labour comes from households, firms, the construction sector and 'exports' from the city. The value of spending on sector s products in cell i is E_i^s

$$E_i^s = \sum_l L^l \sum_j \left(\pi_{ij}^{l1}\beta^{sl} + \pi_{ij}^{l2}\beta^{sl}\right)\left(w_j^l + m_{ij}^l\right) + \sum_z P_i^s I_i^{sz} + \left[\mu^{s1} G_i^1 r_i^1 \gamma/(\gamma - 1) + \mu^{s2} G_i^2 r_i^2 \lambda/(\lambda - 1)\right] + X^s(p_i^s) \tag{13}$$

The terms are household demand, intermediate demand, demand from the construction sector, and a function $X^s(p_i^s)$ giving the value of demand for exports of each sector (i.e. sales to location 0) as a decreasing function of price. Market clearing equates this to the value supplied, as given by the production sector, equations (1) – (4).

The value of each type of labour supplied, $w_i^l L_i^l$, is equal to the value demand for labour coming from firms and from the construction sector, so

$$w_i^l L_i^l = \sum_s w_i^l L_i^{ls} + \left[\mu^{l1} G_i^1 r_i^1 \gamma/(\gamma - 1) + \mu^{l2} G_i^2 r_i^2 \lambda/(\lambda - 1)\right] \tag{14}$$

For housing of type h in cell i the equality of demand and supply, again in value terms, takes the form

$$h = 1: \quad L^l \sum_j \pi_{ij}^{lh}\beta^{hl}\left(w_j^l + m_{ij}^l\right) = G_i^h r_i^h \gamma/(\gamma - 1) \tag{15}$$

$$h = 2: \quad L^l \sum_j \pi_{ij}^{lh}\beta^{hl}\left(w_j^l + m_{ij}^l\right) = G_i^h r_i^h \lambda/(\lambda - 1)$$

Rents, land allocation and city size: There are competing demands for land, coming from commercial use by each sector (in value terms $r_i^s G_i^s$), residential use ($r_i^h G_i^h$), and the possibility that land has outside use, at rent

[25] The CES form has theoretical underpinnings coming from Frechet distributed individual-place specific heterogeneity, see for example Ahlfeldt et al. (2015).

r_0. A land allocation rule divides the total quantity of land in each cell, $\bar{G}_i$, between competing uses according to relative bid-rents. We use a CES function, such that land available for use k, G_i^k, is

$$G_i^k/\bar{G}_i = \left(r_i^k\right)^{\varphi} / \left\{r_0^{\varphi} + \sum_k \left(r_i^k\right)^{\varphi}\right\} \quad (16)$$

where superscript k runs across alternative commercial and residential uses, $k = s, h$. The parameter ϕ measures the intensity of competition between different uses, and as this gets very large so the land market becomes perfect (all land going to the use with highest bid-rent).

B. Data

Table A1: *Consumption shares:* Households consumption shares across consumer goods and housing space are estimated using data in the Uganda National Housing Survey 2012.

Value Shares	**High Skill**	**Low Skill**
Housing	20%	20%
Manufacturing	8.40%	8.40%
Business Services	12.60%	12.60%
Consumer Services	37.90%	29.50%
Single-person firm output	21.00%	29.50%

Table A2: *Sectoral production:* Input-output matrices for each of the four production sectors are estimated from an IFPRI social accounting matrix established for the whole of Uganda (Thurlow, 2008). All sectors are assumed to have elasticity of substitution $\eta^s = 0.8$, set less than unity to capture the low substitutability of land to other factors of production.

Value Shares	**Manufacturing**	**Business Services**	**Consumer Services**	**Single-person firm**
Land	15.8%	9.1%	3.7%	1.8%
Manufacturing	21.0%	9.1%	3.7%	1.2%
Business Services	15.8%	18.2%	7.4%	6.2%
Consumer Services	10.5%	18.2%	6.2%	12.4%
Single-person firm outputs	0.0%	0.0%	0.0%	6.2%
Primary Goods	15.8%	0.0%	37.0%	31.0%
High Skill Labour	10.5%	36.4%	7.4%	0.6%
Low Skill Labour	10.5%	9.1%	37.0%	40.4%

Table A3: *Construction sector:* Input-output matrices construction are given below. K is a redundant scaling parameter, inversely proportional to the amenity parameters; as all regression estimations on the amenity parameters are done within housing type, this has no impact on results, but allows the relative prices of space for informal and formal housing to be reflective of those within the city.

Construction, c_i^h, input shares μ	**Informal**	**Formal**
Manufacturing	30%	50%
Business Services	10%	30%
Consumer Services	60%	20%
Single-person firm output	0%	0%
K	0.45	1
γ		2
λ	4	

Other parameters: The Fréchet parameters are set such that ζ = 25 in the consumer location choice. This is not estimable, as we do not have wage data within the city, and is set a high value relative to much of the literature (eg Ahlfeldt et al. 2015). Using a lower value results in commutes that are unrealistically long; a value of 10 would result in just 20% of the low-skilled population working within 30 minutes travel of their home, compared to more than 40% with this parameter set at 25. Land is allocated using ϕ =10 (equation 16); the aggregate welfare results are relatively insensitive to changes in this parameter, however it does affect the sectoral response. Increasing ϕ to 25 boosts the ability for manufacturing to respond to the change, expanding land use, employment and output. With full adjustment, and 6% returns to scale, manufacturing employment would increase by 131.5% in our final results, compared to 94% as is currently reported. Business services would suffer greater decline in turn, falling 35.4% relative to 24.3%. Additionally, housing choices would be more responsive, with formal housing growing by eight percentage points more than in our main results. However, in terms of aggregate effects, these changes are minimal, boosting aggregate welfare by an additional 0.3 percentage points.

C. Calibration

Preference parameters in the Cobb-Douglas utility functions, β^{sl} are equal to those in appendix Table A1.

Amenity parameters $\{b_i^{l1}, B_i^{l2}\}$ for each housing types 1 and 2, and for each skill level l = 1, 2, and place, i = 1…I, are calibrated such that the number of workers of type l living in houses of type h in cell I, $L_i^{lh} = L^l \sum_j \pi_{ij}^{lh}$ is equal that reported in the population census.

Input parameters in production in the CES production functions, $\{a^{ms}, a^{ls}, a^{zs}, a^{fs}\}$, appendix eqn (5), are calibrated such that, at the base equilibrium, input shares in production are equal to those in appendix Table A2

Input parameters in the Cobb-Douglas construction costs $\{\mu^{lh}, \mu^{sh}\}$ are equal to those in appendix Table A3, which also gives the parameters λ, γ, characterising diminishing returns to building volume per unit area.

Productivity parameters $\{a_i^s\}$ are such calibrated such that the model generated levels of employment in each sector and cell, L_j^s, equal those reported in the census of production. Two further steps are followed. The first concerns the division of employment between the two skill types, $L_j^s = L_i^{1s} + L_i^{2s}$. The census of production does not report employment by skill type, and we make this division according to the labour shares in production in appendix table A2. Although not available by sector in the production census, the number of workers of each skill-type is reported in the population census. The model computes the relative wages of the skill-types such that relative employment of each skill-type matches the population census data.

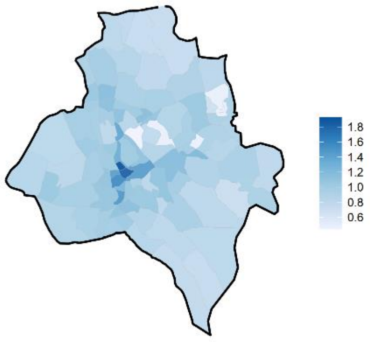
Second, in cases where we assume the presence of localisation economies, the parameter A_i^s is derived from $a_i^s = A_i^s \mathrm{f}^s\left(\sum_j \theta_{ij}^s L_j^s\right)$, (eqn. A6). When present, they are represented by function $\mathrm{f}^s\left(\sum_j \theta_{ij}^s L_j^s\right) = \left(\sum_j exp^{-4.6 dist_{ij}} L_j^s\right)^{\rho_s}$ assumed iso-elastic with elasticity ρ_s of 6% in all sectors[26], and spatial decay parameter θ_{ij}^s exponential in driving time (measured as the share of the maximal driving time to cross the city, therefore a variable between 0 and 1), such that the impact at 30 minutes travel is just under a quarter of that of immediate proximity.

[26] The choice of 6% corresponds to the estimated values of 3-8% reported in Rosenthal and Strange (2004), and is of a similar magnitude to 7% estimate by Ahfeldt et al. (2015)

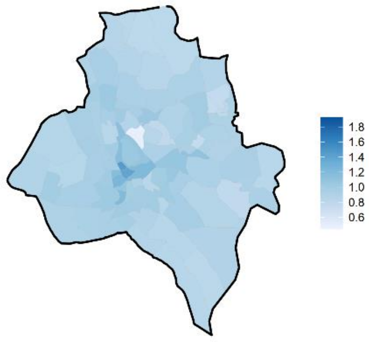
Calibration and Results

Figures A1.a-h (no returns to scale):

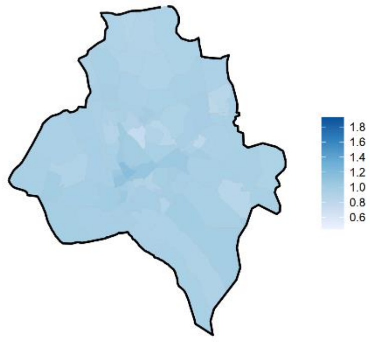
a. Manufacturing



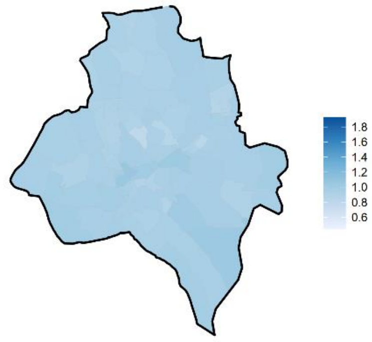
b. Business Services



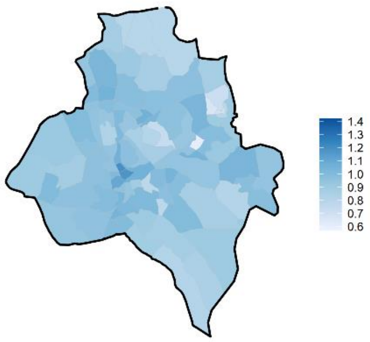
c. Consumer Services



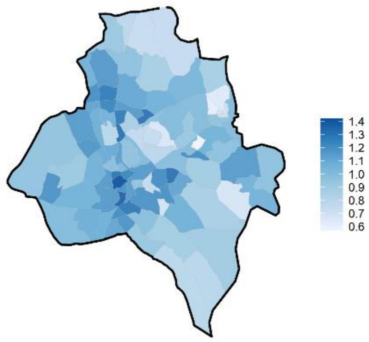
d. One Person firms



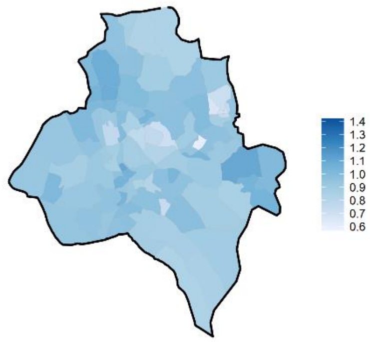
e. High Skilled Formal



f. High Skilled Informal



g. Low Skilled Formal



h. Low Skilled Informal

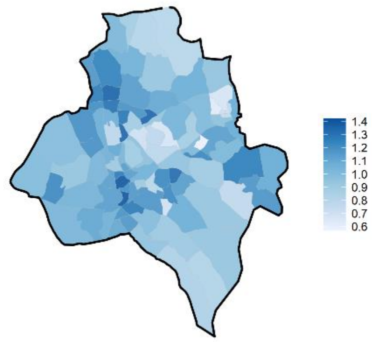


Table A4 Productivity parameters under constant returns to scale

	Manufacturing	Business services	Consumer services	Single person	Manufacturing	Business services	Consumer services	Single person
Customary (share)	0.0226	-0.156	-0.0343	-0.0518	0.0451	-0.115	-0.0271	-0.0462
	(0.166)	(0.175)	(0.0317)	(0.0331)	(0.153)	(0.162)	(0.0300)	(0.0325)
Freehold (share)	-0.0946	-0.174	-0.0273	-0.0276	0.0364	-0.0588	-0.0103	-0.0167
	(0.143)	(0.150)	(0.0273)	(0.0285)	(0.133)	(0.141)	(0.0262)	(0.0283)
Mailo land (share)	-0.101	-0.105	-0.0134	-0.0167	-0.0197	-0.00711	0.00149	-0.00470
	(0.101)	(0.107)	(0.0194)	(0.0202)	(0.0945)	(0.100)	(0.0186)	(0.0201)
Area	-0.00881	-0.00931	0.00409	0.00959***	-0.00645	-0.00591	0.00486*	0.0101***
	(0.0140)	(0.0147)	(0.00267)	(0.00279)	(0.0132)	(0.0140)	(0.00260)	(0.00281)
Distance to Centre	-0.0507***	-0.0454***	-0.00853***	-0.00452**	-0.0290**	-0.0270**	-0.00599***	-0.00300
	(0.0109)	(0.0114)	(0.00207)	(0.00217)	(0.0118)	(0.0125)	(0.00232)	(0.00251)
Elevation	0.458	1.146	0.130	-0.141	-0.585	0.0511	-0.0311	-0.249
	(1.550)	(1.633)	(0.296)	(0.309)	(1.423)	(1.507)	(0.280)	(0.303)
Ruggedness	-9.313**	-10.72**	-1.679*	-0.948	-5.738	-6.817	-1.035	-0.441
	(4.701)	(4.953)	(0.898)	(0.938)	(4.309)	(4.564)	(0.849)	(0.918)
Constant	0.843	0.836	0.523	1.086***	1.835	1.850	0.669**	1.178***
	(1.744)	(1.837)	(0.333)	(0.348)	(1.595)	(1.690)	(0.314)	(0.340)
Other Controls	**No**	**No**	**No**	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	92	92	92	92	92	92	92	92
Adjusted R^2	0.394	0.367	0.275	0.202	0.511	0.483	0.378	0.266

Estimated using a Seemingly Unrelated Regression through the sureg command in stata. Returns to Scale in all sectors of production are set to 0%. Area measured in square kilometers, and distances, elevation and ruggedness in kilometers. Additional controls include distance from nearest school, hospital, major road, and road density. All shares are between 0 and 1. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Amenity Parameters with all controls

	High skilled formal	High skilled informal	Low skilled formal	Low skilled informal
Customary (share)	-0.0974	0.217*	0.0550	0.316**
	(0.0722)	(0.128)	(0.0759)	(0.134)
Freehold (share)	0.00169	0.161	0.0107	0.166
	(0.0629)	(0.112)	(0.0661)	(0.117)
Mailo land (share)	-0.0284	0.202**	-0.0127	0.206**
	(0.0447)	(0.0794)	(0.0470)	(0.0832)
Area	-0.00103	-0.0178	-0.00344	-0.0218*
	(0.00625)	(0.0111)	(0.00657)	(0.0116)
Distance to Centre	-0.00515	-0.0149	0.00866	-0.00126
	(0.00559)	(0.00991)	(0.00587)	(0.0104)
Elevation	1.361**	1.288	1.112	1.086
	(0.674)	(1.196)	(0.708)	(1.253)
Ruggedness	-6.396***	-10.34***	-6.702***	-10.09***
	(2.040)	(3.621)	(2.144)	(3.795)
Distance to School	-0.0446	-0.150**	-0.0584	-0.137*
	(0.0383)	(0.0679)	(0.0402)	(0.0712)
Distance to Hospital	-0.0325	-0.0393	-0.0381*	-0.0464
	(0.0215)	(0.0381)	(0.0226)	(0.0399)
Distance to Major Road	0.00743	0.0141	0.0119	0.0195
	(0.0345)	(0.0612)	(0.0362)	(0.0641)
Road Density	7.579**	14.92**	7.359*	12.66*
	(3.643)	(6.465)	(3.828)	(6.775)
Constant	-0.431	-0.261	-0.223	-0.0781
	(0.755)	(1.340)	(0.794)	(1.405)
Observations	92	92	92	92
Adjusted R^2	0.363	0.487	0.258	0.405

Estimated using a Seemingly Unrelated Regression through the sureg command in stata. Area measured in square kilometers, and distances, elevation and ruggedness in kilometers. Additional controls include distance from nearest school, hospital, major road, and road density. All shares are between 0 and 1. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

D. Sensitivity

The model is calibrated using the input technologies discussed in section 4. However, while we have a source of the relevant shares of inputs for each sector across the other sectors, land, and labour, we do not have a source that breaks down the labour value shares into low and high skill.[27] We therefore re-run the simulations under different labour shares. In the earlier results, 36% of the value of inputs for business services were high-skilled wage bills, and 9% low-skilled wage bills. We now equalise the two, increasing the demand for low-skilled employees from business services, and decreasing the demand for high-skilled employees.

The resultant location specific amenity and productivity parameters are very similar to levels observed in the main analysis. The regression results of these on the shares of land under different tenure systems reveal coefficients of a similar size and the same sign. The significance levels are also the same. We then take projected values of these parameters from an experiment in which we convert all mailo land to leasehold. The results are reported in table A6 below.

As before, the decreases in amenity for informal housing on mailo land, leads to a reduction in market rents in these areas. The result is a boost in manufacturing. The expansion of manufacturing, in part at the expense of business services, no longer brings down the relative wage between high-skilled and low skilled. As such, both the high-skilled and low-skilled wage increases. Manufacturing can expand beyond the levels seen in the main analysis as the relative wage for low-skilled workers grows more slowly. The end result is a greater expansion of the manufacturing sector, with more clustering than in the main analysis boosting productivity and output further. The increase in total welfare under the full 6% returns to scale scenario is now 7.1% under the *Amenity; real cost,* and as much as 11.0% under the *Rent Cap* interpretation. The efficiency gain from the policy with zero returns to scale is now worth 29% of average rent per directly affected household, this rising to 132% with returns to scale of 6%, giving a capital value of the reform per directly affected household ranges from 6 times average city rent to 27 times average city rent.

[27] This could potentially be estimated in the future, using relative wage date for low and high-skilled individuals in the city which is currently being collected.

Table A6 – Impact of converting all the mailo land to leasehold- different input shares

	1	2	3	4	5
	Base	**Direct effect**	**Fixed location**	**Full adjustment RS = 0%:**	**RS = 6%**
Numbers (Thousands)					
Employment Manufacturing	28.9	0.0%	2.2%	19.3%	93.5%
Employment Business Services	74.3	0.0%	0.8%	-0.2%	-19.4%
Employment Consumer Services	123.8	0.0%	-0.6%	-0.6%	0.6%
Employment One-person	71.9	0.0%	-0.7%	-6.5%	-18.6%
Informal Households	161.1	0.0%	-43.8%	-47.4%	-57.3%
Formal Households	103.3	0.0%	68.3%	73.9%	89.4%
Changes in real income (per capita utility)					
Amenity: real cost					
High Skill	100	97.1	100.5	104.6	112.3
Low Skill	100	95.7	97.9	96.6	101.1
Rental income	100	100.0	98.4	101.7	119.5
Aggregate	100	96.0	97.4	98.5	107.1
Amenity: transfer					
High Skill	100	97.1	100.5	104.6	112.3
Low Skill	100	95.7	97.9	96.6	101.1
Rental income	100	106.4	104.8	108.1	125.9
Aggregate	100	100.0	101.4	102.4	111.0