Building African Cities[1] 12/4/2016

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Most cities in the developed world achieve an orderly land-use pattern that enables businesses to achieve high productivity by clustering in areas such as the central business district (CBD), with residential neighborhoods having high-density near the center and lower density further out *(1)*. In contrast, many developing cities have hotchpotches of land uses with office towers bordered by slums, scattered fringe developments, and consequent lack of 'connectivity' between firms, workers, and consumers. Such cities are viewed as not functioning well *(2)* with large numbers of people in informal settlements (62% of the African urban population according to *(3)),* poor transport infrastructure and ability to commute *(4),* and low worker productivity *(5)*.

A key aspect underlying non-functionality is inefficient land-use and organization of cities, driven by construction decisions under weak institutions and reflected in the spatial structure of the built environment. This built environment, which accounts for 2/3 of produced capital in developing countries *(6)*, is long lived. Poor functioning undermines the competitiveness of cities and bad decisions made today have effects lasting for generations.

In HRV *(7)* we model the dynamics of urban land-use and analyze the evolution of the built environment of Nairobi, a city of about 5 million people growing at 3-4% a year, for which we have developed a unique dataset of buildings at several points in time. We map out how the built environment has changed, and ways in which it appears to deviate from an efficient pattern, with insufficient building volume through most of the city. To start we develop an urban model adapted to the circumstances of developing countries. This captures rapid population growth and two types of housing technology. Formal, in which capital is sunk, buildings are long-lived, and construction decisions (such as building height) are based on

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expectations of future rents. And informal, or slum settlement, where construction is flexible or adjustable over time (e.g. corrugated iron sheets), building a single story is cheap, but building high is very expensive. This distinction is illustrated in Nairobi where 57% of slum dwellings are made of sheet metal and 15% of mud & wood, while 90% of formal residences are made of stone, brick, or cement block *(8)*.

In the efficient outcome slums form at the edge of the city where land is cheap. As the city grows, old slums are converted to formal settlement and new ones form on the edge. Formal sector development is then subject to periodic demolition and reconstruction, successively taller and denser as the city grows and land values increase. If slum housing is inherently lower quality, with income growth, slums eventually phase out entirely, just as 19^{th} century tenements and shacks in London and New York disappeared decades ago. The model analyzes two principal sources of inefficiency in the dynamics of city development. One arises from the difficulty of forming expectations so, e.g. pessimism about future city growth undermines willingness to invest and leads to a lower and more sprawling city. The other is institutional obstacles in the process of converting slum developments to formal sector usage.

There are many such obstacles. Formal sector development requires financing and enforcement of contracts which in turn requires land ownership rights to be formalized to mitigate the risk of expropriation. Land rights are often unclear as there are co-existing systems of private ownership (some illegal or quasi legal), communal ownership, and government ownership. There may be competing (il)legal claims that result in lengthy court cases. Slum areas are particularly complex, with 'planning or regulatory powers... split between a galaxy of private sector actors, landlords, chiefs and bureaucrats, and gangs' *(9)*. Administration of the land system is subject to corruption. The Kenyan elite has been guilty of land-grabbing, with a government inquiry alleging that the land allocation process has been subject to corrupt and fraudulent practises and 'outright plunder' *(10)*. There are consequences. The cost and feasibility of conversion to legal formal usage varies by plot histories, and plots with high conversion costs remain informal much longer. A spatial hotchpotch of land rights and conversion costs results in a hotchpotch of uses and different intensities of land use and stages of redevelopment through the city, including close to the centre. Our empirical work quantifies aspects of the potential loss of building space and economic efficiency that follows from this.

To study this requires data on individual buildings, and the ability to track these through time. Data are generally problematic for African cities, but our Nairobi study is based on extremely high resolution aerial photo and satellite data used to derive building footprints and road coverage, and LIDAR data for building heights. To demarcate slums we have used city mapping of slums and ownership/land rights. House and land prices are, for some time periods, available from surveys or scraping the web. We have developed novel methods to integrate and analyse these data, including overlaying building footprints of the city at different points in time to define infill, reconstruction, demolition and no change.

An overview of the city is given in the 3-D map which illustrates building heights and slum coverage. Slums are as identified by city studies in 2003/04 *(11)* and 2012 *(12)*. The 1000 acre slum of Kibera analysed below is to the south-west of the center. The city is monocentric, constrained by national parks to the north and south; undefined spaces within the city include an airport, golf course, and the President's complex.

In the cross section of Nairobi, 2015 land prices decline sharply with distance from the CBD. There are no slums in the CBD and, looking at successive distance bands out from the CBD, the proportion of developed land occupied by slums peaks at 45%, 5km out from the CBD. Slums are not concentrated at the edge (as would be efficient) but appear in a scattered fashion throughout beyond the CBD, indicating potentially significant land market frictions. Building heights in the formal sector *average* about 23 meters in the CBD, indicating there is more height than we expected in Nairobi. Heights decline, falling to about 6-7 meters at 10 kms out. Slums have similar height throughout the city and, at about 5 meters, are less tall than formal buildings, as modelled. The total area of floor space supplied by different types is proxied by building volumes (height x footprint). In the formal sector they average about 120,000 cubic meters per 150x150 meter grid square near the center but decline to about 40,000 at and beyond 5kms out.

In slum areas there is intense ground coverage by buildings compared to the formal sector with, as expected, much less land devoted to green space and roads. A key discovery is that building height in the formal sector trumps intense ground coverage in slums, so that building volume per unit land in slums is always lower than in formal developments. Near the center slums offer volume per unit land of just 16% that of formal buildings, rising to 90% at 5km and then declining somewhat. The implication is that the presence of slums near the CBD has a large impact on building volume. At 2, 3 and 4 kms from the center conversion of slums to formal usage would increase building volumes in those slum areas by 148%, 95% and 53% respectively.

Turning to dynamics, the graph on changes in formal sector volume shows, as a fraction of initial volume, infill (new buildings where there were none in 2004), net redevelopment (new building where there had been an earlier structure) and demolition (buildings demolished and not yet replaced). In the 0-1 km ring at the center, use is locked in by roads, colonial buildings, and tall complexes built over the last 40 years. Near the center land in roads is about 23% of total area which declines sharply with distance, as modelled by Solow and Vickrey *(13)*. From 1- 5kms there is, as the model suggests, substantial net redevelopment in the face of escalating land prices with new buildings taller than their older neighbours. The volume of net redevelopment peaks at 4kms out where it amounts to over 30% of old volume. After 5kms volume changes are dominated by infill.

What about slums? Up to about 2kms from the CBD slums are demolished and redeveloped. Beyond that there is less redevelopment than might be expected. Why? In HRV, we argue that remaining slums nearer the CBD, like Kibera which starts at about 3.5 kms from the center, have high costs of conversion to formal usage. Slum land near the center including Kibera is government owned *(12)*, a code word for conflicting private claims with the government having seized ownership but not responsibility. Slum landlords there make high profits and much of the land is controlled by political figures with a vested interest in non-redevelopment; redevelopment would take away their profits on land to which they have no legal claim. Nearer the fringe land ownership in slums becomes increasingly private. The constraint on slum redevelopment nearer the center has at least two sources of significant welfare costs: there is lost volume of space due to not building high as we described above and the quality of the built space and unit rents are low, compared to the formal sector. We hypothesize that slum landlords have invested little in land improvements such as infrastructure and regularized lay-out near the center since they cannot capture those returns when housing spaces are redeveloped. A back of the envelope calculation (HVR) suggests just the quality differential from lack of redevelopment reduces land values in Kibera by the order of $1b, a magnitude which indicates the potential to buy-out the actors inhibiting redevelopment and help relocate tenants.

In summary, Nairobi has many of the features of a 'normal' city: high buildings in the CBD and declining heights and land prices away from the center. Yet there is substantial evidence of inefficient land-use. There is a significant loss of housing capacity due to the low volume intensity of slums and the persistence of slums relatively close to the center. We hypothesise that such persistence is due to the myriad institutional and political obstacles to redevelopment. While the focus of this paper is the built environment (and much of data is a view from the sky) our continuing work combines this with economic and population censuses and surveys, in order to give detail for what is happening to people and firms on the ground. This, together with an understanding of the institutional details of the city, will combine to give a fuller picture and to inform policy, as the African urban population trebles over the next three decades.

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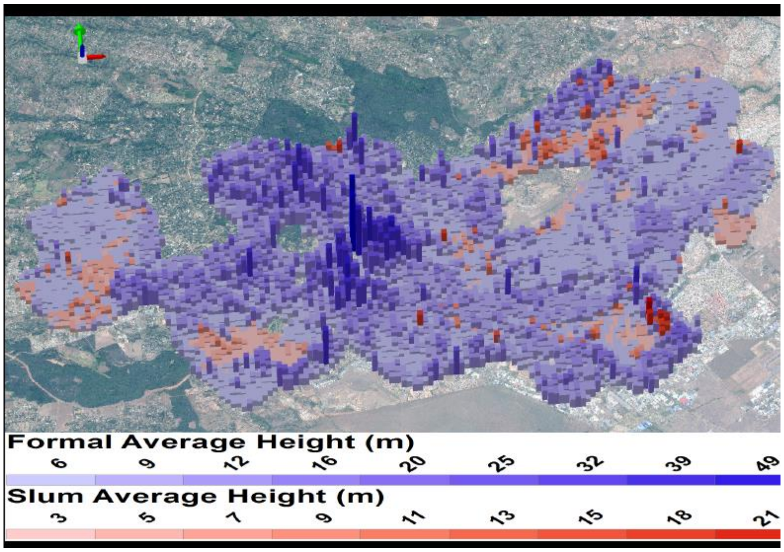
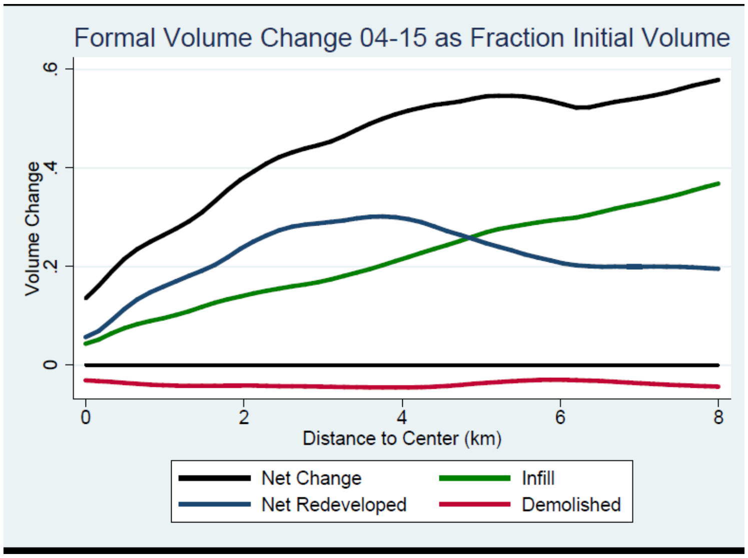
Figure 1 and caption



This 3-D map of Nairobi shows average built height in 2015 by 150x150 metre cells split across the formal and slum sectors. The compass in the upper left corner points north in green. The boundary of the city spans about 22km E to W and 11km N to S; map tilt may distort the appearance of distances. Background imagery copyright Airbus Defence and Space 2016 taken from the SPOT5 satellite the 20th September 2004. Modified from HRV.

Figure 2 and caption



This plot shows formal sector volume change from 2004 to 2015 as a fraction of initial coverage by distance. The ratio of net volume to initial volume is broken down into change due to infill redevelopment and demolition as defined in HRV. This sample excludes cells that had no buildings in both 2015 and 2004. Modified from HRV.