Building the city: urban transition and institutional frictions

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Introduction

- How has a developing city grown?
  - The building stock – evolution across space & time
  - Frictions and imperfections

1) Theory: build a full dynamic model of investment/ urban growth
  - Formal and informal structures
  - Sunk capital and expectations
  - Land market inefficiencies

2) Empirics: Detailed study of Nairobi
  - From aerial photography, 2 time periods
    - Land cover
    - Redevelopment
  - Other data sources
    - Height
    - Land prices, property rents
    - Slum classification

Introduction

3) Calibration:

- Data allows calibration of all parameters of the model

4) What is the cost of delayed formalisation of slums?

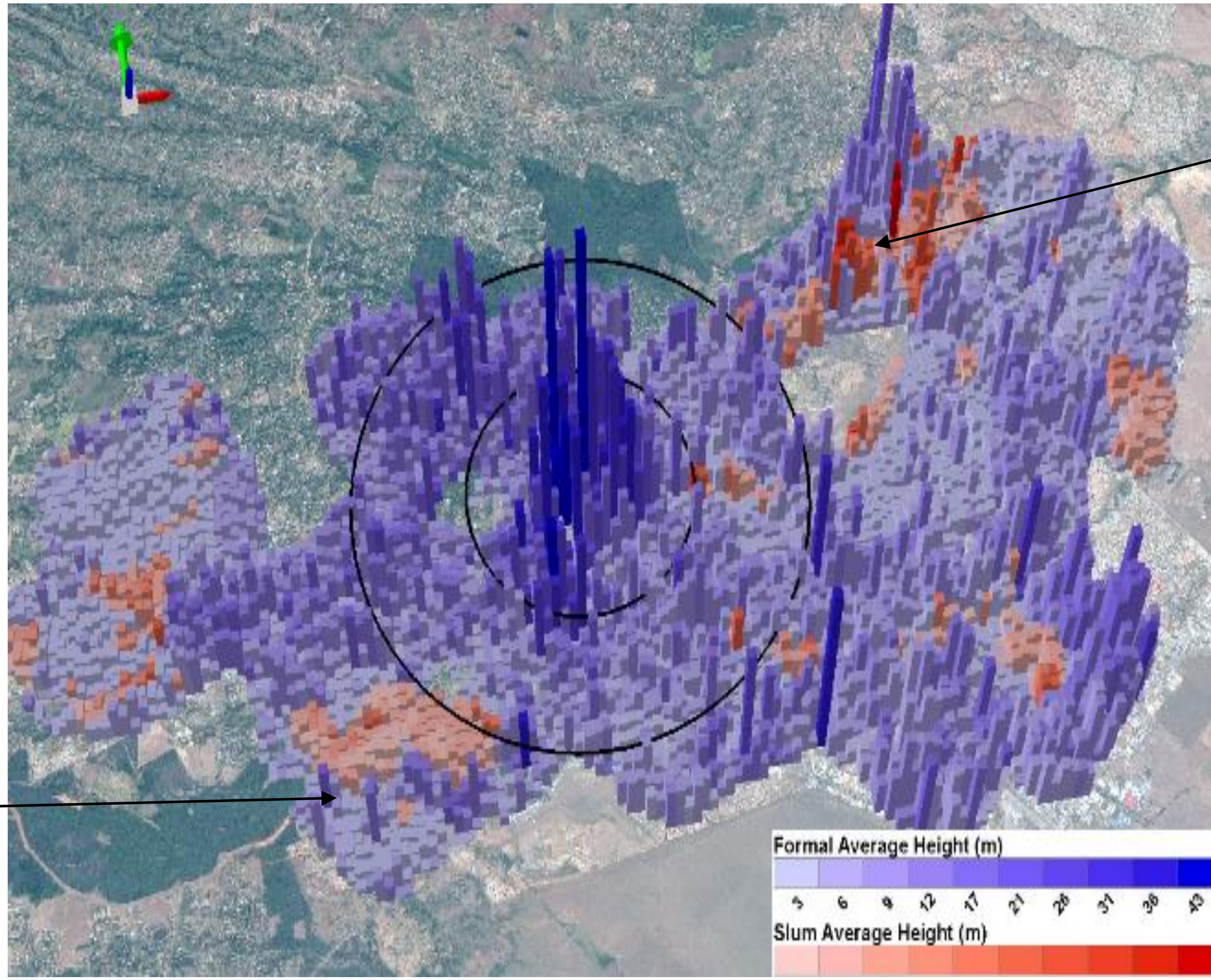
- Slums at edge and near the centre
- Opportunity cost of land not being in its most efficient use:
  - Close to centre, cost of perpetual delay ≈ \$14,000 per household

Introduction

Nairobi background:

- Population ≈ 3mn city, 6.5mn greater metro
- Growth:
  - Population ≈ 3.9% pa
  - Built volume ≈ 3.9% pa
  - Reconstruction: 3kms from CBD, 35% of buildings demolished in last 12 years.
- Slums:
  - Kibera:
    - Africa’s largest slum: ≈ 200k people (some estimates > 1mn)
  - The ‘hodgepodge’:
    - Monocentricity evident in some aspects
    - Slums and formal settlements side-by-side

Nairobi in the 2015 cross-section (includes public sector)
3-D average height of all buildings by 150x150m grid square



Mis-classification

Kibera

Rings at 2 and 4 kms from centre

Theory

City with places, x (*distance from CBD*), date t, development of type i (= *Informal*, *Formal*):

Price of housing (house-rent), quality adjusted: $p_I(x,t) = \overline{p}_I e^{\hat{p}_I t} e^{-\theta_I x}$ $\quad p_F(x,t) = \overline{p}_F e^{\hat{p}_F t} e^{-\theta_F x}$

- Exogenous price growth, price gradient

Built volume $v_i(x,t) = h_i(x,t)c_i(x,t)$ product of building height and cover.

Informal sector (slum):

Cannot build tall – but can increase cover

Utility loss from increasing cover: ‘crowding’

Buildings are malleable (lego): – no sunk costs, expectations unimportant

Formal sector:

Volume achieved by height not cover

Sunk costs – ‘putty-clay’:

Expectations matter

Two sorts of decisions: Volume (either c or h)

Timing – formalisation, waves of redevelopment

Theory

Informal sector:

Land-rent: $r_I(x,t) = \left[p_I(x,t)a\left(v_I(x,t)\right) - \kappa_I\right]v_I(x,t)$

Revenue: price adjusted by amenity loss, $a(v_I(x,t)) = a_I v_I(x,t)^{(1-\alpha)/\alpha}$

constant construction cost per unit housing

Maximised land-rent (bid-rent) $r_I(x,t) = \kappa_I\left(\alpha - 1\right)\left[a_I p_I(x,t)/\kappa_I \alpha\right]^{\frac{\alpha}{\alpha-1}}$

NB: Construction costs share 1/α of revenue

Land-rent share 1 - 1/α of revenue

Theory

Formal sector:

Land-rent: $$R_F(x,\tau_i) = \int_{\tau_i}^{\tau_{i+1}} p_F(x,t)v_F(x,\tau_i)e^{-\rho(t-\tau_i)}dt - k\big(v_F(x,\tau_i)\big)$$

PV over interval $t \in [\tau_i, \tau_{i+1}]$, i is index over successive redevelopments,

Construction cost per unit housing $k(v_F) = \kappa_F v_F{}^{\gamma}$

Maximised PV land rent: $$R_F(x,\tau_i) = \kappa_F(\gamma-1)\left[\frac{p_F(x,\tau_i)\Phi(x,i)}{\kappa_F\gamma}\right]^{\frac{\gamma}{\gamma-1}}$$

Value-to-rent-ratio (over interval): $$\Phi(x,i) \equiv \int_{\tau_i}^{\tau_{i+1}} [p_F(x,t)/p_F(x,\tau_i)]e^{-\rho(t-\tau_i)}dt$$

Flow land-rent (constr. cost amortised over life of building): $$r_F(x,t,\tau_i) = [1-1/\gamma]p_F(x,t)v_F(x,\tau_i)$$

NB: Construction costs share $1/\gamma$ of revenue

Land-rent share $1 - 1/\gamma$ of revenue

Theory

Land development

Present value of not yet developed land at place *x* and date *t*.

$$R(x) = \underbrace{\int_0^{\tau_0} r_0 e^{-\rho t} dt}_{\text{agriculuture}} + \underbrace{\int_{\tau_0}^{\tau_1} r_I(x,t) e^{-\rho t} dt}_{\substack{\text{slum use, house} \\ \text{\& land prices low}}} + \underbrace{\left[R_F(x,\tau_1) - D(x)\right] e^{-\rho\tau_1}}_{\substack{\text{first formal development} \\ D(x)\text{: formalisation cost}}} + \underbrace{\sum\nolimits_{i=2} R_F(x,\tau_i) e^{-\rho\tau_i}}_{\text{successive redevelopments}}$$

Rural to informal, date τ_0: $$\frac{\partial PV(x)}{\partial \tau_0} = e^{-\rho\tau_0}\left[r_0 - r_I(x,\tau_0)\right] = 0$$

Informal to formal, date τ_1: $$\frac{\partial PV(x)}{\partial \tau_1} = e^{-\rho\tau_1}\left[r_I(x,\tau_1) - p_F(x,\tau_1) v_F(x,\tau_1) + \rho\left\{k\left(v_F(x,\tau_1)\right) + D(x)\right\}\right] = 0$$

Formal redevelopment, date $\tau_{2\ldots}$: $$p_F(x,\tau_{i+1})\left[v_F(x,\tau_{i+1}) - v_F(x,\tau_i)\right] = \rho k\left(v_F(x,\tau_{i+1})\right)$$

Development across time

Price path: $p_i(x,t) = \overline{p}_i e^{\hat{p}_i t} e^{-\theta_i x}$

Transition slum → formal if

$$\hat{p}_F \gamma /(\gamma - 1) > \hat{p}_I \alpha /(\alpha - 1)$$

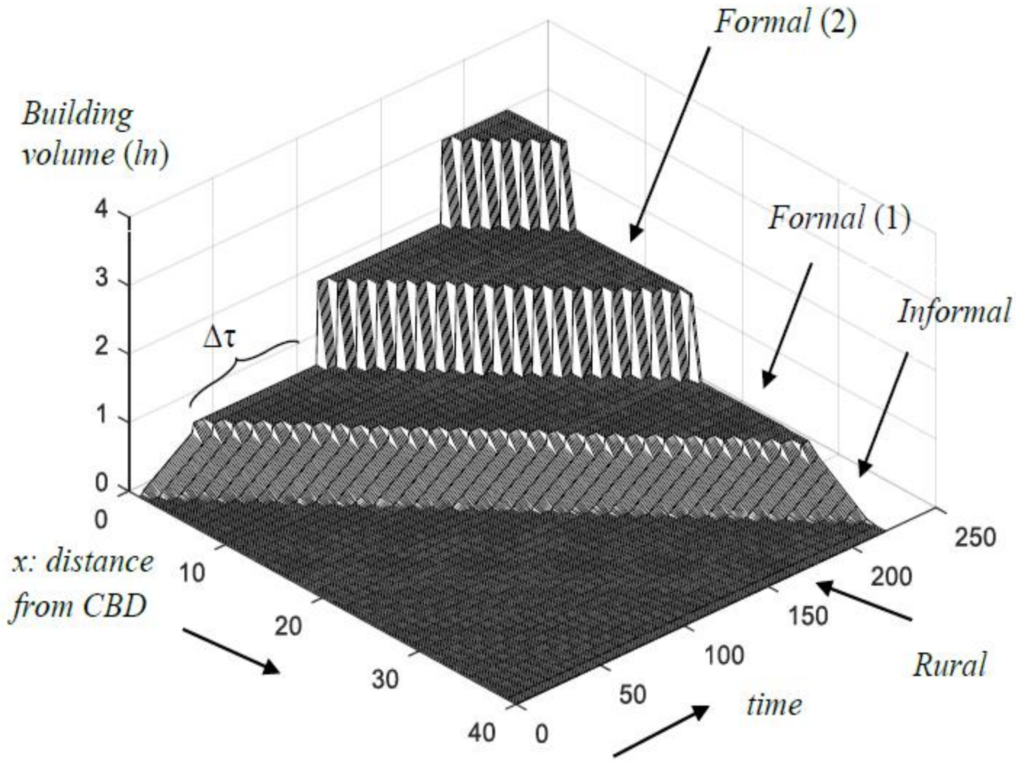
Formal redevelopment

Proposition 1: Time path with perfect foresight:

- The value-to-rent ratio takes constant value Φ, and the time interval between successive formal redevelopments is constant Δτ,
- Successive rounds of formal sector building have greater volume (height) by constant proportional factor.

$$\frac{v_F(x, \tau_{i+1})}{v_F(x, \tau_i)} = e^{\frac{\hat{p}_F \Delta\tau}{(\gamma - 1)}} = \frac{\gamma}{\gamma - \rho\Phi}$$

Figure 1: Urban development with perfect foresight



Development across space

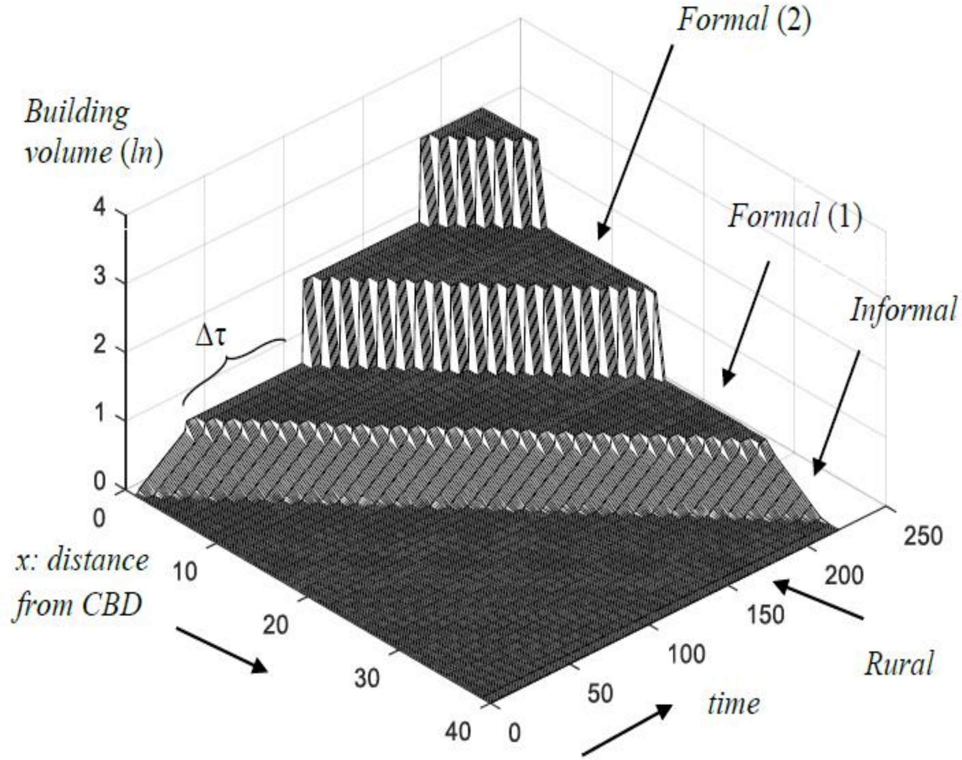
Proposition 2: (across locations)

If (additionally) the conversion cost is the same for all x

- The distance between successive formal sector redevelopments is constant
- The width of the informal sector is shrinking (constant) as

$$\hat{p}_F > (=) \hat{p}_I$$

Figure 1: Urban development with perfect foresight



Formalisation costs:

Figure 2: Formalisation costs

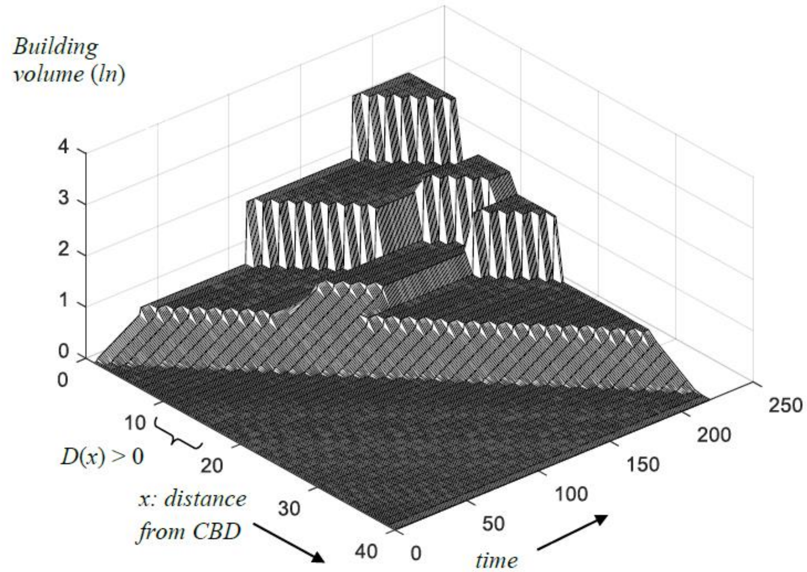
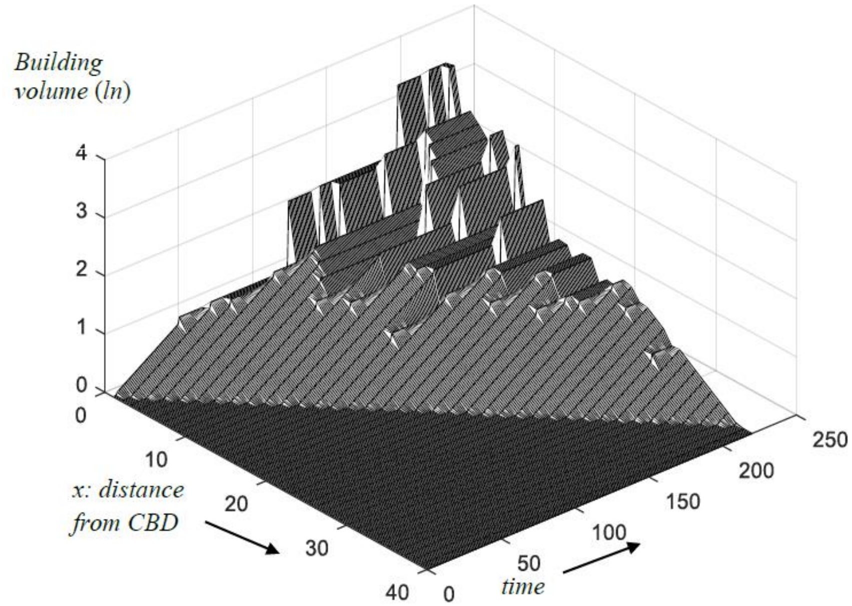


Figure 3: The hotchpotch: random variation in formalisation costs



- *High formalisation cost delays development & successive redevelopments*

- *Low expectations delay initial development, reduce building volume, and reduce the interval between redevelopments*

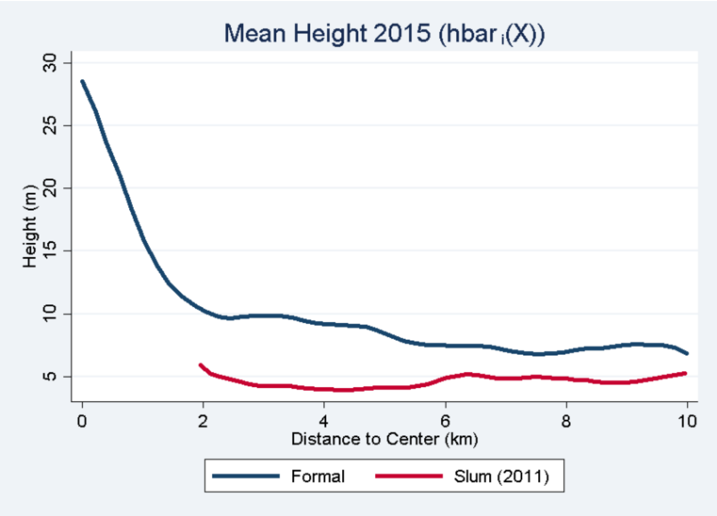
Empirics: cross-section

- Data on Nairobi
  - Building footprints
    - Aerial photo (10-40 cm resolution
    - Gives building footprints for 2003/4 and 2015 and heights for 2015.
    - Characteristics defined at 3mx3m pixels: aggregated to a grid with 6470 cells of 150m by 150m
  - Height (LIDAR 0.3-1m resolution) data for 2015.
    - For 2004 height
      - Know height of unchanged building
      - Teardowns: assigned based on average heights of neighbouring (queen) unchanged buildings (over-estimate)
    - Overlay building polygons in 2003/4 and 2015 to define redevelopment, infill and demolition
  - Land price: scraping web for advertised prices of vacant lots
  - House-rent: House-rent per m^2, formal and informal (2012, NORC)
  - Slum classification

Empirics: cross-section

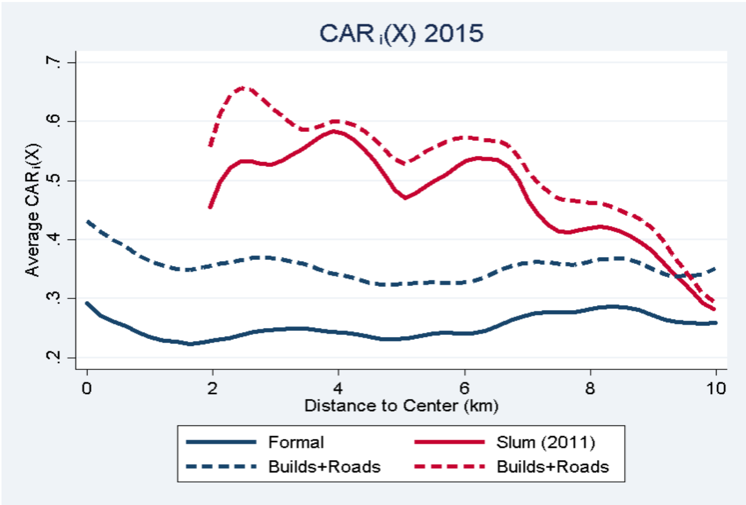
Building height by distance from centre:

- Formal: tall and gradient
- Slum: uniformly low



Building cover-to-area ratio by distance from centre:

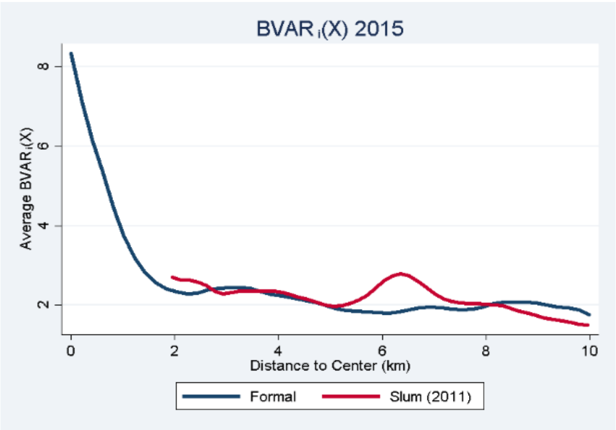
- Formal: low and constant
- Slum: Up to 60%, declining with distance



Empirics: cross-section

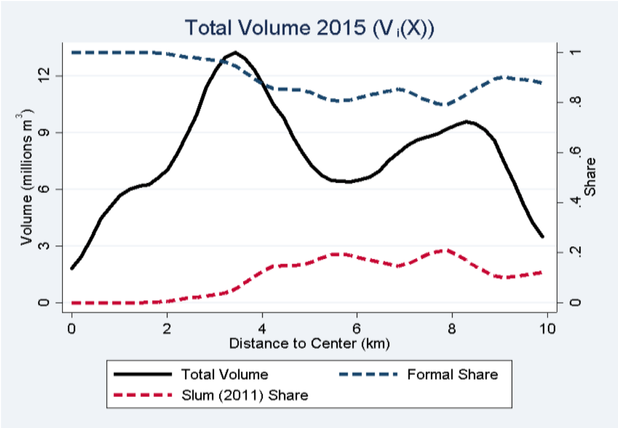
Volume per unit land area: by type

- Slum and formal areas provide about equal building volume per unit area



Total volume by distance

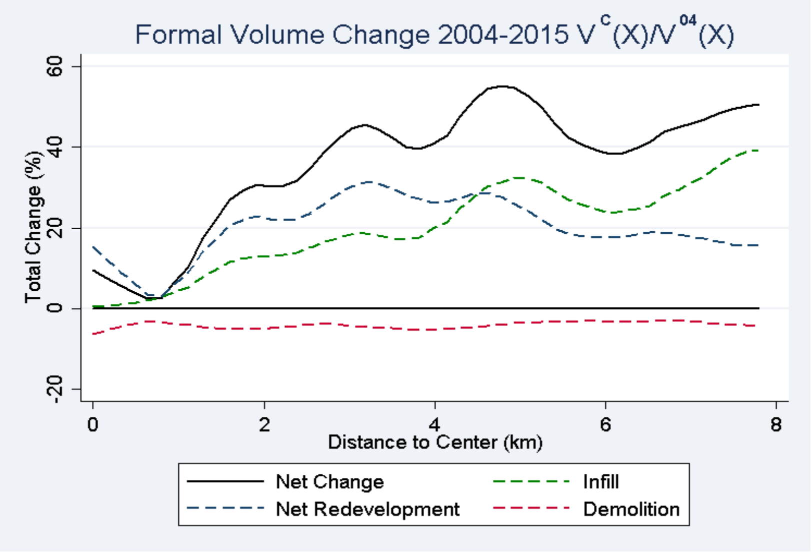
- Total volume provided
- slum greatest share 20% at 5-8kms



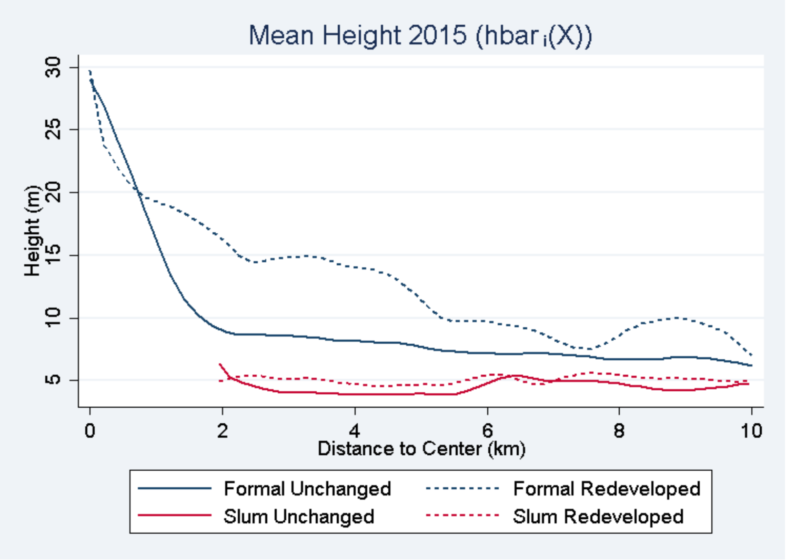
Empirics: changes

- Huge amount of redevelopment:
  - 3 kms from the centre, 35% of buildings replaced in the last 12 years (developed country < 10%).
  - At 3kms from the centre, demolition goes with redevelopment to much taller buildings.
  - Volume per unit area increase by 40%

Volume per unit area



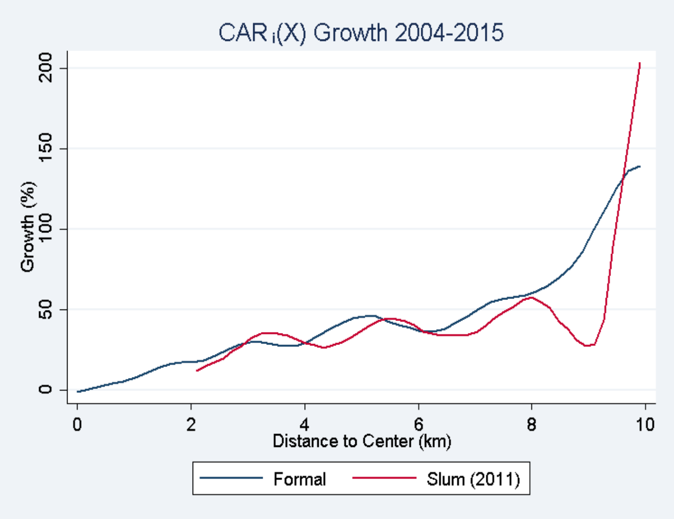
Building height



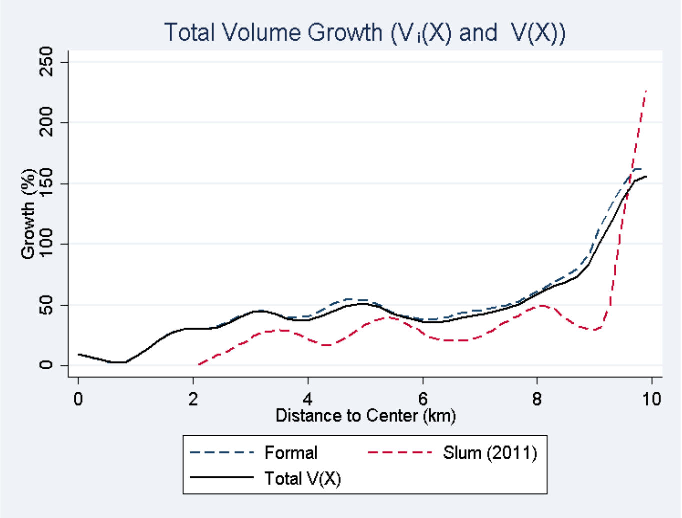
Empirics: changes

- Further out, increasing densification and volume growth in slums

Cover to area ratio



Total volume by distance and sector



Calibration:

Three steps: Spatial gradients/ intertemporal/ levels

I: Gradients:

- Regressions to find gradients of volume, land-prices, land-rents wrt distance from the CBD:

Table 1. Land price, House rent, Height, CAR and BVAR gradients

Panel A. Key gradients used in calibrations

	(1)	(2)	(3)	(4)	(5)
	Ln land sales price (USD per sq m.)	Ln formal house-rent per sq m. floor space	Ln slum house-rent per sq m. floor space	Ln Formal Redeveloped Height	Ln Slum CAR
Distance to centre	-0.173***	-0.103***	0.0462	-0.0965***	-0.104***
	(0.0518)	(0.0317)	(0.0300)	(0.00315)	(0.00825)
Ruggedness	-0.0239	0.0263	-0.0383	0.0153**	-0.0335***
	(0.102)	(0.0524)	(0.0690)	(0.00596)	(0.0116)
Elevation	5.373***	1.450	2.964***	-134.9	-1027.0***
	(1.801)	(1.062)	(0.731)	(129.5)	(220.5)
Constant	-1.365	3.947**	-0.0846	2.975***	1.635***
	(3.233)	(1.791)	(1.264)	(0.223)	(0.385)
Other controls	lot size, lot size sq., month FEs, geo-coded	no	no	no	no
Observations	136	372	503	4589	983
R-squared	0.292	0.106	0.084	0.191	0.145

$a'_I = 0.708$
,
,

Calibration:

I: Gradients:

- Regressions to find gradients of volume and land-prices, land-rents wrt distance from the CBD:
- Calibrate elasticities of building decisions
- Price gradient centre to edge
- α ➔ share of construction in formal house-rent = 74%
- γ ➔ share of construction in informal house-rent = 56%

II: Growth and present values:

- Value to rent ratio = 25
- Interval between redevelopments, 75 years

III: Levels and price/ cost/ amenity parameters (at 2015, 4.5km)

- House rent m². $p_I(x,t)a_I v_I(x,t)^{(1-\alpha)/\alpha} = \$7.56$ $p_F(x,t) = \$18.73$

Application: the cost of delayed formalisation

- Numerous reasons for delayed land conversion:
  - Conflicting claims
    - Kibera history
  - Political economy
    - Slum-lords
    - Tenants
- Calculate the opportunity cost of delayed conversion
  - NB: NOT including cost of disrupted social networks/ relocation or benefit of city reorganisation/ agglomeration/ scale

- PV of land rents at place *x*, discounted to date *s*, if formalisation at date *z*

$$PV(x,s,z) = \int_s^z r_I(x,t)e^{-\rho(t-s)}dt + e^{-\rho(z-s)}\sum_{i=0}^{\infty} R_F(x, z+i\Delta\tau)e^{-\rho i\Delta\tau}$$

$$= r_I(x,s)\frac{1-e^{-(\rho-\hat{p}_I\alpha/(\alpha-1))(z-s)}}{\rho-\hat{p}_I\alpha/(\alpha-1)} + r_F(x,s,s)\Phi\frac{e^{-(\rho-\hat{p}_F\gamma/(\gamma-1))(z-s)}}{1-e^{-(\rho-\hat{p}_F\gamma/(\gamma-1))\Delta\tau}}.$$

Land values: PV(x,2015,z)

Table 4. Present value of land-rent: \$ per m^2					
Date of formalisation, z	3-4 kms	4-5kms	5-6kms	6-7km	7-8kms
$z = 2015$	766.7	644.7	542.3	456.2	383.7
$z = 2040$	683.9	588.9	507.6	438.1	378.5
$z = 2065$	600.4	524.7	459.1	402.2	352.7
$z = 2015+\Delta\tau = 2090$	535.3	472.7	417.8	369.6	327.3
$z = \infty$	409.0	368.6	332.2	299.3	269.8
Optimal z	2000	2005	2011	2017	2023
PV at optimal z	790.0	652.2	543.3	456.6	386.8
Sq. m slum land	1129311	2263428	1946034	1397601	2800755
No. slum households 2009	29070	45810	33100	28390	32690

Present values at $s = 2015$.

The cost of delay

- Perpetual delay vs efficient formalisation date at 3-4kms
  - \$790-\$409 = \$381 per m^2
  - Equivalent to ≈ \$15,000 per household

  (i.e., this the surplus after fully ‘compensating’ slum-lord)

- Drops off further out: at 5-6kms
  - \$284 per m^2
  - Equivalent to ≈ \$12,000 per household

- Total loss up to 6kms ≈ \$1.3bn

- Drops off with shorter delays:
  - 25 year delay from 2015 costs \$56 per m^2 at 4-5 km.
  - Cf, annual informal land-rent at 4-5 kms ≈ \$12

Concluding comments

Research agenda:

- Three elements: firms and jobs /residential/ infrastructure & public:
- Need to build in depth knowledge on each
- Need conceptual framework for whole

Point of departure is standard urban model ++

- MARKET FAILURES & FRICTIONS: Land, regulation, labour and capital markets
- DYNAMICS: Growth and investment with sunk costs ➔ expectations matter
- COMPLEMENTARITIES: Interactions and positive feedback
  - Firm ↔ firm: agglomeration etc.
  - Firm ↔ household: access to markets: access to workers/ jobs:
  - Infrastructure ↔ economic activity:
    - Connectivity
    - Shaping expectations
    - Public finance and source of funds

Collectively ➔ cumulative causation & multiple equilibria