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 $\approx 3\text{mn}$ city, $6.5\text{mn}$ greater metro
- Growth:
  - Population $\approx 3.9\%$ pa
  - Built volume $\approx 3.9\%$ pa
  - Reconstruction: 3kms from CBD, $35\%$ of buildings demolished in last 12 years.
- Slums:
  - Kibera:
    - Africa’s largest slum: $\approx 200k$ people (some estimates $> 1\text{mn}$)
  - 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
City with places, \( x \) (distance from CBD), date \( t \), development of type \( i \) (= Informal, Formal):

Price of housing (house-rent), quality adjusted:  
\[
p_i(x,t) = \bar{p}_i e^{\hat{\beta}_i t} e^{-\theta_i x} \quad p_F(x,t) = \bar{p}_F e^{\hat{\beta}_F t} e^{-\theta_F x}
\]
- 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
Informal sector:

Land-rent: \[ r_i(x,t) = [p_i(x,t)a(v_i(x,t)) - \kappa_i]v_i(x,t) \]

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) \[ r_i(x,t) = \kappa_i (\alpha - 1)[a_i p_i(x,t) / \kappa_i \alpha]^{\alpha/(\alpha-1)} \]

NB: Construction costs share 1/\alpha of revenue

Land-rent share 1 - 1/\alpha of revenue
Formal sector:

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

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

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

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 \( t \).

\[
R(x) = \int_{\tau_0}^{\tau_1} r_0 e^{-\rho t} dt + \int_{\tau_0}^{\tau_1} r_1(x, t) e^{-\rho t} dt + \left[ R_F(x, \tau_1) - D(x) \right] e^{-\rho \tau_1} + \sum_{i=2} \left[ R_F(x, \tau_i) e^{-\rho \tau_i} \right]
\]

- \( \tau_0 \): Rural to informal development
- \( \tau_1 \): Informal to formal development
- \( \tau_i \): Formal redevelopment

Rural to informal, date \( \tau_0 \):

\[
\frac{\partial PV(x)}{\partial \tau_0} = e^{-\rho \tau_0} [r_0 - r_1(x, \tau_0)] = 0
\]

Informal to formal, date \( \tau_1 \):

\[
\frac{\partial PV(x)}{\partial \tau_1} = e^{-\rho \tau_1} \left[ r_1(x, \tau_1) - p_F(x, \tau_1) v_F(x, \tau_1) \right] + \rho \left[ k(v_F(x, \tau_1)) + D(x) \right] = 0
\]

Formal redevelopment, date \( \tau_{2...} \):

\[
p_F(x, \tau_{i+1}) \left[ v_F(x, \tau_{i+1}) - v_F(x, \tau_i) \right] = \rho k(v_F(x, \tau_{i+1}))
\]
Development across time

Price path: \[ p_i(x,t) = \bar{p}_i e^{\hat{\theta}_i t} e^{-\theta_i x} \]

Transition slum \( \rightarrow \) 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 \( \Phi \), and the time interval between successive formal redevelopments is constant \( \Delta \tau \),
- Successive rounds of formal sector building have greater volume (height) by constant proportional factor.

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

$$\hat{p}_F > (\leq) \hat{p}_I$$
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)
    - 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 m², 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 3 kms 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
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>
<thead>
<tr>
<th>Table 1. Land price, House rent, Height, CAR and BVAR gradients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A. Key gradients used in calibrations</td>
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<td>----------------------------------------------------------------</td>
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<tr>
<td>Ln land sales price (USD per sq m.)</td>
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<td>----------------------------------------------------------------</td>
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<tr>
<td>Distance to centre</td>
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<td></td>
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<tr>
<td>Ruggedness</td>
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<td>Elevation</td>
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<tr>
<td>Constant</td>
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<tr>
<td>Other controls</td>
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<td>Observations</td>
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<tr>
<td>R-squared</td>
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</tbody>
</table>
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
- \( \alpha \rightarrow \) share of construction in formal house-rent = 74%
- \( \gamma \rightarrow \) 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 m\(^2\).  
  \[ p_l(x,t) \alpha_l v_l(x,t)^{(1-\alpha)/\alpha} = 7.56 \quad p_F(x,t) = 18.73 \]
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 \( z \)

\[
PV(x, s, z) = \int_s^z r_1(x, t)e^{-\rho(t-s)}dt + e^{-\rho(z-s)}\sum_{i=0}^{\infty} R_F(x, z + i\Delta \tau)e^{-\rho i\Delta \tau}
\]

\[
= r_1(x, s) \frac{1 - e^{-(\rho - \hat{\rho}_1\alpha/(\alpha - 1))(z-s)}}{\rho - \hat{\rho}_1\alpha/(\alpha - 1)} + r_F(x, s, s) \Phi \frac{e^{-(\rho - \hat{\rho}_F\gamma/(\gamma - 1))(z-s)}}{1 - e^{-(\rho - \hat{\rho}_F\gamma/(\gamma - 1))\Delta \tau}}.
\]
Land values: $PV(x, 2015, z)$

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

Present values at $s = 2015$. 
The cost of delay

- Perpetual delay vs efficient formalisation date at 3-4 kms
  - $790-$409 = $381 per m²
  - Equivalent to ≈ $15,000 per household
    (i.e., this the surplus after fully ‘compensating’ slum-lord)

- Drops off further out: at 5-6 kms
  - $284 per m²
  - Equivalent to ≈ $12,000 per household

- Total loss up to 6 kms ≈ $1.3bn

- Drops off with shorter delays:
  - 25 year delay from 2015 costs $56 per m² 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