Territorial control in civil wars:
Theory and measurement using machine learning

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Introduction

Question
How can we measure territorial control across space and over time?

Argument
We can estimate territorial control leveraging variation rebel tactics and using machine learning.

Contribution
1. Measurement model for rebel tactics.
2. Hidden Markov Model (HMM) estimates of territorial control.
Territorial control influences **tactical choices** in civil wars.

[Carter 2015, de la Calle and Sánchez-Cuenca 2015, 2012]
<table>
<thead>
<tr>
<th>Rebel tactical choice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Higher</strong> rebel control</td>
</tr>
<tr>
<td>➔ <em>Conventional</em> tactics</td>
</tr>
<tr>
<td><strong>Lower</strong> rebel control</td>
</tr>
<tr>
<td>➔ <em>Terrorist</em> attacks</td>
</tr>
</tbody>
</table>
Co-occurrence of conventional and terrorist tactics

Event locations in Nigeria 2014

- Conventional (GED)
- Terrorism (GTD)
Co-occurrence of conventional and terrorist tactics

Event locations in Nigeria 2014

- Red dots: Conventional (GED)
- Blue triangles: Terrorism (GTD)
VCo-occurrence of conventional and terrorist tactics

Event locations in Nigeria 2014

- Conventional (GED)
- Terrorism (GTD)
Co-occurrence of conventional and terrorist tactics

Event locations in Nigeria 2014

- Red circle: Conventional (GED)
- Blue triangle: Terrorism (GTD)
Continuum of territorial control

- Full rebel control
- Contested, closer to rebels
- Highly contested
- Contested, closer to government
- Full government control

Higher government control

Higher rebel control
Continuum of territorial control and tactical choice

Conventional fighting C

Terrorist attacks T

Full rebel control

Contested, closer to rebels

Highly contested

Contested, closer to government

Full government control

\[ \text{Tactics}_{it} = A \]
\[ C_{it} \approx T_{it} \approx 0 \]

\[ \text{Tactics}_{it} = B \]
\[ C_{it} > T_{it} \]

\[ \text{Tactics}_{it} = C \]
\[ C_{it} \approx T_{it} \not\approx 0 \]

\[ \text{Tactics}_{it} = D \]
\[ C_{it} < T_{it} \]

\[ \text{Tactics}_{it} = A \]
\[ C_{it} \approx T_{it} \approx 0 \]
Measuring variation in rebel tactics

\[\text{Tactics}_{it} = f \left( E^T_{it}, E^C_{it} \right), \text{where } \text{Tactics}_{it} = \{A, B, C, D\}\]

\[E^T_{it} \text{ area } i's \text{ exposure to terrorist events } K^T \text{ at time } t\]

\[E^C_{it} \text{ area } i's \text{ exposure to conventional events } K^C \text{ at time } t\]
Measuring exposure $E$ to conflict events $K$
Measuring exposure $E$ to conflict events $K$

Unit of observation: cell-month $C_{it}$

- Spatial distance $d_s$ in km, temporal distance $d_t$ in months.

- Logistic weights $w_s$ and $w_t$:
  
  $$ w_s(d_s) = \frac{1}{1 + e^{-7.35d_s}} $$
  $$ w_t(d_t) = \frac{1}{1 + e^{-8.25d_t}} $$

- Exposure $E$:
  
  $$ E_{it} = K \sum_{l=1}^{L} w_s w_t $$

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Measuring exposure $E$ to conflict events $K$

Unit of observation: cell-month $C_{it}$

a) Spatial distance $d_s$ in km, temporal distance $d_t$ in months.

\[ w_s(d_s) = 1 + e^{-7.35d_s} \]

\[ w_t(d_t) = 1 + e^{-8.5d_t} \]

\[ E_{it} = K \sum_{l=1}^\infty w_s w_t \]
Measuring exposure $E$ to conflict events $K$

Unit of observation: cell-month $C_{it}$

a) Spatial distance $d_s$ in km, temporal distance $d_t$ in months.

b) Logistic weights $w_s$ and $w_t$

$$w(d_s) = \frac{1}{1 + e^{-7+0.35d_s}}$$

$$w(d_t) = \frac{1}{1 + e^{-8+2.5d_t}}$$
Measuring exposure $E$ to conflict events $K$

Unit of observation: cell-month $C_{it}$

a) Spatial distance $d_s$ in km, temporal distance $d_t$ in months.

b) Logistic weights $w_s$ and $w_t$

\[
w(d_s) = \frac{1}{1 + e^{-7+0.35d_s}}
\]
\[
w(d_t) = \frac{1}{1 + e^{-8+2.5d_t}}
\]

c) Exposure $E$

\[
E_{it} = \sum_{l=1}^{K} w_s w_t
\]
Hidden Markov Model

Hidden:
- $\text{Territorial Control}_{i,1}$ → $\text{Territorial Control}_{i,2}$ → $\ldots$ → $\text{Territorial Control}_{i,t}$

Observed:
- $\text{Tactics}_{i,1}$
- $\text{Tactics}_{i,2}$
- $\ldots$
- $\text{Tactics}_{i,t}$
Hidden Markov Model

Transition probability
\[ \theta_t = P(q_t | q_{t-1}) \]

Emission probability
\[ \phi_t = P(o_t | q_t) \]

Territorial Control_{i,1} \rightarrow Territorial Control_{i,2} \rightarrow \ldots \rightarrow Territorial Control_{i,t}

Tactics_{i,1} \rightarrow Tactics_{i,2} \rightarrow \ldots \rightarrow Tactics_{i,t}
Decoding via Viterbi algorithm

**Most probable sequence** by returning hidden state labels (argmax) for maximum likelihood path for hidden state $q_h$ at $t$:

$$v_t(h) = \max_{g=1}^N v_{t-1}(g) \theta_{gh} \phi_h(o_t)$$

$h$... indexes current state
$g$... indexed previous state
$v_{t-1}(g)$... path probability of previous time step
$\theta_{gh}$... transition probability from $q_g$ to $q_h$
$\phi_h(o_t)$... emission probability given $h$
HMM estimates for Nigeria

[Discrete monthly-level estimates averaged for each year]
Validity of results

HMM estimates

Annual correlation of monthly cell estimates & validation data: [0.33, 0.50]

ACLED validation data

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Validity of results

HMM estimates

ACLED validation data

Histogramm for all grid-month observations (logged)

In observations per value of control

HMM

ACLED

Full rebel control

Full government control
Next steps

- Learn model parameters.
- Extends to asymmetric civil wars 1994-2015.
- Model spatial dependencies via Hidden Markov Random Fields (HMRF).
HMMs are promising method to estimate territorial control.
