Geographically Informed Policy Response and Intervention

Modeling the Spatial Non-Stationarity of Poverty Determinants

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Outline

► Motivation
► Empirical Literature
► Global Cross-Country Regression
► Geographically Weighted Regression
► Policy Implications
► Q&A
Motivation

- Moving from theory to praxis, we encounter enormous heterogeneity within member States (as the units of analysis) that may mask underlying processes.

- Poverty/growth regressions with subnational data, while affording greater spatial precision, still yield a one-size-fits-all model.

- Perhaps the construction and perpetuation of poverty is intrinsically different over space; can/should we assume parameter stationarity or should we explicitly test for it?
Empirical Literature (1)

- Research literature preoccupied with the missing variable approach to poverty modeling

- Debates continue over the primacy of institutions v. geography; the role of trade liberalization, cultural cleavages, structural adjustment, demographic momentum, etc.

- However, the empirical literature relies without exception on the cross-country regression approach where we assume, implicitly, that there exists a universal construction of poverty
Some poverty analysts are cognizant of tenuous universal explanations and appreciate the place specificity and scale dependencies of poverty:

The empirical relationship between poverty or inequality and indicators of development, such as economic growth, is typically examined in a cross-country regression framework. It is difficult, however, to control for the enormous heterogeneity which exists across countries; heterogeneity which may mask true relationships (Hentschel et al., 1998: 2).

[Variations in poverty determinants are] assumed to have the same effect in a poor country as in a rich country, in a primary-resource exporter as in a manufactures exporter, and in a country with well-developed institutions as in a country with underdeveloped institutions (Rodriquez, 2007: 2).
Spatial Determinants of Poverty in Africa
Child Malnutrition, 1990-2002 (% Underweight Under Age 5)

\[ I = 0.41 \]

Source: Gridded Underweight Children Raster (2.5') from the Center for International Earth Science Information Network (CICGIN) at Columbia University
Spatial Determinants of Poverty in Africa
Gross Domestic Product Per Capita, 2005

I = 0.32

Source: Gridded GDP Raster (1/4°) from the Center for International Earth Science Information Network (CICGIN) at Columbia University
Spatial Determinants of Poverty in Africa

Infant Mortality Rate, 2000
(Per 100 Infants Under Age 1)

\[ I = 0.36 \]

Source: Gridded IMR Raster (2.5') from the Center for International Earth Science Information Network (CICGIN) at Columbia University

Geoinformation at the UN Economic Commission for Africa
http://geoinfo.uneca.org
Spatial Determinants of Poverty in Africa

Multidimensional Poverty Factor
(Principal Components Analysis of GDP, Infant Mortality, and Child Malnutrition)

**Poverty Principal Component Score**
-3.158 - 0.933
-0.932 - 0.044
-0.043 - 0.463
0.464 - 0.843
0.844 - 1.604

Poverty\_pc = -0.405(GDP Per Capita) + 0.388(Infant Mortality) + 0.404(Child Malnutrition)

Poverty\_pc Eigenvalue = 2.09 and Variance Explained = 69.677%

Poverty\_pc Communalities
  - GDP Per Capita = 0.718
  - Child Malnutrition = 0.714
  - Infant Mortality = 0.658

Source: Gridded GDP, Infant Mortality, and Child Malnutrition Rasters from the Center for International Earth Science Information Network (CIGSIN) at Columbia University
Spatial Determinants of Poverty in Africa
Control/Explanatory/Predictor Variables

Surface Freshwater

Urbanization

Composite Natural Hazard Risk

...and 20+ other variables...

Sources: CIESIN; FAO; SRTM; ESRI; UN; DCW

Geoinformation at the UN Economic Commission for Africa
http://geoinfo.uneca.org
## Standard Cross-Country Linear Regression

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.228</td>
<td>0.755</td>
<td>0.302</td>
</tr>
<tr>
<td>Demography/Settlement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population Density (person/km²)</td>
<td>-0.000</td>
<td>0.002</td>
<td>-0.049</td>
</tr>
<tr>
<td>Pop. Growth Rate, 1960-2000</td>
<td>-0.002</td>
<td>0.002</td>
<td>-0.958</td>
</tr>
<tr>
<td>% Urban</td>
<td>-1.802</td>
<td>0.756</td>
<td>-2.384</td>
</tr>
<tr>
<td>Environmental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Elevation (in metres)</td>
<td>-0.000</td>
<td>0.001</td>
<td>-0.525</td>
</tr>
<tr>
<td>Topography (std. dev. in metres)</td>
<td>0.000</td>
<td>0.001</td>
<td>0.302</td>
</tr>
<tr>
<td>Composite Natural Hazard Index</td>
<td>0.030</td>
<td>0.014</td>
<td>2.020</td>
</tr>
<tr>
<td>Agricultural Resources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Surface Freshwater</td>
<td>0.013</td>
<td>0.007</td>
<td>1.828</td>
</tr>
<tr>
<td>Mean Rainfall Runoff (mm/annum)</td>
<td>0.001</td>
<td>0.000</td>
<td>1.382</td>
</tr>
<tr>
<td>% Regosols</td>
<td>0.040</td>
<td>0.021</td>
<td>1.956</td>
</tr>
<tr>
<td>% Yermosols</td>
<td>-0.024</td>
<td>0.014</td>
<td>-1.643</td>
</tr>
<tr>
<td>Infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Network Density (km/km²)</td>
<td>-0.072</td>
<td>0.036</td>
<td>-1.979</td>
</tr>
<tr>
<td>Land Use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Shrubland/Savannah</td>
<td>0.020</td>
<td>0.013</td>
<td>1.520</td>
</tr>
<tr>
<td>% Cropland</td>
<td>0.012</td>
<td>0.013</td>
<td>0.909</td>
</tr>
<tr>
<td>% Bare Soil</td>
<td>0.006</td>
<td>0.008</td>
<td>0.683</td>
</tr>
</tbody>
</table>

$t_{\alpha=0.05,n=30} \geq 1.697$ are in bold; $R^2 = 0.412; N = 54$
Interpretation

► Urbanization is a salient predictor of poverty across Africa with a constant coefficient of -1.802
► Natural hazard risk is uniformly proportional to poverty with a coefficient of 0.03
► Transport infrastructure is an equally significant (and inversely related) predictor of poverty across the continent
► All other variables are insignificant predictors of poverty
► etc...
Spatially Invariant Coefficients

\[ B_{\%\text{Urban}} = -1.802 \]

\[ t_{\%\text{Urban}} = -2.384 \]
Spatially Invariant Explanatory Power

Global $R^2 = 0.412$
Is such an interpretation empirically sustainable?
The standard regression equation (in matrix form) is estimated by
\[ Y = X\beta + \epsilon \]
which yields a vector of parameters, \( \beta \), that remain constant over space.

GWR weights observations around regression point \( i \) (having easting \( e_i \) and northing \( n_i \)) through a spatial weights matrix \( W \)
\[ \hat{\beta}(e_i, n_i) = \left( X^T W(e_i, n_i) X \right)^{-1} X^T W(e_i, n_i) Y \]
Spatial Kernel (2D)

Impose spatial kernels on our regression points, informed by theory, cross-validation, or arbitrarily.
Kernels not only establish a bandwidth of inclusion but also weight the observations around the regression point by some function of their distance from it.
<table>
<thead>
<tr>
<th>Predictor</th>
<th>Min.</th>
<th>Lower Quartile</th>
<th>Median</th>
<th>Upper Quartile</th>
<th>Max.</th>
<th>Spatial Variability (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.977</td>
<td>-0.482</td>
<td>-0.313</td>
<td>-0.126</td>
<td>0.733</td>
<td>0.77</td>
</tr>
<tr>
<td>Demography/Settlement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population Density (person/km²)</td>
<td>-0.005</td>
<td>-0.004</td>
<td>0.002</td>
<td>0.008</td>
<td>0.008</td>
<td>0.01</td>
</tr>
<tr>
<td>Pop. Growth Rate, 1960-2000</td>
<td>-0.004</td>
<td>-0.003</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.002</td>
<td>0.87</td>
</tr>
<tr>
<td>% Urban</td>
<td>-3.752</td>
<td>-3.567</td>
<td>-1.712</td>
<td>-0.712</td>
<td>-0.409</td>
<td>0.00</td>
</tr>
<tr>
<td>Environmental</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Elevation (in metres)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.63</td>
</tr>
<tr>
<td>Topography (std. dev. in metres)</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.002</td>
<td>0.000</td>
<td>0.001</td>
<td>0.06</td>
</tr>
<tr>
<td>Composite Natural Hazard Index</td>
<td>0.018</td>
<td>0.028</td>
<td>0.038</td>
<td>0.051</td>
<td>0.060</td>
<td>0.19</td>
</tr>
<tr>
<td>Agricultural Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Surface Freshwater</td>
<td>0.005</td>
<td>0.007</td>
<td>0.008</td>
<td>0.010</td>
<td>0.011</td>
<td>0.82</td>
</tr>
<tr>
<td>Mean Rainfall Runoff (mm/year)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.001</td>
<td>0.42</td>
</tr>
<tr>
<td>% Regosols</td>
<td>0.013</td>
<td>0.025</td>
<td>0.054</td>
<td>0.075</td>
<td>0.077</td>
<td>0.08</td>
</tr>
<tr>
<td>% Yermosols</td>
<td>-0.039</td>
<td>-0.037</td>
<td>-0.035</td>
<td>-0.013</td>
<td>-0.003</td>
<td>0.35</td>
</tr>
<tr>
<td>Infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Network Density (km/km²)</td>
<td>-0.109</td>
<td>-0.038</td>
<td>-0.022</td>
<td>0.000</td>
<td>0.083</td>
<td>0.57</td>
</tr>
<tr>
<td>Land Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Shrubland/Savannah</td>
<td>-0.001</td>
<td>0.001</td>
<td>0.008</td>
<td>0.027</td>
<td>0.032</td>
<td>0.00</td>
</tr>
<tr>
<td>% Cropland</td>
<td>-0.031</td>
<td>-0.028</td>
<td>-0.016</td>
<td>0.023</td>
<td>0.027</td>
<td>0.00</td>
</tr>
<tr>
<td>% Bare Soil</td>
<td>0.000</td>
<td>0.004</td>
<td>0.012</td>
<td>0.017</td>
<td>0.023</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Local R² Range: 0.742 – 0.868; N Nearest Neighbours = 52
Poverty-Urbanization Parameter Surface
Local Significance Estimates from Local Coefficients and Std. Errors
Local Adjusted $R^2$
The poverty-urbanization relationship is directionally stable across the continent.

The magnitude of the effect is not constant and ranges from -3.752 to -0.409, a ratio of 9.

But the local standard errors also vary spatially (not shown) and so the statistical salience of urbanization varies spatially.

Repeat this kind of interpretation for each variable.

The explanatory power of the model is also spatially variable.
Spatially Targetted Interventions
S613: Gender Parity Index in Secondary Level Enrolments

- Target Already Achieved
- Progressing
- Regressing
- No / Insufficient Data
Spatially Targetted Interventions
S613: Gender Parity Index in Secondary Level Enrolments

Ratio of Girls to Boys in Secondary Education

The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.
SITR, Economic Commission for Africa, 2007
Data Source: MGCINFO
Spatial Determinants of Poverty in Africa

Foster, Greer, Thorbecke Headcount Index

Sources: CIESIN Small Area Poverty Estimates

National
N = 1

Level 1: Faritany
N = 5

Level 2: Fivondrona
N = 111

Level 3: Firaisanana
N = 1238
Policy Implications

- GWR poverty models estimated with GWR may offer spatially prescriptive cues on local programme design and delivery.
- Geographic targeting of specific intervention mixtures that are place and scale specific.
- Mitigate ineffectual and inefficient spend.
- Don't assume stationarity; test for it.
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