

ANALYZING ENERGY CONSUMPTION, ECONOMIC GROWTH, & URBANIZATION

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Overview

- Simultaneously consider Urbanization, GDP, & Energy consumption
 - Macro-level, time series/cross section data
 - Panel cointegration, panel DOLS, & panel Granger-causality
- Split countries into Rich, Middle, & Poor panels to examine sensitivity to development

Outline

- Background
 - Energy consumption & economic growth
 - Urbanization & economic growth
 - Urbanization & energy consumption
- Model, Data, Methods, & Pre-testing Results
- Main Results
 - Long-run elasticity estimates
 - Impact of development
 - X-sect. variance
 - Granger-causality
- Conclusions

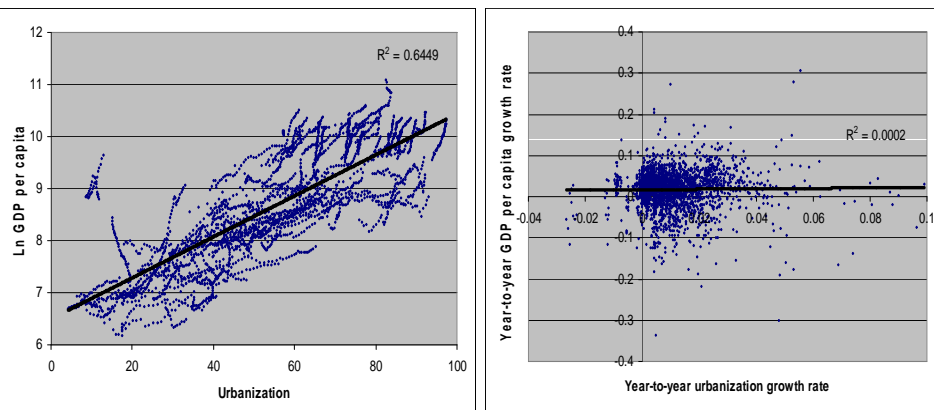
Energy GDP Causality

- Extensive & exponential causality literature
 - Over 101 paper from 1978-2008; half published since 2005; & 35 published in 2007-8 (Payne 2010)
- Literature hasn't reached consensus on results
- But has on methods
 - Use panel (TS-CS) data & time series methods recently developed for panels
 - Panel cointegration, FMOLS, DOLS for panels, & panel Granger-causality
 - Use multivariate models
 - $Y_{it} = K_{it}^{\alpha} L_{it}^{\beta} E_{it}^{\gamma}$
 - Cointegrated; $E \rightarrow Y$
 - Ignored urbanization

Urbanization \leftrightarrow GDP

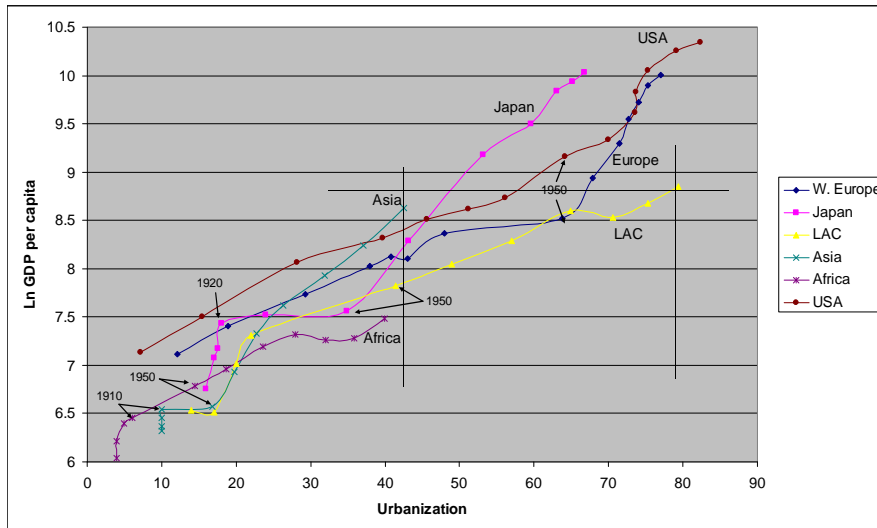
- GDP \rightarrow Urbanization
 - Industrialization: rural agricultural labor force migrates to urban manufacturing plants
- Urbanization \rightarrow GDP
 - Economies of scale in infrastructure, capital, labor, managerial resources
 - Knowledge spillovers

Urbanization-GDP

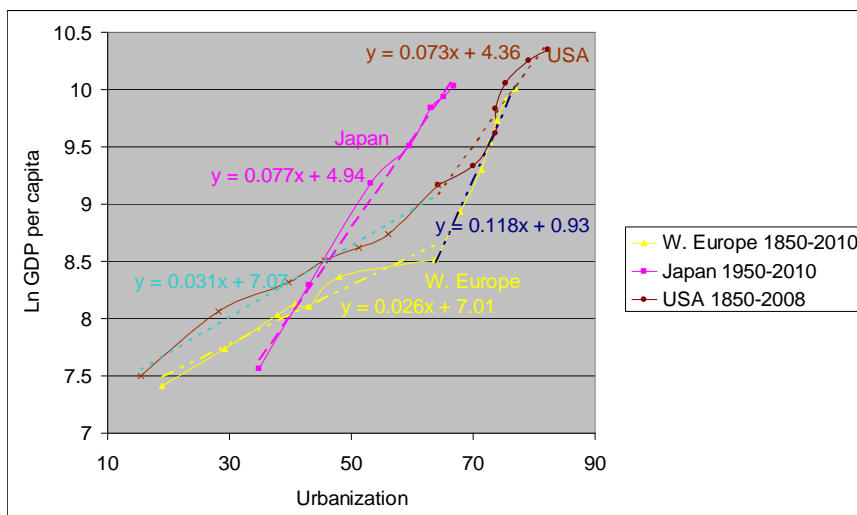


- Urbanization & GDP per capita negatively correlated w/ share labor in agriculture

Urbanization-GDP Paths, 1800/20-2010



Urbanization-GDP Paths



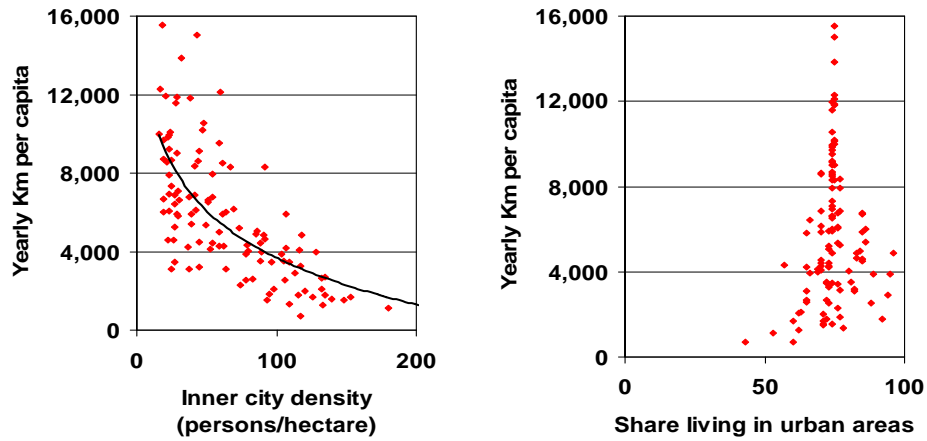
Urbanization-GDP Causality

- Bloom et al. (2008)
 - 163 countries; 4-5 observations per country
 - Bi-variate & no cointegration
 - No causality found
- Cointegration, causality studies
 - Halicioglu (2007)
 - Residential electricity in Turkey
 - Mishra et al. (2009)
 - Nine Pacific Island countries
 - No short-run causality

Urbanization \leftrightarrow Energy

- Urbanization leads to greater energy consumption
 - Urbanization associated w/ GDP & energy is normal good
 - Urbanization proxy for access to energy/electricity grid
- Urbanization leads to lower energy consumption
 - Cities benefit from energy efficiencies
 - High-rise buildings
 - Public transit
 - Energy-free modes

Urban *Density* vs. Urbanization Driving per capita



Urbanization → Energy

- Urbanization associated w/ industrialization—shift from agriculture to industry & services (Jones 1991):
 - Agriculture mechanizes
 - Food consumers & producers spatially separated
 - Industry more energy intensive than traditional agriculture/manufacturing
 - Location of energy intensive sectors depends on natural endowment
 - Energy intensity of technologies varies across countries & time

Model

- Production function w/ energy & urbanization as a shift factor (McCoskey & Kao 1999):

$$y_{i,t} = (U_{i,t})^\lambda (K_{i,t}^\beta E_{i,t}^\alpha L_{i,t}^{1-\beta+\alpha})$$

Where $y_{i,t}$ is GDP for country i in time period t ,
 $U_{i,t}$ is the percent of the population living in urban areas,
 $K_{i,t}$ is capital stock,
 $E_{i,t}$ is energy consumption,
and $L_{i,t}$ is the labor force.

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$$\ln y_{i,t}^* = a_i + b_t + \beta \ln K_{i,t}^* + \alpha \ln E_{i,t}^* + \lambda \ln U_{i,t} + \varepsilon_{i,t}$$

where * denotes per capita variables,
 a & b are country & time fixed effects, respectively,
& ε is the error term.

Methods

- Panel unit root tests on all variables
- Panel cointegration tests from Kao & Pedroni
- Pedroni's panel dynamic ordinary least squares (DOLS) for long-run elasticity estimates
- Panel Granger-causality tests

Relationship with Development (EKC or Inverted-U)

- Add GDP per capita squared (& higher order) terms to regression
 - Nonlinear transformations of $I(1)$ variables requires a different (and undeveloped?) asymptotic theory (Wagner 2008)
- Split into development-based panels (rich, middle, poor)
 - Construct confidence intervals from DOLS estimations to determine if coefficients are significantly different

Data

- Time-series, cross-section spanning 1971-2007 for 79 countries
- Three panels: 22 rich, 27 middle, & 30 poor countries
- IEA
 - Real GDP per capita at PPP & total final energy consumption per capita
- World Bank
 - Gross fixed capital formation per capita & urbanization in percentage points

Pre-testing Results

- Panel unit root tests suggest that GDP per capita, physical capital per capita, energy consumption per capita, and urbanization are panel $I(1)$ variables for all three panels
 - OLS in levels would be inefficient & spurious
- All four variables are panel cointegrated for all three panels
 - There is a long-run equilibrium relationship among the variables

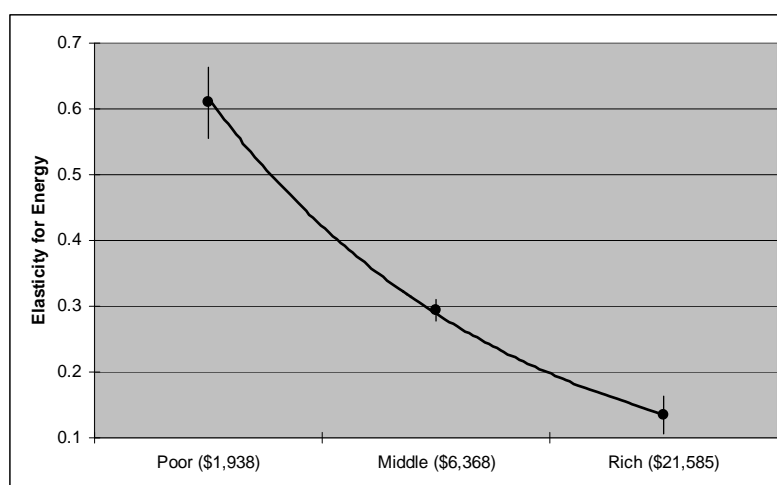
Long-Run Elasticity Estimates from DOLS

Panel	E		K		Urban	
	Coeff.	1% C.I.	Coeff.	1% C.I.	Coeff.	1% C.I.
Rich	0.13*	[0.11, 0.16]	0.25*	[0.24, 0.27]	0.52*	[0.42, 0.61]
Middle	0.29*	[0.28, 0.31]	0.24*	[0.22, 0.25]	0.51*	[0.35, 0.66]
Poor	0.61*	[0.56, 0.66]	0.22*	[0.21, 0.24]	-0.41*	[-0.70, -0.12]

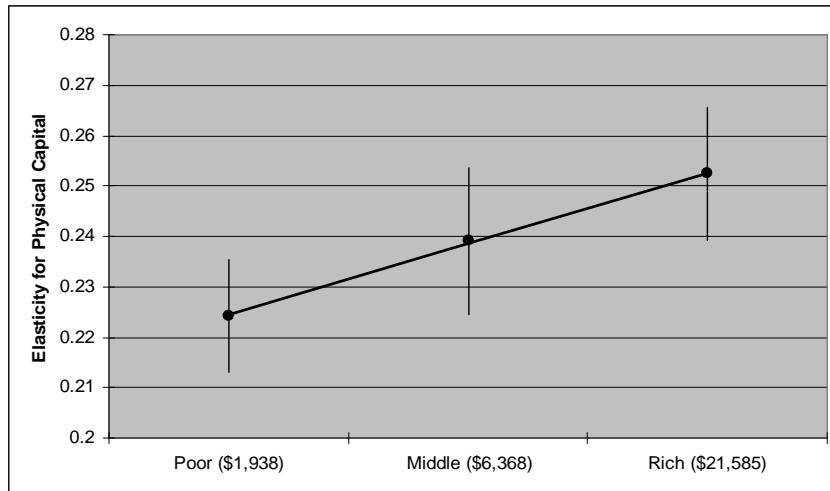
* P < 0.001

- Rich countries:
 - K > E; Urban >> K
- Middle countries:
 - E > K; Urban >> E
- Poor countries:
 - E >> K
 - Urban < 0 → “over-urbanized”

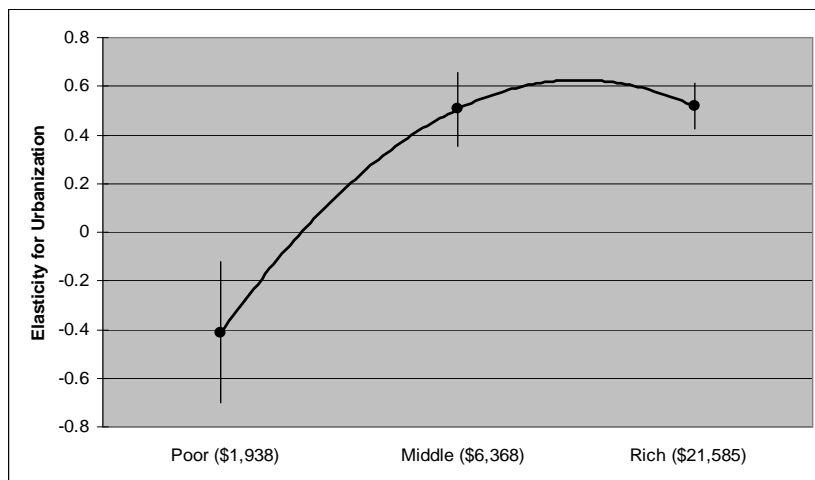
Importance of Development: Energy Consumption



Importance of Development: Physical Capital



Importance of Development: Urbanization



Variation in Individual Country Estimates				
Panel	Var.	No. x-sects. w/ insig. coeff.	No. x-sects w/ sig. neg. coeff.	Range & St. dev. sig. coeff.
Rich	E	5	6	[-1.37, 1.51] 0.73
(22	K	3	1	[-0.16, 0.83] 0.22
countries)	Urban	1	8	[-5.22, 4.42] 2.53
Middle	E	4	5	[-1.00, 1.20] 0.57
(27)	K	5	1	[-0.21, 0.86] 0.20
	Urban	5	10	[-3.36, 6.62] 2.76
Poor	E	8	6	[-6.68, 3.70] 2.28
(30)	K	4	3	[-0.91, 0.94] 0.36
	Urban	7	11	[-18.2, 28.02] 8.10

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- Both urbanization & energy consumption display large variance

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- Physical capital's elasticity is robust, narrow, & highly similar

Panel Granger-Causality

- All three panels (short-run)
 - $K \rightarrow GDP$
 - No causality between GDP & Urban
 - $GDP \rightarrow Energy$
- Rich countries (short-run)
 - $Energy \leftrightarrow GDP$; $K \rightarrow Energy$; $Urban \leftrightarrow Energy$
- Middle & Poor countries in long-run
 - $K, Energy, Urban \rightarrow GDP$
 - $K, GDP, Urban \rightarrow Energy$

Conclusions: Urbanization & Economic Growth

- GDP per capita, energy consumption per capita, physical capital per capita, & urbanization highly interrelated
 - Cointegrated & highly mutually causal
- Urbanization is important to & associated w/ economic growth
- Urbanization *does not directly cause* economic growth
- Poor countries are over-urbanized

Conclusions: Cross-section Variance

- Urbanization-development & energy-development relationship varies considerably across countries
- Importance of physical capita to economic growth highly robust & similar across panels/countries

Conclusions: Role of Development

- Importance of energy consumption to economic growth declines w/ development
- Physical capital more important for economic growth than energy consumption for rich countries
- Energy consumption more important for economic growth than physical capital for middle & poor countries

Conclusions: Methods

- To determine development's influence split into panels according to development level
 - Avoid nonlinear transformations of $I(1)$ variables
 - Panel-based model of development assumes history matters & that development is not a continually smooth process where all countries follow same path