Is infrastructure capital productive?

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Motivation

From development perspective, two reasons to care about infrastructure:

- Infrastructure and growth
  - Infrastructure raises productivity / reduces cost of private production
- Infrastructure and poverty / inequality
  - Infrastructure expansion has a disproportionate effect on the income / welfare of the poor
    - Reduces their cost to access markets (e.g., labor)
    - Raises the return on their assets (e.g., land)
    - Facilitates human capital accumulation directly (sanitation, water effect on health) or indirectly (transport to school etc)

Infrastructure and growth

How important is infrastructure for economic growth?

- Old question – even in Adam Smith's *Wealth of Nations*
- Empirically revived after Aschauer (1989) – who found huge rates of return on public capital in U.S.
- Big macro literature since then using various approaches and econometric techniques
  - Also micro studies looking at firm-level growth, investment, TFP
- Two common approaches
  - Growth regressions augmented with infrastructure measures
  - Infrastructure as another input in an aggregate production function (or its dual, the cost function)

Infrastructure and growth

On balance, majority of studies – especially recent ones on developing economies – find significant positive effects

But major caveats with most:

1. Multidimensionality of infrastructure: not just telephones (omitted variable bias?)
2. Monetary measures of infrastructure often misleading (Pritchett 2000; Keefer-Knack 2007)
3. Non-stationarity of aggregate output and infrastructure capital (*spurious regression* problem; Gramlich 1994)
4. Reverse causality: richer countries / times demand more infrastructure services
5. Potential heterogeneity in cross-country estimations

Calderón, Moral-Benito and Servén (2010)

Methodological approach addressing these caveats:

1. Considers the multidimensionality of infrastructure by using a synthetic index of telecom, transport and power.
2. Uses physical measures of infrastructure assets, rather than cumulative expenditures (Canning; Roller-Waverman)
3. Panel time-series approach to deal with non-stationarity of the variables.
4. Verifies that only one long-run relationship (= the aggregate production function) exists among the variables.
5. Allows for unrestricted short-run heterogeneity, and tests for homogeneity across countries of the long-run parameters.

Calderón, Moral-Benito and Servén (2010)

- Focus on the contribution of infrastructure to labor productivity (GDP per worker)
- Production function approach (under CRS):

  $Y/L = f(K/L, H/L, Z/L)$

  where *Y, K, H* and *Z* are GDP, physical capital, human capital, and infrastructure capital.
- Data from 88 industrial and developing countries,1960-2000 (> 3,500 obs)
- *Z* measured by *synthetic infrastructure index* – 1st principal component of road density, telephone density and power generation capacity [details]
- *f*(.) viewed as a long-run cointegrating relation whose parameters may be different across countries

Production function approach

- Cobb-Douglas technology: in log per worker terms,
$$y = \alpha k + \beta h + \gamma z$$
- Infrastructure capital appears twice in the equation (as part of *k*, and separately as z). [details]
- The parameter γ captures the "excess return" on infrastructure relative to other capital.
- The marginal product of infrastructure is higher the lower are infrastructure endowments per unit of output $z - y$

Empirical strategy

Three-step approach – based on recent panel time-series literature.

(1) Test for (non-)stationarity of the variables

(2) Test for cointegration and for a common cointegrating rank across countries [details]

(3) Estimate the cointegrating relation(s), and test for parameter homogeneity across countries

Estimation approach

- Tests reveal a common cointegrating rank of 1 [details]
- To estimate the cointegrating relation, use Pooled Mean Group estimator (Pesaran, Shin and Smith 1999)
  - Test for weak exogeneity, so single-equation approach suffices
  - Intercepts, error variances and short-run dynamics can differ freely across countries
    - Frictions and adjustment costs may vay across countries
    - Experiment with alternative dynamic specifications
    - Allow for cross-country error correlation (common shocks)
  - Long-run coefficients restricted to be equal for all countries
    - Test the restrictions through individual and joint Hausman tests of parameter homogeneity

Basic estimation results

Column	(1)	(2)	(3)	(4)	(5)	(6)
Max # of lags	2	2	2	1	4	2
Information criterion	SBC	AIC	Imposed	SBC	SBC	SBC
Common factors	Yes	Yes	Yes	Yes	Yes	No
Physical Capital	**0.34**	**0.33**	**0.36**	**0.35**	**0.34**	**0.41**
t-ratio	35.2	30.5	22.7	31.4	32.4	33.4
hausman p-value	0.54	0.95	0.43	0.78	0.44	0.52
Human capital	**0.10**	**0.12**	**0.10**	**0.12**	**0.11**	**0.12**
t-ratio	15.6	14.8	8.09	18.7	17.1	16.0
hausman p-value	0.24	0.19	0.21	0.19	0.20	0.64
Infrastructure	**0.08**	**0.07**	**0.10**	**0.08**	**0.08**	**-0.02**
t-ratio	7.45	6.73	6.58	8.33	8.77	-1.49
hausman p-value	0.21	0.18	0.16	0.40	0.88	0.40
joint hausman p-value	0.44	0.38	0.24	0.25	0.45	0.85
Average R^2	0.36	0.40	0.48	0.28	0.42	0.35
Observations	3432	3432	3432	3520	3256	3432

Basic estimation results

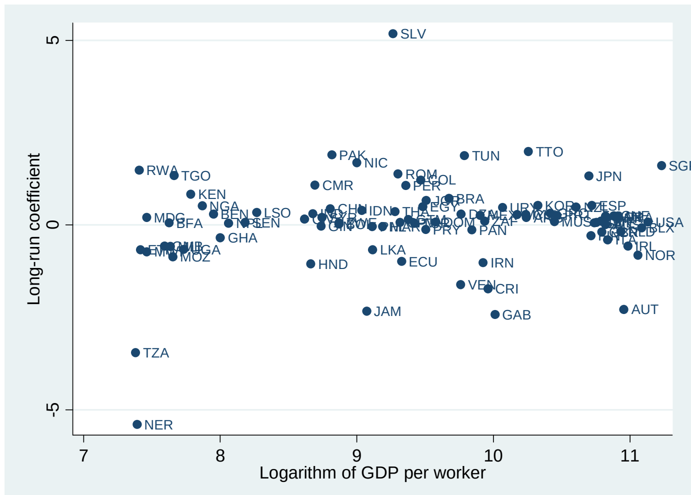
- Estimates are robust across specifications
  - Except if cross-country error correlation ignored
  - Little changed when using alternative measures of infrastructure, *h* and *k* [details]
- Coefficients on standard variables (physical and human capital) in line with literature (around 0.35, 0.10)
- Infrastructure coefficient in range .07 to .10
- No evidence of cross-country parameter heterogeneity
  - Accords with with empirical evidence on stability of factor shares (Gollin 2002)
  - But country-specific estimates are noisy (especially in poorer countries)

Further homogeneity tests

- No evidence of (general) parameter heterogeneity across countries – but tests may have low power
- Same conclusion from (more powerful) tests for *specific* forms of heterogeneity: [details]
  - By income level: infrastructure elasticity could be different in rich and poor countries
  - By level of infrastructure endowment: nonlinear effects of infrastructure (network effects?) [details]
  - By population size: economies of scale / congestion effects.
  - By quality of policy framework: high / low distortions – (close to 10% significance)

Further homogeneity tests

Output elasticity of infrastructure vs. per capita GDP



Economic significance

Direct increase in output per worker
from infrastructure catch-up to OECD median (percent)

Region	Increase in output per worker
East Asian Tigers	11.5%
Eastern Europe	8.3%
Latin America	13.7%
Middle East & N. Africa	15.5%
South Asia	26.0%
Sub-Saharan Africa	36.3%

From analysis to action

- All this is about the *benefit* side – what about the *cost*?
- Cost-benefit comparison needed to determine extent of under-provision of infrastructure – and whether it is greater than that of other inputs (e.g., *H*)
  - Limited evidence on this (e.g., Canning and Pedroni 2008: no generalized infrastructure shortage across countries / sectors)
  - Calderón and Servén (2010): big income impact of infrastructure catch-up in Africa – but massive cost involved [details]
  - Loayza and Odawara (2010): big income impact in Egypt too – but only if much of the cost is financed by spending cuts elsewhere
- Quality (not only quantity) of spending matters
  - impact on assets/services depends on government technical capacity, fiscal institutions, governance

Summary

Robust evidence of a positive contribution of infrastructure to GDP / productivity – a 10% rise in infrastructure assets *directly* raises GDP per worker by 0.7 to 1%.

The effect is highly significant and robust to alternative empirical specifications.

Little evidence that it varies across countries – so the returns to infrastructure are higher where the endowment is lower.

Effects are *economically* significant – potentially big income gains, especially for poor countries.

But careful before calling for big infrastructure spending rise – extent of underprovision unclear; refroms needed to enhance the link between spending and assets.

End

Data

- Output given by real PPP GDP from PWT 6.2
- Physical capital: perpetual inventory method with investment from PWT 6.2
- Human capital from Barro and Lee (2000)
- Infrastructure capital: power, transport and telecom
  - Electricity Generating Capacity (EGC) from United Nations Energy Statistics
  - Telephone lines from ITU
  - Road length in km from IRF
- These three infrastructure assets are summarized in a *synthetic index* constructed through a principal-component procedure. [back]

Production function approach

- Cobb-Douglas technology: in log per worker terms,
$$y = \alpha k + \beta h + \gamma z$$
- Infrastructure capital appears twice in the equation (as part of k, and separately as z).
- Let $\tilde{k}$ denote non-infrastructure physical capital. Then:
$$k = (1-\theta)\tilde{k} + \theta z \quad \text{and} \quad \frac{\partial y}{\partial z} = \alpha\theta + \gamma \quad \text{where } \theta = \frac{p_z Z}{p_z Z + p_{\tilde{k}} \tilde{K}}$$
- The parameter γ captures the “excess return” on infrastructure relative to other capital. Note also θ is usually a small number.

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Empirical strategy

Test for the existence of long-run relation(s):

- How many cointegrating relations are there?
- Is the number the same for all countries?
  - Find the minimum across countries (LR-bar test)
  - Find the maximum across countries (PC-bar test)
  - Test if they are equal

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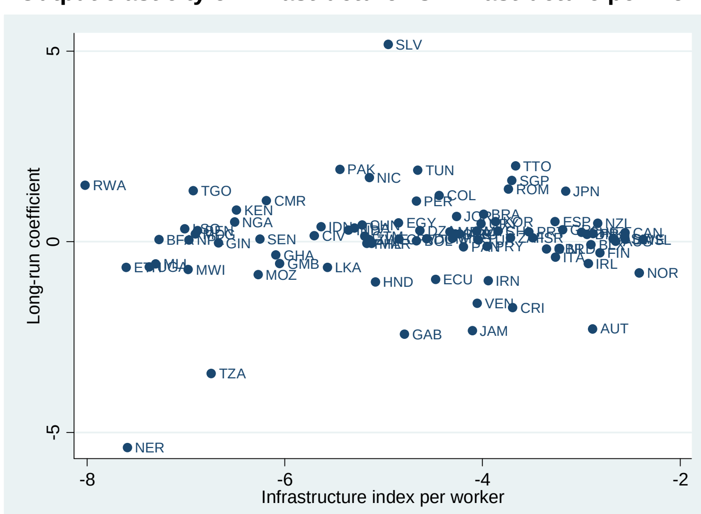
Cointegration test results [back]

PANEL A: Panel Unit Root Test	
Variable	Test Statistic
GDP	-6.20
Physical Capital	-7.08
Human capital	-1.77
Infrastructure	-3.35
PANEL B: Panel LR-bar Test	
Maximum rank	Test Statistic
0	9.03
1	0.85
PANEL C: Panel PC-bar Test	
Minimum rank	Test Statistic
1	1.21
5% critical value for the null hypothesis is 1.96 in all cases.	

Further homogeneity tests [back]

Output elasticity of infrastructure vs. infrastructure per worker



Further homogeneity tests [back]

Break sample into high / low along the relevant dimension – and test for equality of mean infrastructure coefficient

	Per Capita Income (A)	Per Capita Income (B)	Infrastructure Endowment	Total Population	Distortions
High	0.054	0.044	0.059	-0.016	-0.156
Low	0.059	0.062	0.055	0.131	0.271
p-value	0.985	0.94	0.988	0.576	0.102

Additional results: alternative explanatory variables [back]

Column	(1)	(2)	(3)	(4)	(5)
Variable Changed	Base	Total Phone Lines	Roads plus Rails	Paved Roads	BC Physical Capital
Physical Capital	**0.34**	**0.35**	**0.34**	**0.34**	**0.33**
t-ratio	35.2	32.8	35.2	26.6	18.0
hausman p-value	0.54	0.80	0.48	0.58	0.05
Human Capital	**0.10**	**0.07**	**0.10**	**0.05**	**0.10**
t-ratio	15.6	6.84	15.8	3.98	10.3
hausman p-value	0.24	0.55	0.24	0.11	0.20
Infrastructure	**0.08**	**0.07**	**0.08**	**0.07**	**0.09**
t-ratio	7.45	5.45	7.51	5.20	5.53
hausman p-value	0.21	0.37	0.23	0.41	0.14
joint hausman p-value	0.44	0.69	0.43	0.33	0.20
Average R^2	0.36	0.37	0.36	0.35	0.35

Sub-Saharan Africa: cost of infrastructure catch-up

Investment required for halving the infrastructure quantity gap with other regions

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