Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach.

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Motivation

- How important is infrastructure capital for economic growth?
- Since the seminal work of Aschauer (1989), a lot of studies have been concerned with the effect of public capital on economic growth.
- Standard way to incorporate infrastructure capital in an economic model is to introduce public capital as an additional production factor in a production function.
- In particular, Canning (1999), Canning and Bennathan (2000) and Röller and Waverman (2001) among others, attempted to measure the aggregate output effect of different types of infrastructure capital.

Why this paper?

- There are five major caveats in previous empirical literature:
  1. Non-stationarity of aggregate output and infrastructure capital.
  2. Problems of reverse causality.
  3. Potential heterogeneity across countries.
  4. Multidimensionality of infrastructure.
  5. Monetary measures of public capital might be misleading proxies of infrastructure.
- The paper's approach allows us to address these caveats:
  1. We use a panel cointegration approach to deal with the non-stationatiry of the variables.
  2. We test that the single (and common) cointegrating relationship among the variables can be interpreted as a production function.
  3. We allow for short-run heterogeneity across countries, and we test the homogeneity in the long-run relationship.
  4. We consider the multidimensionality of infrastructure by using a synthetic PCA index of telecommunications, transport and power.
  5. We use physical measures of infrastructure.

Data

- A balanced panel of 88 countries and 41 years (1960-2000)
- Output has been approximated by using the real GDP in 2000 PPP US dollars from PWT 6.2
- Physical capital: perpetual inventory method with investment from PWT 6.2 and initial stock from PWT 5.6
- Human capital from Barro and Lee (2000).
- Infrastructure capital:
  - Electricity Generating Capacity (EGC) in kilowatts from United Nations Energy Statistics
  - Number of telephone main lines (MLINES) from Canning (1998) and International Telecommunications Union.
  - Road length in kilometers (ROADS) from the International Road Federation World Road Statistics.
  - These three infrastructure assets are summarized into a synthetic index constructed through a principal-component procedure.

Production Function Approach

- We consider a Cobb-Douglas production function such that:

$$y = \alpha k + \beta h + \gamma z$$

where y,k,h and z are respectively output, physical capital, human capital and infrastructure capital in logs per worker terms. (CRTS assumed)

- Infrastructure capital appears twice in the equation (as part of k, and separately as z).
- Thus, letting $\widetilde{k}$ denote noninfrastructure physical capital:

$$\begin{aligned} k &= (1-\theta)\widetilde{k} + \theta z \\ \frac{\partial y}{\partial z} &= \alpha\theta + \gamma \ \text{ where } \theta = \frac{p_z Z}{p_z Z + p_{\widetilde{k}} \widetilde{K}} \end{aligned}$$

- Hence, the parameter γ captures essentially the excess return on infrastructure relative to other capital. Note also that θ is typically a small number so that the difference between $\alpha\theta + \gamma$ and the 'naive' estimate γ should be fairly modest.

Empirical Strategy

- We have a panel dataset of 88 countries (N) and 41 years (T).
- Our approach is based on recent panel time-series literature.
- Therefore, the production function may represent a long-run cointegrating relationship.
- Given the above, this research is based on three steps:
    1. Test the non-stationarity of the variables. [Details]
    2. Test whether there exist a common cointegrating relationship or not. [Details]
    3. If the variables are cointegrated, estimate consistently the long-run parameters and test for homogeneity.

Unit Root and Cointegration Test Results

Table: Testing Results

PANEL A: Panel Unit Root Test	
Variable	Test Statistic
GDP	-6.20
Physical Capital	-7.08
Secondary Education	-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 of unit root is 1.96 in all cases.

Estimation Method

- If there is only one cointegrating relationship among the variables, we can use the PMG estimator proposed by Pesaran, Shin and Smith (1999) [Details]
- This ML estimator allows the intercepts, short-run coefficients, and error variances to differ freely across groups, but constrains the long-run coefficients to be the same:

$$\Delta Y_i = \phi_i \left(Y_{i,-1} - X_{i,-1}\theta \right) + W_i \kappa_i + \varepsilon_i \quad i = 1, 2, ..., N$$

where $x_{it} = (physical\ capital_{it}, human\ capital_{it}, infrastructure_{it})$
$Y_i = (y_{i1}, ..., y_{iT})'$,
$W_i = (\Delta Y_{i,-1}, ..., \Delta Y_{i,-p+1}, \Delta X_{i,-1}, ..., \Delta X_{i,-p+1}, \iota)$ and
$\kappa_i = (\lambda_{i1}, ..., \lambda_{i,p-1}, \delta'_{i1}, ..., \delta'_{i,p-1}, \mu_i)'$.

- Moreover, long-run homogeneity can be tested.

Estimation Results

[Additional Results]

Table: Estimation Results

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
Secondary Education	**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

Concluding Remarks

- Output, physical capital and human capital represent a cointegrating relationship in all the 88 countries under analysis.
- Our estimates place the output elasticity of infrastructure in a range between 0.07 and 0.10.
- This result suggests that there is an excess return of infrastructure capital over that of non-infrastructure capital.
- On the other hand, tests of parameter homogeneity reveal little evidence that the output elasticity of infrastructure varies across countries.

Testing for non-stationarity

- Im, Pesaran and Shin (2003) propose a test based on the "normalized" average of ADF statistics computed for each group in the panel.
- Given the ADF(p_i) regressions:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{p_i} \rho_{ij} \Delta y_{i,t-j} + \varepsilon_{it}, \quad i = 1, ..., N, \; t = 1, ..., T$$

- The test is based on:
  - $H_0 : \beta_i = 0$ for all i
  - $H_1 : \beta_i < 0 \;\; i = 1, 2, ..., N_1, \;\; \beta_i = 0 \;\; i = N_1 + 1, N_1 + 2, ..., N.$
- The IPS test statistic is shown to converge in probability to a standard normal variate under the null.
- Monte Carlo simulations show that the IPS test performs reasonably well in finite samples. In particular, given the dimensions of our panel, we could expect to obtain high power. [Go Back]

Testing for Cointegration

- In previous studies, cointegration among variables has been assumed but not tested.
- In this multivariate panel setting, three questions emerge:

1. Are the series cointegrated?
2. If so, how many cointegrating relationships are there?
3. Is this number equal for all units in the panel?

- We follow a two step procedure that allow us to answer these three questions:
  1. LR-bar Test ⇒ It gives the maximum cointegration rank
  2. PC-bar Test ⇒ It gives the minimum cointegration rank.
- If they coincide, we conclude that there exists one common cointegration rank among all units. [Go Back]

LR-bar Test (Step 1)

$$H_0 \quad : \quad rank(\Pi_i) = r_i \leq r \quad \text{for all } i = 1, ..., N$$
$$H_1 \quad : \quad rank(\Pi_i) = p \quad \text{for all } i = 1, ..., N$$

- The LR-bar statistic converges to a standard normal as N and $T \rightarrow \infty$:

$$\Upsilon_{\overline{LR}}(r|p) = \frac{\sqrt{N}[N^{-1}\sum_{i=1}^{N} LR_{iT}(r|p) - E(Z_K)]}{\sqrt{Var(Z_K)}} \Rightarrow N(0,1)$$

where $LR_{iT}(r|p)$ is the individual trace statistic for unit i and $E(Z_K)$ and $Var(Z_K)$ are the mean and the variance of the asymptotic trace statistic provided by Larsson et. al. (1998)

- We employ the sequential procedure suggested by Johansen (1988)
- If one country has a higher rank than the hypothesed, the LR-bar statistic would asymptotically reject the null.
- Hence, this test gives the maximum cointegrating rank. [Go Back]

PC-bar Test (Step 2)

$$H_0 \;:\; cointegrating\ rank_i = r \quad \text{for all } i = 1, ..., N$$
$$H_1 \;:\; cointegrating\ rank_i < r \quad \text{for all } i = 1, ..., N$$

- The PC-bar statistic converges to a standard normal as N and $T \to \infty$:

$$PC_r = \frac{\sqrt{N}[N^{-1}\sum_{i=1}^{N}\widehat{c}_r^i - E(X_K)]}{\sqrt{Var(X_K)}} \Rightarrow N(0,1)$$

where $\widehat{c}_r^i$ is the individual PC Harris statistic for unit i and $E(X_K)$ and $Var(X_K)$ are the mean and the variance of the variable X that has the same distribution as the asymptotic distribution of $\widehat{c}_r^i$

- This panel test is based on the principal component analysis of cointegrated time series of Harris (1997).
- If (at least) one of the individual ranks is less than the hypothesed, the test asymptotically rejects the null. [Go Back]

Estimation Method in More Detail

- Considering y_{it} as the output for country i in year t and $x_{it} = (physical\ capital_{it},\ human\ capital_{it},\ infrastructure_{it})$
- The equation to be estimated can be written as:

$$\begin{aligned} \Delta Y_i &= \phi_i \xi_i(\theta) + W_i \kappa_i + \varepsilon_i \quad i = 1, 2, ..., N \\ \xi_i(\theta) &= Y_{i,-1} - X_{i,-1}\theta \quad i = 1, 2, ..., N. \end{aligned}$$

where $Y_i = (y_{i1}, ..., y_{iT})'$, $\xi_i(\theta)$ is the error correction component, $W_i = (\Delta Y_{i,-1}, ..., \Delta Y_{i,-p+1}, \Delta X_{i,-1}, ..., \Delta X_{i,-p+1}, \iota)$ and $\kappa_i = (\lambda_{i1}, ..., \lambda_{i,p-1}, \delta'_{i1}, ..., \delta'_{i,p-1}, \mu_i)'$.

- Because the parameters of interest are the long-run effects, we work directly with the concentrated log-likelihood function.
- Moreover, once the pooled MLE of the long-run parameters is computed, the short-run and the error-correction coefficients can be consistently estimated by running the individual OLS regressions of ΔY_i on $(\xi_i(\widehat{\theta}), W_i)$ [Go Back]

Alternative Explanatory Variables

[Go Back]

Table: Additional Results

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
Secondary Education	**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

Additional Homogeneity Tests

[Go Back]

Table: Homogeneity Tests

Column	(1)	(2)	(3)	(4)
	Per Capita Income (A)	Per Capita Income (B)	Infrastructure Endowment	Total Population
High	0.054	0.044	0.059	-0.016
Low	0.059	0.062	0.055	0.131
p-value	0.985	0.940	0.988	0.576