Endogenous Transport Investment, Geography, and Growth Take-offs

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Motivation: Geography Matters

Motivation

- Industrial revolution: why Britain?
- Why do some countries manage growth take-off – and some don't?

- Stylized fact: inter alia, growth take-off is associated with rapid urbanization / agglomeration
  (cf. e.g. recent World Bank WDR 2009)
- Economic Geography attributes both effects to falling transport costs - but does not explain how these obtain.

Motivation: Transport matters

Economic Geography (NEG) Approach

- Economic Geography (Krugman, 1991, . . .), theoretical:
  Spatial concentration depends on exogenous transport cost parameter:
  - Two symmetric regions: Initially static gains from trade.
  - If transport costs sink below a certain threshold: agglomeration

  $\Rightarrow$ All modern firms cluster in one region (beneficial / 'take-off')

Critique

✗ In NEG, transport costs are causal to economic growth

✗ Transport cost change is exogenous, arbitrary, and even for free!

✗ NEG does not explain why transport costs fall and
if, *why* and *when* the threshold is reached

Transport & Growth: Literature

- Empirical findings:
  - Transport infrastructure hardly causal to growth (e.g. Bose & Haque 2005)
  - Transport infrastructure is costly - not easy to afford
  - Historically, a decrease in physical transport costs – not tariffs – is related to industrial revolution (O'Rourke 2000)
- Analytical models:
  - very few: Vishny & Shleifer (1989), Kelly (1997), NEG: Takahashi (2006)
  - coordinate investment into one technology with externalities (EoS): 'Big Push' – result is trivial

Paper Strategy

Objective: Model that features

1. Static benefits from economic integration
2. Agglomeration-enhanced innovation
3. Endogenous transport that comes at a cost

1 & 2: Use Baldwin, Martin and Ottaviano (2001) NEG & growth model

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Note: Features borrowed from Baldwin et al. (2001) marked in grey

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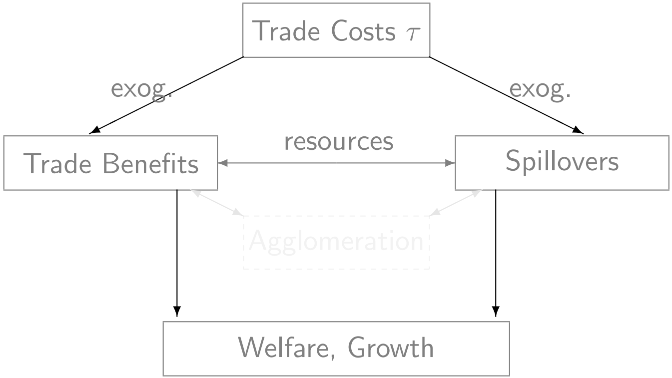
Endogenize Transport



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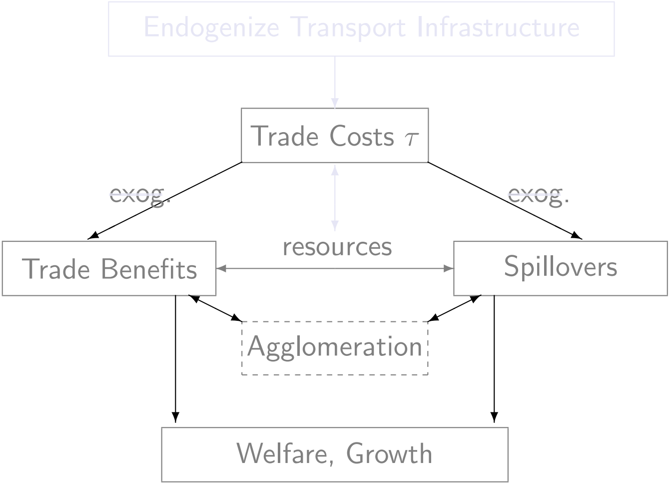

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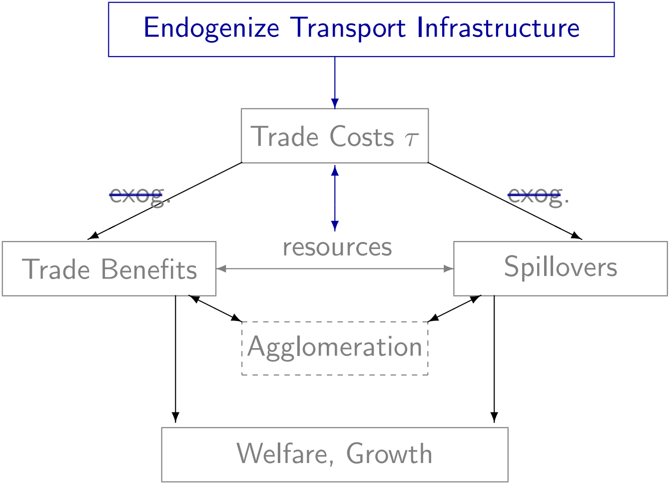
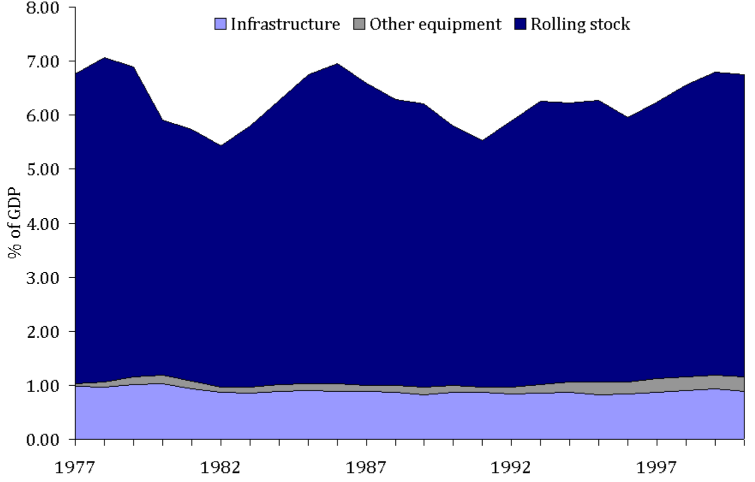


Endogenize Transport: Fleet Investment

This paper concentrates on *'fleet investment'*: private, bottom-up transport capital, no (direct) externalities
Each private firm builds improves its own 'fleet' of vehicles

- Why private bottom-up?
  - In 19th century Europe and poor countries, fixed transport infrastructure mostly built privately (Keller & Shiue 2008)
  - Most large infrastructure projects designed to meet private demand
- Why no externalities?
  - Majority of transport investment is in rolling stock (US) – should apply even more to poor countries.
  - In 18th century Britain, transport improvements financed by private ventures and local merchants

Overall Transport Investment in the US



Investment in transport capital by household, private business, and government sector
Data source: Bureau of Transport Statistics (2004)

Model Set-up: borrowed from Baldwin et al. (2001)

- Two regions, symmetrical endowments
- Two production factors: labor L, L^* and capital $K + K^* = K^w$
- Three sectors:
  - Consumer good *Agriculture* (A): numéraire, perfect competition
  - Consumer good *Manufacturing* (M): monopolistic competition, standard mark-up pricing, profits accrue to capital owners
  - *Innovation* sector (I): AK productivity with localized spillovers
    $A \equiv \frac{K}{K^w} + \lambda \frac{K^*}{K^w} = s + \lambda(1-s) \qquad \lambda \in (0,1)$
- Representative consumer: Cobb-Douglas between A and M, CES over manufacturing products (elasticity $\sigma > 1$)

Geography: Iceberg Costs

- Trade agricultural goods at no cost (equalizes wages)
- Immobile L & K, K has to be employed where it is constructed
- *Iceberg costs* for manufacturing goods:
  - Need $\tau \geq 1$ goods shipped for 1 unit to arrive in South (τ^* v.v.)
  - Thus export price $p^* = \tau p$ (τ times domestic price)
  - Define free-ness of trade $\phi \equiv \tau^{1-\sigma} \in (0, 1]$ (ϕ^* v.v.)

Fleet Investment

- Each firm *i* ships its goods by its own 'fleet'
- Fleet capital mapped to individual $\phi_i \in (\underline{\phi}, 1)$:
  - minimum value $\underline{\phi}$ and depreciation rate δ_T
  - capital law of motion mapped to $\dot{\phi}_i$
  - fleet investment rate Q_i, with quadratic adjustment costs
- Firm's transport capital problem:

$$\max_{Q_i} \quad \int_0^\infty e^{-rt}\Big(\overbrace{\pi_i(\phi_i)}^{\text{operating profits}} - \overbrace{a_T Q_i^2 w_L}^{\text{adjustment costs}} \Big)dt$$

$$s.t. \quad \frac{\dot{\phi}_i}{(1-\phi_i)} = \big(Q_i - \delta_T(\phi_i - \underline{\phi})\big)$$

$\Rightarrow$ Dynamic system in ϕ_i and Q_i, unique steady state $(\hat{\phi}, \hat{Q})$

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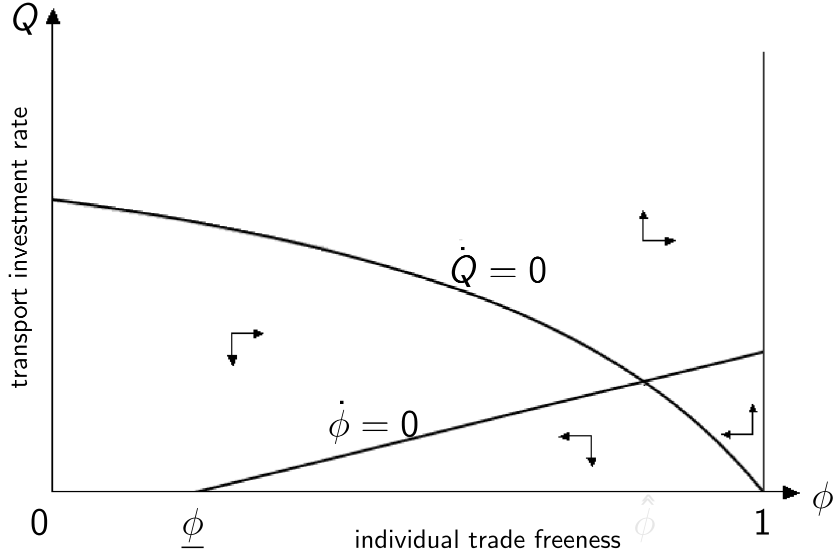
Fleet Investment Phase Diagram



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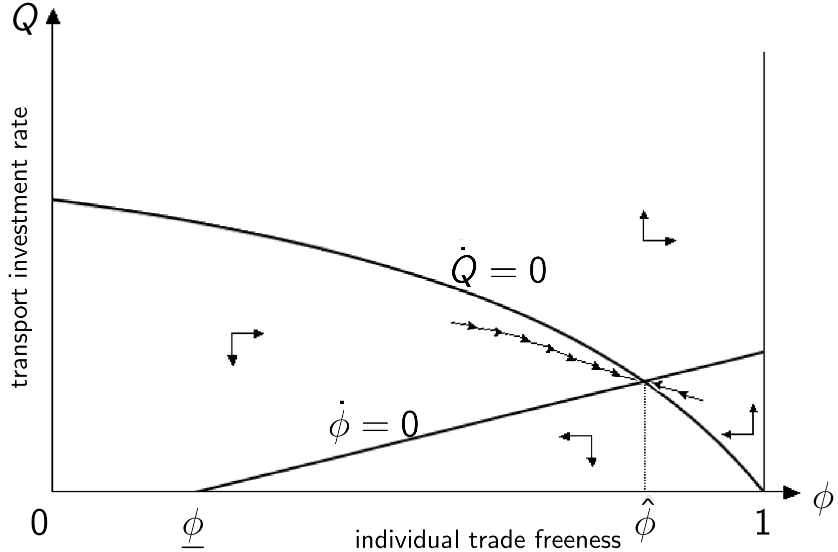

Equilibrium and Steady State

Two kinds of steady state:

- *Interior Equilibrium:* $\frac{\dot{K}}{K} = \frac{\dot{K}^*}{K^*}$
- *Core-Periphery (CP) Equilibrium:* $s \equiv \frac{K}{K^w} = 1$ or $s = 0$

Two relations must hold in Steady State:

'EE' Relation

$\Rightarrow$ Northern income share $s_E^{\text{EE}}(s) = \frac{E(s)}{E^w(s)}$ strictly increasing in s

'nn' Relation

$\Rightarrow$ From equal return on capital (in interior equilibria): $s_E^{\text{nn}}(s)$

$\Rightarrow$ Dynamics: CP and Symmetric ($s_E^{\text{nn}} = s_E^{\text{EE}} = \frac{1}{2}$) are always solution, but may be *stable or unstable*

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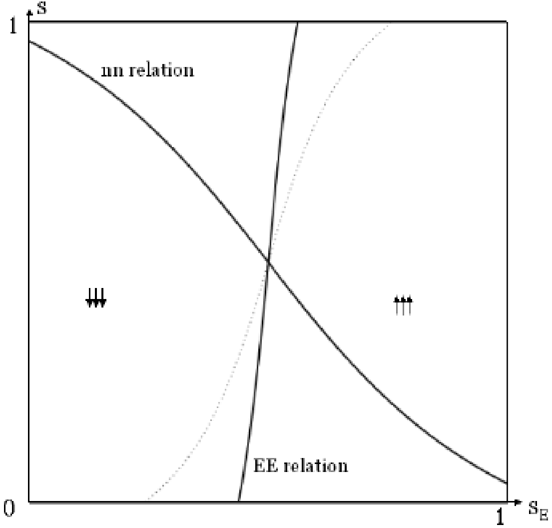
Steady State: Phase Diagram



Isolation vs. Agglomeration

Initial Stage $\phi = \underline{\phi}$

Start from symmetric (stable) equilibrium $\phi = \underline{\phi}$

- capital / real wage growth $g_{\text{iso}} = bL^w \frac{1+\lambda}{2} - \Theta$

Intermediate Integration $\hat{\phi}_{sym} > \underline{\phi}$

If L^w, $\underline{\phi}$ low: Firms build fleets ϕ_{sym}, remain in symmetric steady state: Diverts resources from innovation to transport, lose on growth

- growth $g_{\text{sym}} < g_{\text{iso}}$

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Rapid Agglomeration $\hat{\phi}_{CP} > \hat{\phi}_{sym}$

Only if L^w, $\underline{\phi}$ large enough: large $\hat{\phi}_{CP}$ renders CP stable

growth $g_{\text{CP}} \geq g_{\text{sym}}$

$\Rightarrow$ For virtually all parameter schedules: $g_{\text{sym}} \leq g_{\text{iso}} \leq g_{\text{CP}}$

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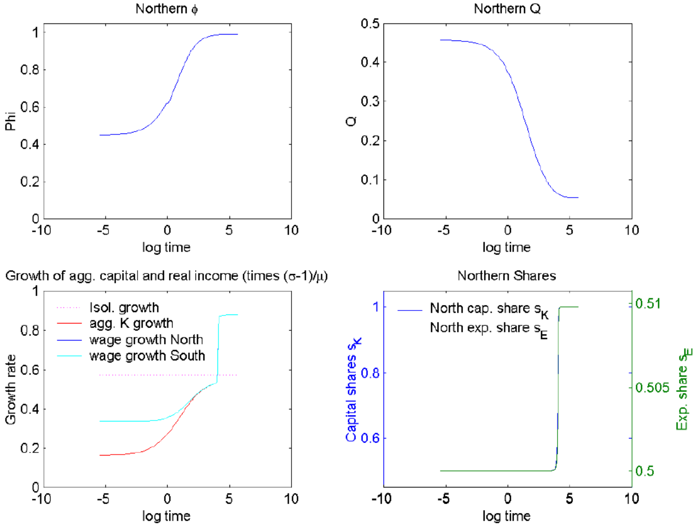
Simulation: From Isolation to Agglomeration



Parametrization: $\delta_T = \delta = 0.05, \rho = 0.04\ \lambda = 0.3,\ L^W = 2,\ \underline{\phi} = 0.45,\ \frac{\mu}{\sigma} = 0.5$

Policy Implications

- This paper presents an endogenous growth model with growth take-offs – which may occur without government intervention
- Rather a role for government: complement private initiative, to push the economy to the CP steady state.
- Raising $\underline{\phi}$: for instance, investing in *complementary public good* transport infrastructure ('ports'), removing obstacles, ...
- Decreasing fleet maintenance cost δ_T
- Reasons for lack of rolling infrastructue (e.g. Congo river, some rail lines)

Conclusion

- Endogenized transport infrastructure in Economic Geography via 'fleet investment': decentral, local, and endogenous

$\Rightarrow$ resolves causality shortcomings in the literature

- Result: Economic density L^w vs. $\underline{\phi}$ determines *if, why, when & where* economies reach an 'agglomeration threshold' / 'take-off'

- Note: Case with transport monopoly (same technology) yields broadly similar results

Appendix

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Backup: 'Credit Constraints'

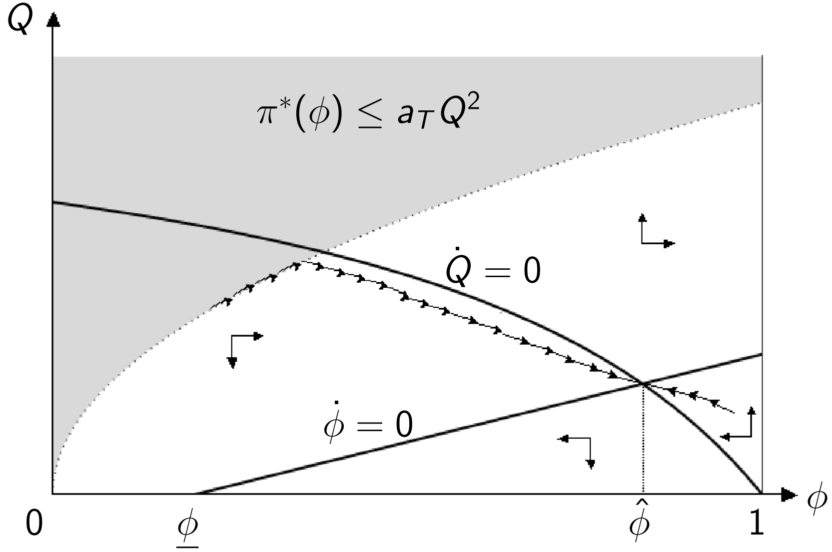
- Firms may not be able to embark on their investment trajectory right away due to credit restrictions:

Export profitability constraint (EPC)

Operating profits from export $\pi_i^*(\phi_i)$ larger than fleet maintenance cost

$$\pi_i^*(\phi_i) \geq a_T Q_i^2$$

Fleet Investment with Export Profitability Constraint



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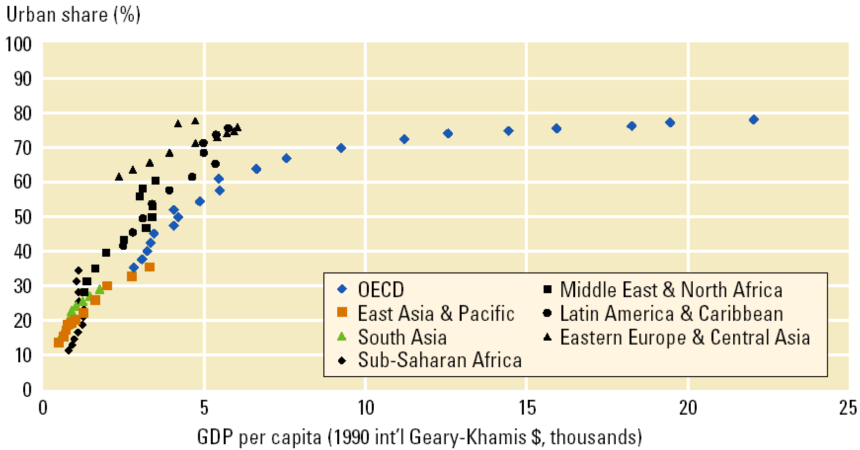
- In case initial investment costs too expensive, firms invest little and move along the EPC until they hit the standard saddle path

$\Rightarrow$ will severely delay time until steady state is reached

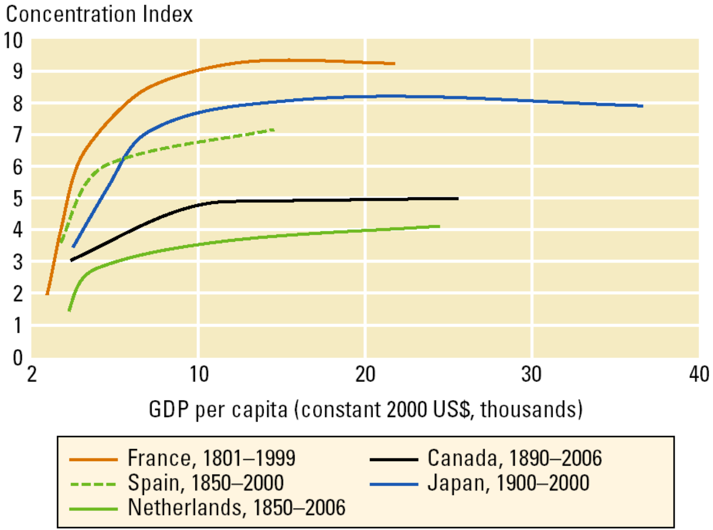
$\Rightarrow$ but has no effect on the position of steady state $\hat{\phi}$, CP or symmetric (since EPC is never binding in steady state)

Backup: Urbanization and Growth go Hand-in-Hand



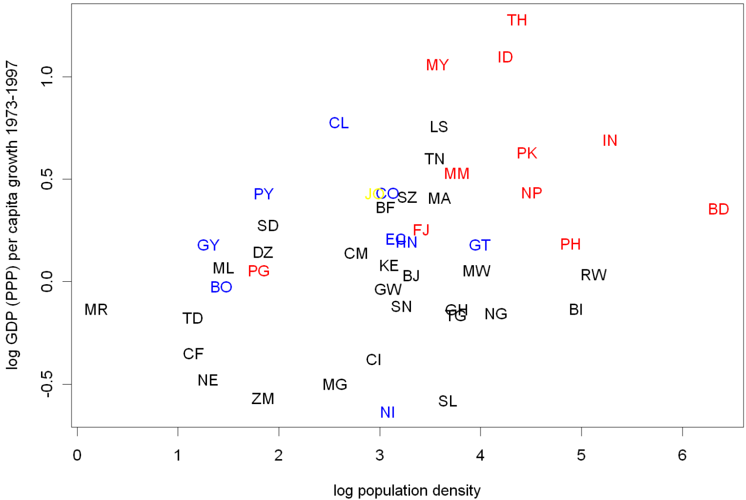
Source: World Bank (2008, p.58)

Backup: Economic Density and Growth are Concurrent



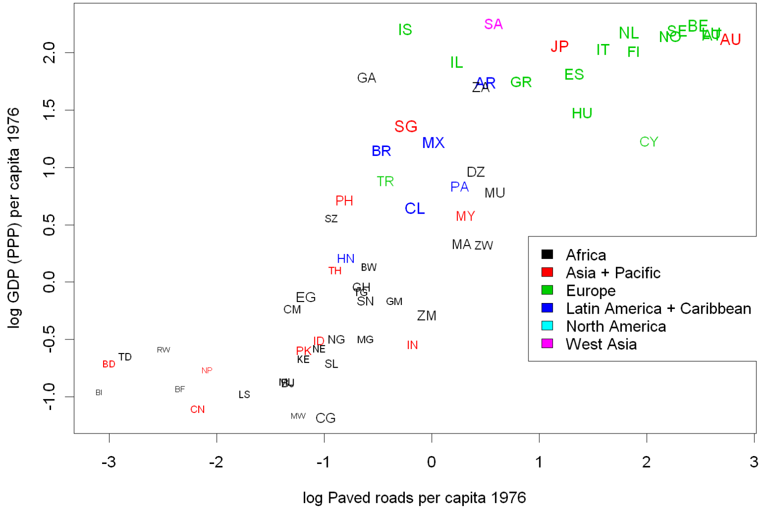
Source: World Bank (2008, p.83)

Backup: Take-off vs. Economic Density



Data sources: World Bank (2007), Canning (2007)

Backup: Infrastructure Stocks and GDP/cap.



Note: size of data points indicates urbanization share
Data sources: World Bank (2007), Canning (2007)

Backup: Fleet Dynamics

$\dot{Q}_i$ from f.o.c.:

$$\dot{Q}_i = \left(\rho + \delta_T(1-\phi)\right) Q_i - \frac{\partial \pi(\phi)}{\partial \phi} \frac{(1-\phi)}{2 a_T w_L}$$

Loci:

$$Q_i(\phi_i)|_{\dot{\phi}_i=0} = \delta_T \left(\phi_i - \underline{\phi}\right)$$
$$Q_i(\phi_i)|_{\dot{Q}_i=0} = \frac{\partial \pi(\phi)}{\partial \phi} \frac{(1-\phi)}{2 a_T w_L \left(\rho + \delta_T(1-\phi)\right)}$$

Backup: Transport Capital I

- Suppose transport capital K_i^T s.th. $\phi_i(K_i^T) : [0, \infty) \to (0, 1]$, monotone
- Firm's problem:

$$\max_{p_{i,t}, p^*_{i,t}, Q_{i,t}} \int_0^\infty e^{-rt} (x_i(p_{i,t}) p_{i,t} + x_i^*(p^*_{i,t}, \phi(K^T_{i,t})) p^*_{i,t} - F -$$

$$- w_L a_M \left(x_i(p_{i,t}) + \tau x_i^*(p^*_{i,t}, \phi(K^T_{i,t})) \right) - C(\overline{Q}_{i,t}, K^T_{i,t}) w_L)\, dt$$

$$s.t. \quad \dot{K}_i^T = \overline{Q}_i - \overline{\delta}_T K_i^T$$

- Under no uncertainty, simultaneous optimization equivalent to sequential optimization:

$$\max_{Q_i} \int_0^\infty e^{-rt} \left(\pi_i(\phi_i(K_i^T)) - C(\overline{Q}_i, K_i^T) w_L \right) dt$$

$$s.t. \quad \dot{K}_i^T = \overline{Q}_i - \overline{\delta}_T K_i^T$$

Backup: Transport Capital II

- Specific parametrization:

$$\phi_i = \frac{K_i^T + \underline{\phi}}{K^T + 1} \Leftrightarrow K_i^T = \frac{\phi - \underline{\phi}}{1 - \phi} \qquad C(\overline{Q}_i, K_i^T) = a_T \left(\frac{\overline{Q}}{K+1} \right)^2$$

- As ϕ_i is bijective to K_i^T, express K_i^T in terms of ϕ_i
- Redefine $Q_i \equiv \frac{\overline{Q_i}}{K_i+1}$, $\delta_T \equiv \frac{\bar{\delta}_T}{(1-\underline{\phi})}$

$\Rightarrow$ Reduced problem:

$$\max_{Q_i} \int_0^\infty e^{-rt} \left(\pi_i(\phi_i) - w_L a_T Q_i^2\right) dt$$
$$s.t. \quad \dot{\phi}_i = (1 - \phi_i)\left(Q_i - \delta_T(\phi_i - \underline{\phi})\right)$$

Fleet Investment: Additional Assumptions

Spillovers: capital stock K eases transport

- Basic Assumption: spillovers from capital stock extend to fleet investment
- Technical Assumption: for analytical tractability, specific transport capital productivity $(s + \phi(1-s))\,K^w$, i.e. akin to capital spillovers

Transport: Constant Returns to Scale

The transport capital technology is CRS with respect to the number of shipped goods

Backup: Market Clearing

- Free trade in agriculture ⇒ agricultural price equals wage: $w_L = w_L^* = 1$

⇒ 'mill price' of manufacturing good normalized to $p_i = 1$, Southern import price $\tau_i \geq 1$

⇒ Northern manufacturing firm operating profits:

$$\pi = \frac{\mu}{\sigma} \frac{E^w}{K^w} \left(\frac{s_E}{s + \phi^*(1-s)} + \phi \frac{(1-s_E)}{\phi s + (1-s)} \right)$$

⇒ Northern consumption expenditure

$$E = \frac{L^w}{2} + (\pi - a_T Q^2) s K^w - L_I$$

Backup: Steady State – Return on Capital

- At any steady state: firm present value v equals capital cost a_I for North and South:

$$v = \frac{\pi - a_T Q^2}{\rho + \delta + g} = \frac{1}{AK^w} = a_I \qquad v^* = a_I^*$$

$\Rightarrow$ Pins down expenditure in both interior and CP steady state:

$$E(s) = \frac{L^w}{2} + \rho \frac{s}{A} \qquad E^*(s) = \frac{L^w}{2} + \rho \frac{(1-s)}{A^*}$$

$\Rightarrow$ Returns $\hat{\phi}$, $\hat{Q}$ as a function of s

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Backup: Steady State – Fleet

$$\left(1-\hat{\phi}(s)\right) = -\frac{\frac{b}{2\delta_T^2}E^* + \frac{\rho}{\delta_T} - (1-\underline{\phi})}{2} + \\ + \sqrt{\left(\frac{\frac{b}{2\delta_T^2}E^* + \frac{\rho}{\delta_T} - (1-\underline{\phi})}{2}\right)^2 + \frac{\rho}{\delta_T}(1-\underline{\phi})}$$

$$\hat{Q}^2 = (\hat{\phi}-\underline{\phi})\delta_T\left(\delta_T(1-\underline{\phi})+\rho\right) - \frac{b}{2}\underbrace{\left(\frac{L^w}{2}+\rho\frac{(1-s)}{A^*}\right)}_{=E^*}(1-\hat{\phi})$$

Backup: Steady State – 'EE' relation

- From $E(s)$: $\Rightarrow$ market clearing ('EE') relation $s_E^{\mathrm{EE}}(s) = \frac{E}{E^w}$ as a strictly increasing function of s

$$s_E^{EE} = \frac{\frac{1}{2}L^w + \rho\frac{s}{A}}{L^w + \rho\left(\frac{s}{A} + \frac{(1-s)}{A^*}\right)}$$

Backup: Steady State – 'nn' relation

- From $v = a_I$, $v^* = a_I^*$ at all interior equilibria: innovation sector earnings equalization:

$$A(\pi - a_T Q^2) = A^*(\pi^* - a_T^* Q^{*2})$$

$\Rightarrow$ Defines 'nn' relation $s_E^{\text{nn}}(s)$

$$s_E^{nn}(s) = \frac{\frac{1}{bE^w}\left(A\Delta\hat{Q}^2 - A^*\Delta^*\hat{Q}^{*2}\right) + \Delta\left((1-\hat{\phi}\lambda) - (1+\hat{\phi})(1-\lambda)s\right)}{\left(1-\hat{\phi}\hat{\phi}^*\right)\left(A^*s + A(1-s)\right)}$$

Dynamics

- if $s_E^{\text{nn}}(s) < s_E^{\text{EE}}(s)$, then $\dot{s} > 0$ (due to $\frac{v}{a_I} > \frac{v^*}{a_I^*}$)

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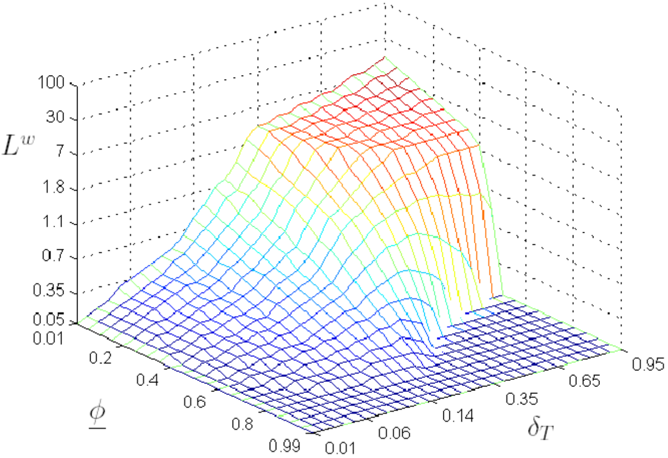
Dynamics

- if $s_E^{\mathrm{nn}}(s) < s_E^{\mathrm{EE}}(s)$, then $\dot{s} > 0$ (due to $\frac{v}{a_I} > \frac{v^*}{a_I^*}$)

Backup: Threshold for Agglomeration

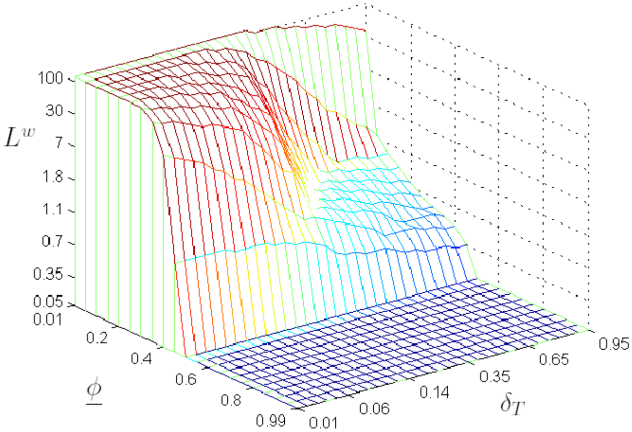
Parameter settings for which the the symmetric steady state is unstable (above the surface)



Parametrization for this figure: $\delta = 0.05$, $\rho = 0.02$, $\lambda = 0.5$, $b = \frac{\mu}{\sigma} = 0.2$

Backup: Isolation Trap

Parameter settings for which the export profitability constraint $\pi_i^* \geq a_T Q_i^2$ is binding (below the surface)



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Backup: Alternative Transport Sector

- Monopolist with toll and no CRS: revenue accruing to shipper per firm: $(\theta-1)\tau x_i^*$; τx_i^* is exported goods of firm i.
- Results: firm profits downweighted by $\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \Rightarrow$, $\hat{\phi}_{monop} < \hat{\phi}_{fleet}$.
- Moreover in sym. and CP steady state: $E_{monop} < E_{fleet}$.
- Broadly, mechanics are quite similar.
- Did not manage to analytically solve for s_E^{nn} and s_E^{EE} i.e. steady state.
- seems that all growth rates are lower since bE^w term is downweighted.
- Downsides with my formulation:
  - Also at $\underline{\phi}$ there is toll
  - monopolist does not take effect on price level into account (i.e. one monopolist per firm)