In Harm's Way? Infrastructure Investments and the Persistence of Coastal Cities by Clare Balboni

Skand Goel

Spatial Reading Group: May 13, 2020

Motivation

- How should we make investments in transportation infrastructure today, when the future might look different from today?
- Depends on how future changes in environment affect net present value from today's investments.
- People respond to infrastructure changes and environmental changes, so the NPV is an equilibrium object.
- This paper provides a framework for comparing this NPV under alternative investment scenarios.

Context

- Sea level rise will "flood" many low lying coastal areas.
- Yet, currently these areas globally have high concentration of economic activity and population.
- Vietnam is a classic case of this.
- However, from 2000-2010 massive infrastructure upgrades were made to connect coastal areas to inland.
- Is this misallocation? How much?

Plan

- Focus on theoretical framework
- Testing the model and calibration
- Solving the model and counterfactuals

Theoretical Framework

- Discrete time t, several locations $n, i \in N$.
- Locations differ in productivity $A_{n,t}$, amenities $B_{n,t}$, supply of land $H_{n,t}$ and initial labor endownment $L_{n,0}$.
- Monopolistically competitive firms in each location produce horizontally differentiated varieties using labor.
- Forward looking consumers in each locations
  - choose consumption (goods and housing) and where to live/work next period, and
  - inelastically supply one unit labor.
- Locations trade goods with each other and also with rest of the world.

Consumers

Value function in location n at time t is given by

$$v_{n,t} = \underbrace{\alpha \log\left(C_{n,t}/\alpha\right) + (1-\alpha)\log\left(H_{n,t}/(1-\alpha)\right)}_{\text{consumption choice at } t \text{ given income and prices in } n}$$

$$+ \max_{i \in N}\left[\beta E\left(v_{i,t+1}\right) - \underbrace{\mu_{in}}_{\substack{\text{time-invariant} \\ \text{migration cost}}} + B_{i,t} + \underbrace{b_{i,t}}_{\substack{\text{location preference shock:} \\ \text{Gumbel} \sim (-\gamma\nu, \nu)}}\right]$$

where $C_{n,t}$ is the CES demand aggregator

$$C_{n,t} = \left[\Sigma_{i \in N} \int_0^{M_{i,t}} c^*_{ni,t}(j)^{\frac{\sigma-1}{\sigma}} \mathrm{d}j\right]^{\frac{\sigma}{\sigma-1}}$$

- $c^*_{ni,t}(j)$: consumption *choice* of variety j from location i in n at time t
- $M_{i,t}$: endogenously determined measure of varieties supplied by location i (from production)

Consumers: migration choice

- With algebra and Gumbel properties, we get

$$\max_{i\in N}\left[\beta E\left(v_{i,t+1}\right)-\mu_{in}+B_{i,t}+b_{i,t}\right]=\nu\log\Sigma_{i\in N}\left(\exp\left[\beta E\left(v_{i,t+1}\right)-\mu_{in}+B_{i,t}\right]\right)^{\frac{1}{\nu}}$$

and also the share of location n workers that migrate to i at the end of t

$$m_{in,t}=\frac{\left(\exp\left[\beta E\left(v_{i,t+1}\right)-\mu_{in}+B_{i,t}\right]\right)^{\frac{1}{\nu}}}{\Sigma_{m\in N}\left(\exp\left[\beta E\left(v_{i,t+1}\right)-\mu_{mn}+B_{m,t}\right]\right)^{\frac{1}{\nu}}}$$

Consumers: consumption choice

- Think of two stage problem: Each labor unit allocates income $y_{n,t}$ to $C_{n,t}$ and $H_{n,t}$, then allocate income $y^C_{n,t}$ within $C_{n,t}$ to $c_{ni,t}(j)$.
- Given the Cobb-Douglas preference over C and H, $\alpha y_{n,t}$ is spent on C and $(1-\alpha)y_{n,t}$ is spent on H.
- Within $C_{n,t}$, CES functional form implies

$$c^*_{ni,t}(j) = p_{ni,t}(j)^{-\sigma} y^C_{n,t} P^{1-\sigma}_{n,t}$$

  where

$$P_{n,t} = \left[\Sigma_{i \in N} \int_0^{M_{i,t}} p_{ni,t}(j)^{1-\sigma} \mathrm{d}j \right]^{\frac{1}{1-\sigma}}$$

  and $p_{ni,t}(j)$ is the price of $c_{ni,t}(j)$.
- With this setup, $C_{n,t} = y^C_{n,t}/P_{n,t} = \alpha y_{n,t}/P_{n,t}$
  - $P_{n,t}$ comes from *firm's problem* given CES demand,
  - $y_{n,t}$ next.

Consumers: Income

- Workers get income from two sources: wages $w_{n,t}$ and lump sum transfers of land rental income, which is transferred lump sum to workers.
- Total income at n, t is given by

$$y_{n,t} L_{n,t} = w_{n,t} L_{n,t} + (1 - \alpha) y_{n,t} L_{n,t} \implies y_{n,t} = w_{n,t} / \alpha$$

- Also, given $H_{n,t}$ and $y_{n,t}$, land market clearing pins down $r_{n,t}$:

$$(1 - \alpha) y_{n,t} L_{n,t} = r_{n,t} H_{n,t}$$

Consumers: Expected Indirect utility

Putting all the pieces together, we get *expected* indirect utility in location n at time t:

$$V_{n,t} = \alpha \log\left(\frac{w_{n,t}}{\alpha}\right) - \alpha \log P_{n,t} + (1-\alpha)\log\left(\frac{H_{n,t}}{(1-\alpha)L_{n,t}}\right)$$
$$+ \nu \log \Sigma_{i \in N}\left(\exp\left[\beta V_{i,t+1} - \mu_{in} + B_{i,t}\right]\right)^{\frac{1}{\nu}}$$

- Benefit of transportation infrastructure: $V_{n,t} \downarrow$ in $P_{n,t} \rightarrow P_{n,t} \uparrow d_{ni}$ (production)
- Congestion: $V_{n,t} \uparrow$ in $\frac{H_{n,t}}{L_{n,t}}$

Production: prices

- Two endogenous objects: $p_{ni,t}(j)$ and $M_{i,t} \rightarrow P_{n,t}$
- Producing $x_{i,t}(j)$ quantity of variety j at location i needs requires labor

$$l_{i,t}(j) = F + \frac{x_{i,t}(j)}{A_{i,t}}$$

- Given iceberg costs for transporting from i to n, $d_{ni,t}$ and CES demand functions above, each firm j sets same price

$$p_{ni,t} = \left(\frac{\sigma}{\sigma - 1}\right) \frac{d_{ni,t} w_{i,t}}{A_{it}}$$

Production: $M_{i,t}$

- With this, zero profit condition implies labor demand for variety j

$$l_{i,t}(j) = \sigma F$$

- Labor market clearing in n, t

$$\underbrace{\int_0^{M_{i,t}} l_{i,t}(j)}_{\text{labor demand}} = M_{i,t}\sigma F = \underbrace{L_{i,t}}_{\text{labor supply}}$$

- Agglomeration economies via CES demand: More varieties at cheaper prices
  - $M_{n,t}$ proportional to $L_{n,t}$, and
  - locally produced variety is cheaper - $p_{ni}(j) \uparrow$ in d_{ni}

Bilateral trade

- Gravity: Value of bilateral trade flows from i to n

$$X_{ni,t} = \alpha \left(X_{n,t} P_{n,t}^{\sigma-1} \right) M_{i,t} p_{ni,t}^{1-\sigma}$$

- Share of n's expenditure on goods from i

$$\pi_{ni,t} = \frac{X_{ni,t}}{\Sigma_{k \in N} X_{nk,t}} = \frac{M_{i,t} p_{ni,t}^{1-\sigma}}{\Sigma_{k \in N} M_{k,t} p_{nk,t}^{1-\sigma}}$$

- **Trade balance**: Total income at location i is equal to the total expenditure on goods produced in location i

$$w_{i,t} L_{i,t} = \Sigma_{n \in N} \pi_{ni} X_{n,t}$$

Bilateral trade

- Under symmetric trade costs, trade balance is a set of two *static* conditions

$$w_{i,t}L_{i,t} = L_{i,t}\left(\frac{w_{i,t}}{A_{i,t}}\right)^{1-\sigma} MA_{i,t}$$

$$MA_{i,t} = \sum_{n \in N} \frac{d_{ni,t}^{1-\sigma} X_{n,t}}{MA_{n,t}} = \sum_{n \in N} \frac{d_{ni,t}^{1-\sigma} w_{n,t} L_{n,t}}{MA_{n,t}}$$

- $MA_{i,t}$ useful for testing the model.
- International trade: Add RoW to the set of locations.
  - Treat exports E_t are exogenous.
  - Model implies that only data on total exports and bilateral international trade costs is needed.

Sequential equilibrium

Given $\{d_{in,t}, \mu_{in}, A_{n,t}, B_{n,t}, H_{n,t}, E_t\}$, a sequential equilibrium is a set of labor allocations $\{L_{n,t}\}$, wages $\{w_{n,t}\}$, migration shares $\{m_{ni,t}\}$, market access terms $\{MA_{n,t}\}$ and expected lifetime utilties $\{V_{n,t}\}$ that solve

- Trade equilibrium: previous slide
- Consumer's problem: Expected indirect utility satisfies the $V_{n,t}$ recursion
- Migration shares

$$m_{in,t} = \frac{\left(\exp\left[\beta V_{i,t+1} - \mu_{in} + B_{i,t}\right]\right)^{\frac{1}{\nu}}}{\Sigma_{m\in N}\left(\exp\left[\beta V_{m,t+1} - \mu_{mn} + B_{m,t}\right]\right)^{\frac{1}{\nu}}}$$

- Law of motion of $L_{n,t}$

$$L_{n,t+1} = \Sigma_{i\in N} m_{ni,t} L_{i,t}$$

Testing the model

- Taking logs and first-differencing

$$w_{i,t}L_{i,t} = L_{i,t}\left(\frac{w_{i,t}}{A_{i,t}}\right)^{1-\sigma} MA_{i,t}$$

implies

$$\triangle \log w_i = \left(\frac{\sigma-1}{\sigma}\right)\triangle \log A_i + \left(\frac{1}{\sigma}\right)\triangle \log MA_i$$

- Measuring MA: Use data on $\{d_{ni,t}w_{n,t}L_{n,t}\}$ for $t =$2000 and $t =$2010, and solve

$$MA_{i,t} = \sum_{n\in N} \frac{d_{ni,t}^{1-\sigma} w_{n,t}L_{n,t}}{MA_{n,t}}$$

  and compute $\triangle \log MA_i = \log MA_{i,2010} - \log MA_{i,2000}$.
- Compare coefficient on $\triangle \log MA_i$ to $\frac{1}{\sigma}$.

Testing the model

$$\triangle \log w_i = \left(\frac{\sigma - 1}{\sigma}\right) \triangle \log A_i + \left(\frac{1}{\sigma}\right) \triangle \log MA_i$$

- Endogeneity: $\triangle \log A_i$ is unobserved
  - Productivity trends correlated with $\triangle MA$ - controls and region FE
  - Transportation improvements correlated with district-level unobservables
  - Spatial correlation between $\triangle w_n$ or $\triangle L_n \rightarrow$ spurious correlation between $\triangle \log w_i$ and $\triangle \log MA_i$
- Use IV based announcement of a highway project to be built along the route of the historic Ho Chi Minh Trail from 2000.
- Exclusion: Trail constructed as logistical supply route for soldiers from 1969-1973
  - Add controls for district geography, US bombing and district characteristics.
- Calibrated $\frac{1}{\sigma} = \frac{1}{7}$ lies within the 95% CI of coefficient.

Data and Calibration

- 541 spatial units (districts) - geographic, demographic and economic data for 2010, and some for 2000.
- d_{ni} measured as lowest cost route between any two district centroids (more details)
- Road construction costs from engineering
- α, β, σ, ν (migration elasticity) from external sources.
- Calibrate $MA_{i,2010}$ as above and use trade balance to get $A_{i,2010}$.
- Set assumptions about future inundation - gradual inundation of land below 1m over 100 years.
    - $H_{n,t}$ gradually goes down by fraction of area of district n below 1m.
    - d_{ni} gradually goes up for all road stretches below 1m.

Solving the model

- We don't observe $\{\mu_{in}\}$ or $\{B_{n,t}\}$ (even in initial period).
- Solve the model in relative time differences - Caliendo et. al. (2019).
  - Closed form expressions for $Y_{n,t} = [\exp(V_{n,t+1} - V_{n,t})]^{\frac{1}{\nu}}$ and ratio of migration shares.
  - time-invariant $\{\mu_{in}\}$ cancel out, also B_n
  - In general, we don't need to know the levels of some of the fundamentals
- Solution method has two requirements:
  - Need to know initial conditions and paths for model fundamentals - $\{d_{in,t}\}, \{A_{n,t}\}, \{H_{n,t}\}$ and $\{E_t\}$ - and agents have perfect foresight.
  - Sequential equilibrium converges to a stationary equilibrium i.e. all endogenous objects are constant in the long run.

Solving the model

Simulation-based solution method

- Fix T (when path becomes stationary) and $\{d_{in,t}, A_{n,t}, H_{n,t}, E_t\}_{t=0}^{T}$.
- Guess a path of $Y_{n,t}$ such that $Y_{n,T} = 1$.
- Given $m_{in,-1}$, solve for path of $\{m_{in}\}$, and use this to infer path of $\{L_{nt}\}$.
- Solve the static equilibrium conditions for MA_{nt} each period and get w_{nt}.
- Use these to calculate $Y_{n,t}^{new}$, which serves as the updated guess until convergence.

Counterfactuals

- The paper derives a closed form expression for expected lifetime utility

$$W_{n,t} = \Sigma_{s=t}^{\infty}\beta^{s-t}\log\left(\frac{\frac{w_{n,s}}{\alpha}\exp(B_{n,s})}{P_{n,s}^{\alpha}\left(\frac{(1-\alpha)L_{n,s}}{H_{n,s}}\right)^{1-\alpha} m_{nn,s}^{\nu}}\right) = \Sigma_{s=t}^{\infty}\beta^{s-t}\log\left(\Omega_{n,s}\right)$$

- Denoting a counterfactual scenario by $\hat{}$, time t compensating variation in consumption $\delta_{n,t}$ satisfies

$$\hat{W}_{n,t} = \Sigma_{s=t}^{\infty}\beta^{s-t}\log\left(\delta_{n,t}\hat{\Omega}_{n,s}\right)$$

which gives a measure of change in welfare

$$\triangle\text{Welfare}_{n,t} = \log\left(\delta_{n,t}\right) = (1-\beta)\Sigma_{s=t}^{\infty}\beta^{s-1}\log\left(\hat{\Omega}_{n,s}/\Omega_{n,s}\right)$$

- Each counterfactual scenario comprises a different set of model fundamentals $\{\hat{d}_{in,t}, \hat{A}_{n,t}, \hat{H}_{n,t}, \hat{E}_t\}_{t=0}^{T}$.
- The all scenarios assume fixed $A_{n,t} = A_{n,2010}$ and $B_{n,t} = B_n$, which drop out in relative time differences.

Counterfactuals

- Ex-post evaluation of roads built from 2000-2010 - average welfare 1.47% higher with future inundation, 2.49% higher without.
- Ex-ante evaluations of infrastructure projects with same total cost as the ones realized
  - non-targeted: connect all districts, maximize market potential (distance weighted market size)
  - targeted: maximize market potential outside sub-1m zone, sub-5m zone.
- Important findings
  - upgrades that maximize market potential outside sub1-m zone give 72% welfare improvements.
  - even the non-targeted projects do not favor coastal areas!
  - without sea-level rise 72% reduced to 48% - still substantial!
- Robustness with changes in $A_{n,t}$ and $B_{n,t}$, and more...