In Harm's Way? Infrastructure Investments and the Persistence of Costal Cities

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Research Question

- Coasts historically contain a large share of the world's population, reflecting historical advantages.
  - Access to ports.
  - Fertile farmland.
- Coasts have thus historically received the majority of infrastructure investment.
- Climate change and rising sea levels may eliminate these advantages and destroy of infrastructure in low-elevation coastal zones (LECZs).
- This paper considers whether large infrastructure investments should continue to favor coastal areas.

Related Literature

- Transport infrastructure investments influencing trade costs and hence the distribution of economic activity across space and aggregate growth: Allen and Arkolakis (2022); Fajgelbaum and Schaal (2020); Redding and Turner (2015).
  - This paper: looks at climate change's effect on the pattern of gains associated with infrastructure.
- How the coastal advantage diminishes through structural change and development of inland transport networks: Crompton (2004); Fujita and Mori (1996); Donaldson and Hornbeck (2016).
  - This paper: models how climate change will affect the coastal advantage.
- Geographic models in which firms in each location produce horizontally-differentiated varieties under monopolistic competition and increasing returns to scale: Krugman (1991); Helpman (1998); Redding (2016); Caliendo, Dvorkin, and Parro (2019); Kucheryavyy, Lyn, and Rodríguez-Clare (2023).
  - This paper: uses a similar framework to analyze the potential effect of climate change on the returns to infrastructure investment.

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Results Preview

- Accounting for future sea level rise significantly alters estimates of the returns to infrastructure investments made today.
  - Without accounting for sea level rise, the net present value of aggregate welfare gains from realized road investments made in Vietnam from 2000 to 2010 would have been 1.56%.
  - Assuming a 1-meter rise in the sea level realized gradually over 100 years, this decreases by 12% to 1.37%.
- Taking future sea level rise into account meaningfully changes our assessment of where infrastructure should be allocated today.
  - Counterfactual allocations of infrastructure's returns differ significantly when accounting for sea level rise.
    - Accounting for sea level rise, the unconstrained market access maximizing allocation of new roads results in lower welfare gains than foresighted allocations maximizing market access while excluding districts with more than 33% of their land is below 1 meter of elevation.

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Locations

- Several locations indexed by $n \in N$ differ in their
  - Productivity, $A_{n,t}$, which captures natural advantages (e.g., proximity to natural resources) or induced advantages (e.g., infrastructure).
  - Amenity value, $B_{n,t}$, which captures characteristics of each location that make them more or less desirable places to live.
  - Supply of (immobile) land, $H_{n,t}$.
  - Initial endowment of (imperfectly mobile) workers, $L_{n,0}$.

Consumers

- Inelastically supply one unit of labor each period.
- Preferences over:
  - Land $H_{n,t}$.
  - Amenity $B_{n,t}$.
  - A goods consumption index $C_{n,t}$ defined over an endogenously-determined measure $M_{i,t}$ of horizontally differentiated varieties.
    - Preferences are CES across location bundles with an elasticity of substitution η and CES across varieties within a location bundle with elasticity of substitution σ:

$$C_{i,t} = \left[\sum_{n=1}^{N} \left(\sum_{j=1}^{M_j} c(j)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma(\eta-1)}{(\sigma-1)\eta}} \right]^{\frac{\eta}{\eta-1}}$$

- Work, earn the market wage, and consume consumption goods and land in the location where they begin the period.

Value Function

- Then decide whether to remain in the location where they began to period, or relocate and pay an additive migration costs.
  - If they relocate, they receive utility from the new location's amenity and from an idiosyncratic iid shock, $b_{i,t} \sim \text{Gumbel}(-\gamma\nu, \nu)$, where γ is Euler's constant.
- The value function is

$$
\begin{aligned}
v_{n,t} =& \alpha \ln\left(\frac{C_{n,t}}{\alpha}\right) + (1-\alpha)\ln\left(\frac{H_{n,t}}{1-\alpha}\right) \\
&+ \max_{i \in N}\left\{\beta \mathbb{E}[v_{i,t+1}] - \mu_{i,n} + B_{i,t} + b_{i,t}\right\}
\end{aligned}
$$

- The expected lifetime utility of an agent at location n is given by

$$
\begin{aligned}
V_{n,t} = \mathbb{E}[v_{n,t}] =& \alpha \ln\left(\frac{C_{n,t}}{\alpha}\right) + (1-\alpha)\ln\left(\frac{H_{n,t}}{1-\alpha}\right) \\
&+ \nu \ln\left(\sum_{i \in N} \exp\left\{\beta V_{i,t+1} - \mu_{in} + B_{i,t}\right\}\right)
\end{aligned}
$$

Migration Gravity Equations

- The share of workers starting period t in region n who migrate to region i is

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

- Therefore, the evolution of population in each location n evolves according to

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

Production, Prices, and Trade

- No capital; firms take labor as input and produce consumption varieties $\longrightarrow$ static optimization problem.
- Firms incur fixed cost of F units of labor each period, and additional workers each produce $A_{n,t}$ units of output. Therefore, the amount of labor required to produce $x_{i,t}(j)$ units of variety j is $l_{i,t}(j) = F + \frac{x_{i,t}(j)}{A_{i,t}}$.
- Firms face iceberg costs when shipping goods between locations. Must ship $d_{ni,t} \geq 1$ units from location i to have one unit arrive at location n.

Equilibrium Consumption Price Index and Trade Shares

Combining the first-order conditions of the household and firm yields

$$P_{n,t}^{1-\eta} = \sum_{i \in n} \left(\frac{L_{i,t}}{\sigma F} \right)^{\frac{1-\eta}{1-\sigma}} \left(\frac{\sigma}{\sigma - 1} \cdot \frac{d_{ni,t} w_{i,t}}{A_{i,t}} \right)^{1-\eta}$$

$$\pi_{ni,t} = \left(\frac{P_{ni}}{P_n} \right)^{1-\eta} = \frac{X_{ni,t}}{X_{n,t}} = \frac{L_{i,t}^{\frac{1-\eta}{1-\sigma}} \left[\frac{d_{ni,t} w_{i,t}}{A_{i,t}} \right]^{1-\eta}}{\sum_{l \in N} L_{l,t}^{\frac{1-\eta}{1-\sigma}} \left[\frac{d_{nl,t} w_{l,t}}{A_{l,t}} \right]^{1-\eta}}$$

$X_{ni,t}$ is total value of bilateral trade flows from i to n. $X_{n,t}$ is aggregate expenditure at location n at t.

Income

- Let $y_{n,t}$ denote nominal income per labor unit (same across all sectors within a location in equilibrium due to competitive labor markets) and $r_{n,t}$ denote land rent at location n in time t.
- Real income in n then $Y_{n,t} = \frac{y_{n,t}}{P_{n,t}^{\alpha} r_{n,t}^{1-\alpha}}$.
- Assumption: land in each location is owned by immobile landlords who receive worker expenditure on residential land as income and only consume goods in the location in which they live. Thus, workers' only receive wage income: $y_{n,t} L_{n,t} = w_{n,t} L_{n,t}$.

Equilibrium Land Rent

Equilibrium land rent determined by land market-clearing condition:

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

Plugging this into $V_{n,t}$ yields

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

Trade I

- Follows Baum-Snow et al. (2020) version of Eaton and Kortum (2002) allowing for domestic and international trade.
    - Requires only data on the total value of a country's international exports and bilateral trade costs from each region tot he nearest international port.
- Domestic regions indexed by i, k, and n. Rest of world indexed by x.
- Now, allowing for international trade, the share of region n's expenditure on goods from region i at time t is

$$\pi_{ni,t} = \frac{L_{i,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{ni,t} w_{i,t}}{A_{i,t}}\right)^{1-\eta}}{\sum_{k \in N} L_{k,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{nk,t} w_{k,t}}{A_{k,t}}\right)^{1-\eta} + L_{x,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{nx,t} w_{x,t}}{A_{x,t}}\right)^{1-\eta}}$$

Trade II

- Price index becomes

$$P_{n,t}^{1-\eta} = \left(\frac{\sigma}{\sigma - 1}\right)^{1-\eta} \left(\frac{1}{\sigma F}\right)^{\frac{1-\eta}{1-\sigma}} \left[\sum_{i \in N} L_{i,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{ni,t} w_{i,t}}{A_{i,t}}\right)^{1-\eta} + L_{x,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{nx,t} w_{x,t}}{A_{x,t}}\right)^{1-\eta}\right]$$

Trade III

Combining expressions for $\pi_{ni,t}$, the price index, and the definition $\pi_{ni,t} = \frac{X_{ni,t}}{X_{n,t}}$ yields equations for total international imports and exports in a period t.

$$
\begin{aligned}
I_t &= \frac{L_{x,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{w_{x,t}}{A_{x,t}}\right)^{1-\eta}}{(\sigma F)^{\frac{1-\eta}{1-\sigma}} \left(\frac{\sigma}{\sigma-1}\right)^{\eta-1}} \sum_{n \in N} \frac{d_{nx,t}^{1-\eta} X_{n,t}}{P_{n,t}^{1-\eta}} \\
E_t &= \frac{X_{x,t}}{P_{x,t}^{1-\eta} (\sigma F)^{\frac{1-\eta}{1-\sigma}} \left(\frac{\sigma}{\sigma-1}\right)^{\eta-1}} \sum_{n \in N} L_{n,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{xn,t} w_{n,t}}{A_{n,t}}\right)^{1-\eta}
\end{aligned}
$$

Trade IV

- For markets to clear, income of location I must equal its total expenditure $X_{i,t}$

$$X_{i,t} = \sum_{n \in N} \frac{L_{i,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{ni,t} w_{i,t}}{A_{i,t}} \right)^{1-\eta}}{P_{n,t}^{1-\eta} (\sigma F)^{\frac{1-\eta}{1-\sigma}} \left(\frac{\sigma}{\sigma - 1} \right)^{\eta - 1}} X_{n,t} + \frac{E_t L_{i,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{xi,t} w_{i,t}}{A_{i,t}} \right)^{1-\eta}}{\sum_{n \in N} L_{n,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{xn,t} w_{n,t}}{A_{n,t}} \right)^{1-\eta}}$$

- Then possible to define consumer market access $CMA_{i,t} = P_{i,t}^{1-\eta}$ and firm market access $FMA_{i,t} = \sum_{n \in N} \frac{X_{n,t}}{P_{n,t}^{1-\eta}} d_{xi,t}^{1-\eta} + \frac{X_{x,t}}{P_{x,t}^{1-\eta}} d_{xi,t}^{1-\eta}$. Assuming symmetric trade costs and imports equal exports, get

$$CMA_{i,t} = FMA_{i,t} = MA_{i,t} = \sum_{n \in N} \frac{d_{ni,t}^{1-\eta} X_{n,t}}{MA_{n,t}} + \frac{E_t d_{xi,t}^{1-\eta}}{\sum_{k \in N} d_{xk,t}^{1-\eta} \frac{X_{k,t}}{MA_{k,t}}}$$

Equilibrium Definition

Labor units $\{L_{n,t}\}$, migration shares $\{m_{ni,t}\}$, wages $\{w_{n,t}\}$, market access terms $\{MA_{n,t}\}$, and expected lifetime utilities $\{V_{n,t}\}$ such that for all $I, n \in N$ and time periods t

1. Each location's income equals expenditure on goods produced in that location:

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

2. Market access is given by

$$MA_{i,t} = \sum_{n \in N} \frac{d_{ni,t}^{1-\eta} w_{n,t} L_{n,t}}{MA_{n,t}} + \frac{E_t d_{xi,t}^{1-\eta}}{\sum_{k \in N} d_{xk,t}^{1-\eta} \frac{w_{k,t} L_{k,t}}{MA_{k,t}}}$$

Equilibrium Definition

3. Expected lifetime utilities satisfy

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

4. Migration shares satisfy

$$m_{in,t} = \frac{\left(\exp\{\beta V_{i,t+1} - \mu_{in} + B_{i,t}\}\right)^{\frac{1}{\nu}}}{\sum_{k \in N} \left(\exp\{\beta v_{k,t+1} - \mu_{kn} + B_{jk,t}\}\right)^{\frac{1}{\nu}}}$$

Equilibrium Definition

5. The evolution of labor units is given by

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

A stationary equilibrium of the model is a sequential equilibrium such that $\{L_{n,t}, m_{ni,t}, w_{n,t}, MA_{n,t}, V_{n,t}\}_{t=0}^{\infty}$ are constant for all t.

Notion of Welfare

- Expected lifetime utility of resident in location n at time t can be shown to be

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

- Welfare is aggregated across locations using a utilitarian approach capturing the mean welfare across all locations weighted by their respective initial population shares

$$W_t = \sum_{n \in N} \frac{L_{n,0}}{\sum_{i \in N} L_{i,0}} \left[\sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{w_{n,s}^{\alpha} \exp\{B_{n,s}\}}{P_{n,s}^{\alpha} \left(\frac{(1-\alpha)L_{n,s}}{H_{n,s}} \right)^{1-\alpha} (m_{nn,s})^{\nu}} \right) \right]$$

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Data I

- $N = 541$ spatial units based off districts in Vietnam.
- Geographic data
  - Gridded Population of the World 4 data set from the Center for International Earth Science Information Network for land areas without permanent ice and water.
  - NASA Shuttle Radar Topographic Mission dataset the Consultative Group on International Agricultural Research's Consortium of Spatial Information for vulnerability of different districts to inundation.
- Population data
  - Population for each spatial unit in 2010 calculated using GPW dataset.
- Economic Data
  - Central measure of district-level economic activity is expenditure per capita from Lanjouw, Marra, and Nguyen (2013). Combined with Vietnam Household Living Standards Survey.
  - At province level, model is calibrated with 2010 data on income from all sources from the General Statistics Office of Vietnam.
  - International exports data also from the GSO of Vietnam. Converted to 2010 values using CPI deflator.

Data II

- Migration data
  - Data on internal migration IPUMS International 15% sample of the 2009 Population and Housing Census.
  - Internal migrant defined as an individual aged five or older who lives in Vietnam and whose place of residence five years prior to the census was different from their current place of residence.
- Transport cost data
  - Manually digitized data on Vietnam's road, inland waterway, and coastal shipping networks in 2000 and 2010.
  - Assign each stretch of network in each year a cost in terms of ton-km and travel time for transport.
  - Also assigns a fixed mobilization charge per ton. Travel cost from each region to international markets calculated as cost to ship to nearest international port plus a fixed amount accounting for cost of shipping goods from an international market.
- Road construction costs
  - From engineering literature:

$$Cost = 1 + Slope + (25 \cdot Builtup) + (25 \cdot Water) + (25 \cdot Wetland)$$

Parametrization I

- Iceberg trade costs
  - Model $d_{ni} = t_{ni}^{\phi} e_{ni}$, so d_{ni} consists of a constant elasticity function of measured transport costs t_{ni} and a stochastic error.
  - Taking logs of each side of the gravity equation

$$\pi_{ni,t} = \frac{L_{i,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{ni,t} w_{i,t}}{A_{i,t}}\right)^{1-\eta}}{\sum_{k \in N} L_{k,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{nk,t} w_{k,t}}{A_{k,t}}\right)^{1-\eta} + L_{x,t}^{\frac{1-\eta}{1-\sigma}} \left(\frac{d_{nx,t} w_{x,t}}{A_{x,t}}\right)^{1-\eta}}$$

$$\ln(\pi_{ni}) = \chi_i + \psi_n + \phi(1-\eta)\ln(t_{ni}) + \varepsilon_{ni}$$

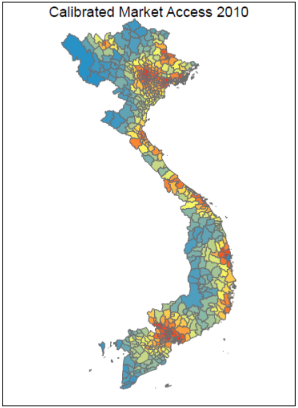
    - χ_i controls for i's population, wages, and productivity in the gravity equation.
    - ψ_n controls for the multilateral resistance term in the denominator of the gravity equation.
  - Gets estimate of $\phi(1-\eta) = -2.0$.
  - Combining Kucheryavyy, Lyn, and Rodríguez-Clare (2023) methods with existing World Bank, estimates trade elasticity $\eta = 7.92$, implying $\phi = 0.3$.

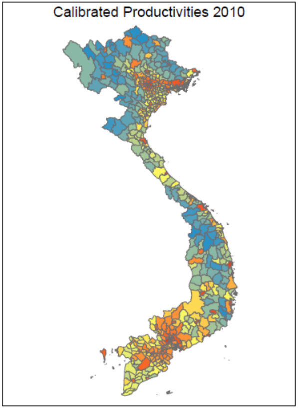
Parametrization II

- CES parameter
  - Also constructed using Kucheryavyy, Lyn, and Rodríguez-Clare (2023) method. Industry-level estimates of scale elasticities combined with industry shares imply $\sigma = 10.55$.
- Kozel (2014) estimates consumption aggregates in Vietnam based on the 2004-2010 rounds of the VHLSS and finds that housing consumption represented 15%, 15%, 16%, and 15% of total consumption in each survey. So, assumes a residential land share of 15% and sets $\alpha = 0.85$.
- Estimation of the migration elasticity $\frac{1}{\nu}$ in the literature vary from two to four, so she takes 3 as her baseline value and considers values in $[2, 4]$ in robustness tests.
- Uses annual discount factor of 0.96, which implies a five-year discount factor of 0.82. Considers annual discount factor of 0.986 in robustness tests.

Calibration

- Inverting equilibrium conditions (1) and (2) yields calibrated estimates for market access and productivity in each district.
  - As a robustness check, estimates total factor productivity using the Vietnam Enterprise Census and finds strong positive correlation assuming both a Cobb-Douglas production function and one that is linear in labor.





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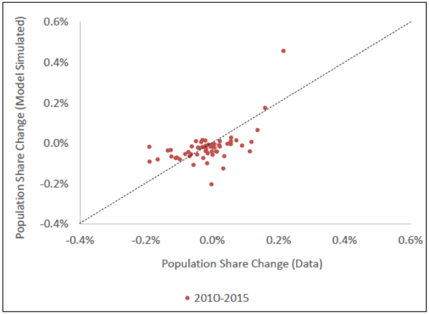
Model Simulation

- Simulated forward a five-year intervals to solve for the sequential equilibrium path of endogenous variables $\{L_{n,t}, m_{ni,t}, w_{n,t}, M_{n,t}\}$ in each location.
  - Takes as given $L_{n,2010}$, $w_{n,2010}$, $m_{in,2005-2010}$, E_{2010}
  - Assumed time path of land areas $H_{n,t}$ and transport costs $d_{ni,t}, d_{xn,t}$.
    - Assumes sea-levels gradually rise, reaching an increase of one meter in 2110.
    - Results in a decrease in land area, $H_{n,t}$ and an increase in trade cost matrices (assumes per-km cost of traversing a stretch of inundated road is double the cost of traversing the most costly road type in 2010.
    - Assumes agents are perfectly foresighted about these changes.
- Iterative solution algorithm solves for equilibrium conditions, assuming the economy approaches a stationary equilibrium in 250 years.
- On the province level, the changes in population across districts in the 2010-2015 and 2015-2020 periods match the observed data well, with R^2 of 0.25 and 0.58, respectively.

Model Simulated and Actual Population Change



Sea Level Rise and Welfare Effects of Realized Road Upgrades

- Simulates model with d_{ni} and d_{ni} reflecting the transport network that would have existed if there were no road improvements made from 2000-2010.
- In the model with sea level rise, the net present value of aggregate welfare is 1.37% higher as a result of the realized road upgrades from 2000-2010.
- In the model without sea level rise, the estimate is 1.56%, 12% higher.

Alternative Allocations

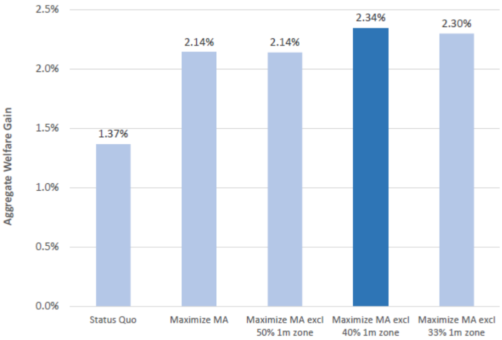
- Uses pairwise market access between districts and between a district and the international market as objectives, constrained to have the same cost as realized road upgrades from 2000-2010.

$$MA_{ij} = \left[\frac{w_i L_i}{MA_i} + \frac{w_j L_j}{MA_j}\right] d_{ij}^{1-\eta} \quad MA_{ix} = \left[\frac{w_i L_i}{MA_i} + \frac{X_x}{P_x^{1-\eta}}\right] d_{ix}^{1-\eta}$$

  - Calculates allocation of road upgrades which maximizes market access.
  - Excludes districts with more than 50%, 40%, and 33% of land below one meter.
- Unconstrained allocation has 6.3% of projects under one meter of elevation. 5.4%, 5.1%, and 3.8% for allocations under respective constraints
  - Realized road upgrades in 2000-2010 were 11%.

Welfare Effects of Alternative Allocations

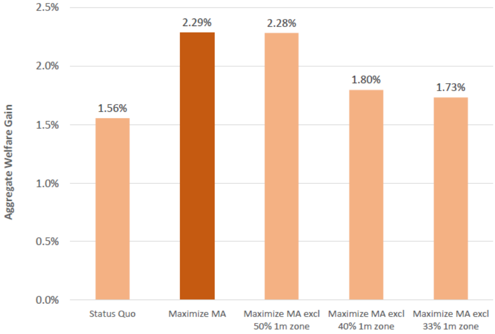
Figure 7: Welfare gains from counterfactual road investments with 1m sea level rise over 100 years



Notes: Net present value of aggregate welfare gains versus a scenario in which no roads had been upgraded, in a scenario with a 1 meter rise in the sea level realized gradually over 100 years. Counterfactual 'maximizing market access' maximizes pairwise market access between districts. Counterfactuals 'maximizing market access excluding 50%/ 40%/ 33% 1m zone' maximize pairwise market access excluding connections for districts with more than 50%/ 40%/ 33% of their land area below 1 meter.

Welfare Effects of Alternative Allocations

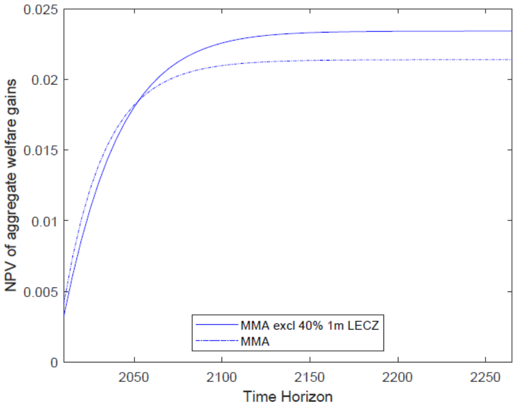
Figure 8: Welfare gains from counterfactual road investments without sea level rise



Notes: Net present value of aggregate welfare gains versus a scenario in which no roads had been upgraded, in a scenario with no future sea level rise. Counterfactual 'maximizing market access' maximizes pairwise market access between districts. Counterfactuals 'maximizing market access excluding 50%/ 40%/ 33% 1m zone' maximize pairwise market access excluding connections for districts with more than 50%/ 40%/ 33% of their land area below 1 meter.

Dynamics

- Previous result driven by tradeoff between short-term gains in market access in densely populated, productive coastal areas and long-term gains from reducing exposure to inundation.
- Unconstrained allocation results in larger gains in the short run.



Robustness Checks

- Secular trend in productivity of districts.
  - Allows trends in districts' productivities from 2000-2010 to continue over next decade.
- Increasing coastal amenity.
  - Allows coastal amenities only to grow 22% gradually over 100 years.
- Growing world GDP.
  - Lets real-value output of wold increase each year from 2010-2020 in line with the average annual growth rate of real world GDP.
- Unanticipated Sea Level Rise
  - Allows agents to expect sea levels to rise for 50 years and then stop.
- Depreciation of Roads
  - Allow roads to fully depreciate in a period of time.
  - Unconstrained allocation wins when roads fully depreciate in 30 years.
- Timing of stationary equilibrium
  - Results nearly identical assuming it is reached in 200 or 400 years.

% welfare gains from realized and counterfactual road investments

	Realized upgrades		Maximize market access		Maximize market access excl 40% 1m LECZ		Maximize market access excl 33% 1m LECZ	
	1m SLR	No SLR	1m SLR	No SLR	1m SLR	No SLR	1m SLR	No SLR
Central simulations	1.37%	1.56%	2.14%	2.29%	2.34%	1.80%	2.30%	1.73%
$\beta = 0.986$	1.20%	1.56%	2.02%	2.29%	2.85%	1.80%	2.82%	1.74%
$\beta = 0.94$	1.42%	1.56%	2.18%	2.29%	2.19%	1.80%	2.14%	1.73%
Coastal productivities climate impacts	1.37%	1.56%	2.14%	2.29%	2.34%	1.80%	2.29%	1.73%
Coastal productivities secular trends	1.33%	1.53%	2.06%	2.21%	2.28%	1.74%	2.23%	1.68%
Coastal amenities	1.37%	1.56%	2.14%	2.29%	2.37%	1.80%	2.32%	1.74%
Real value of output in rest of world	1.40%	1.59%	2.23%	2.37%	2.41%	1.86%	2.37%	1.80%
Myopia	0.66%	1.56%	1.16%	2.29%	1.85%	1.80%	1.85%	1.73%
100 year depreciation of investments	1.35%	1.53%	2.11%	2.26%	2.29%	1.77%	2.24%	1.71%
30 year depreciation of investments	1.10%	1.18%	1.68%	1.75%	1.62%	1.37%	1.58%	1.32%
Formal sector wage data	1.14%	1.33%	1.44%	1.58%	1.76%	1.28%	1.72%	1.22%
$\frac{1}{\nu} = 2$	1.37%	1.56%	2.14%	2.29%	2.35%	1.80%	2.30%	1.73%
$\frac{1}{\nu} = 4$	1.37%	1.56%	2.14%	2.29%	2.34%	1.80%	2.29%	1.73%

Notes: Blue (orange) shading indicates the counterfactual that implies the highest welfare gains under the scenario with a gradual 1 meter sea level rise by 2110 (no sea level rise).

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Conclusion and Thoughts

- Estimates a dynamic spatial model, allows rising sea levels to affect available land and transportation costs.
- Quantifies significant gains that will be unrealized if infrastructure investments are not moved away from areas vulnerable to environmental change.
  - Relevant beyond Vietnam.
- Limitation: results only partially robust to evolving amenities of productivities.
  - Next step might be to endogenize A_i and B_i.
  - In baseline, a district that is 75% under water and whose inhabitants have all moved away has the same productivity and amenity value as in 2010.
  - Robustness checks only allow A_i and B_i to continue to evolve along the same trend they were on from 2000-2010 for one more decade.