Economic Consequences of Climate Change: Evidence from the Philippines

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Introduction

Climate matters to the Economy

- Relationship with economic growth (Nordhaus 1993, 2008, 2010)
- Climate and geography partly shaped institutions and cities of the past (Bleakley and Lin, 2012; Allen and Donaldson, 2018)

Rapidly changing environment → disruptive in numerous outcomes

- Health outcomes, agriculture, conflict, productivity (Dell et all, 2014; Burke et. al 2015)

Heterogeneous effects: there can be winners

- Climate-induced migration → higher urbanization (Barrios et al, 2006; Henderson and Storeygard, 2016)
- Siberia, Canada, and Alaska are expected to see gains (Cruz and Rossi-Hansberg, 2021)

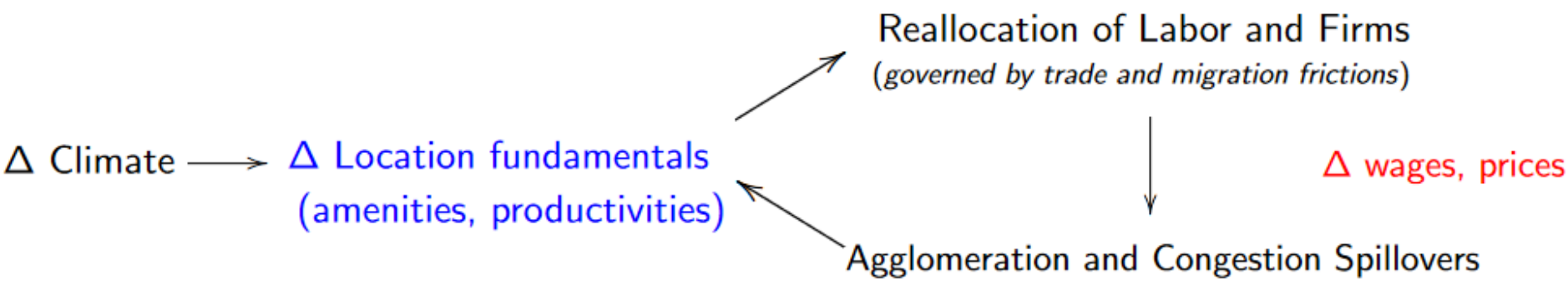
Research Questions

1. **How to quantify the effects of climate change on output, welfare, and inequality?**
2. **What are the implications for lower-middle income countries?**
3. **What is the most cost-effective policy that can attenuate losses in the future?**

Research Questions (1)

1. **How to quantify the effects of climate change on output, welfare, and inequality?**
   - Quantitative spatial general equilibrium model (Ahlfeldt et al., 2015; Allen and Arkolakis, 2018)
   - Heterogeneous workers of high- and low-skill types (Tsivanidis, 2019; Zárate, 2022)

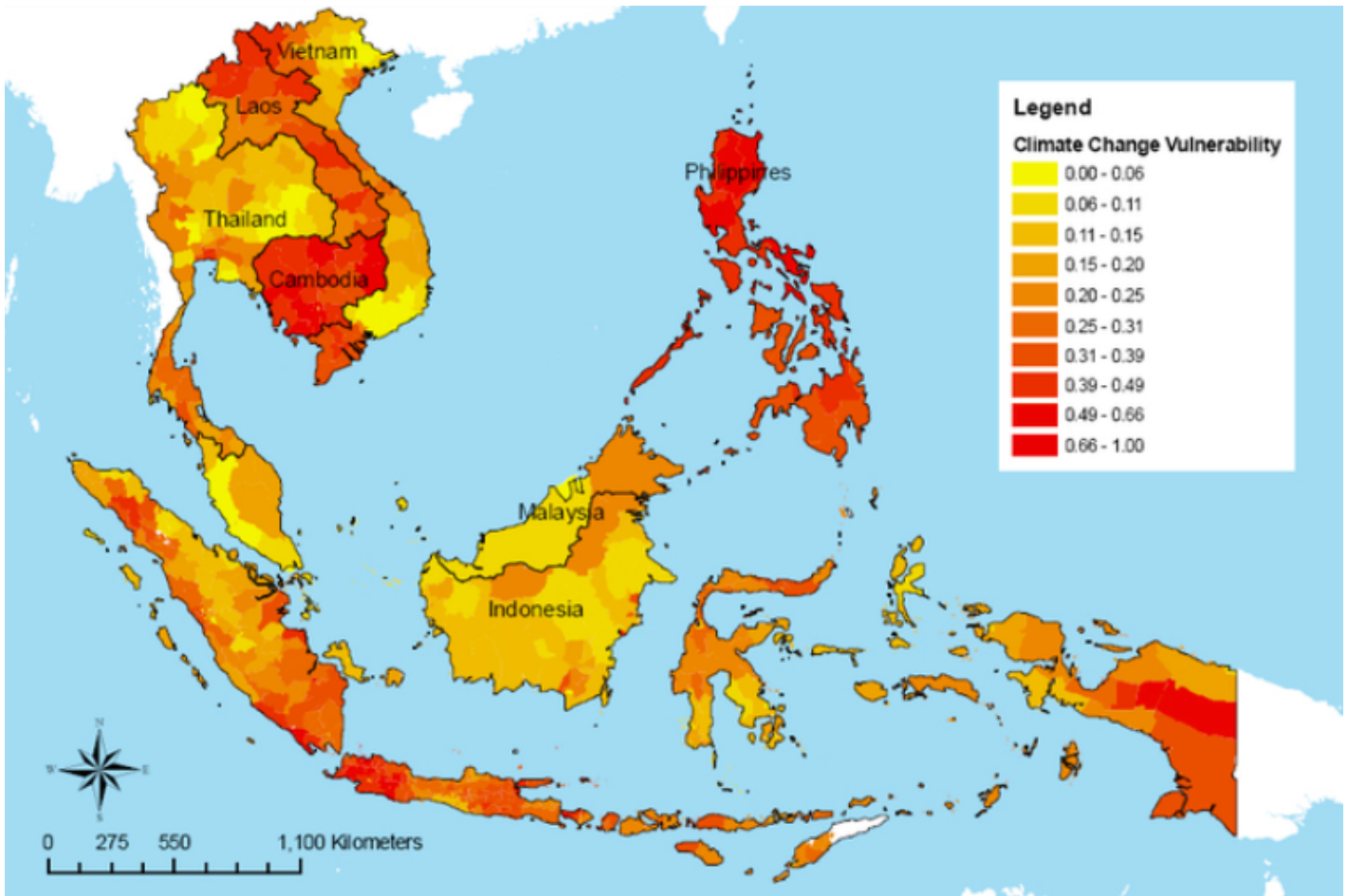
Model Sketch:



Research Questions (2)

3 **What are the implications for lower-middle income countries?**

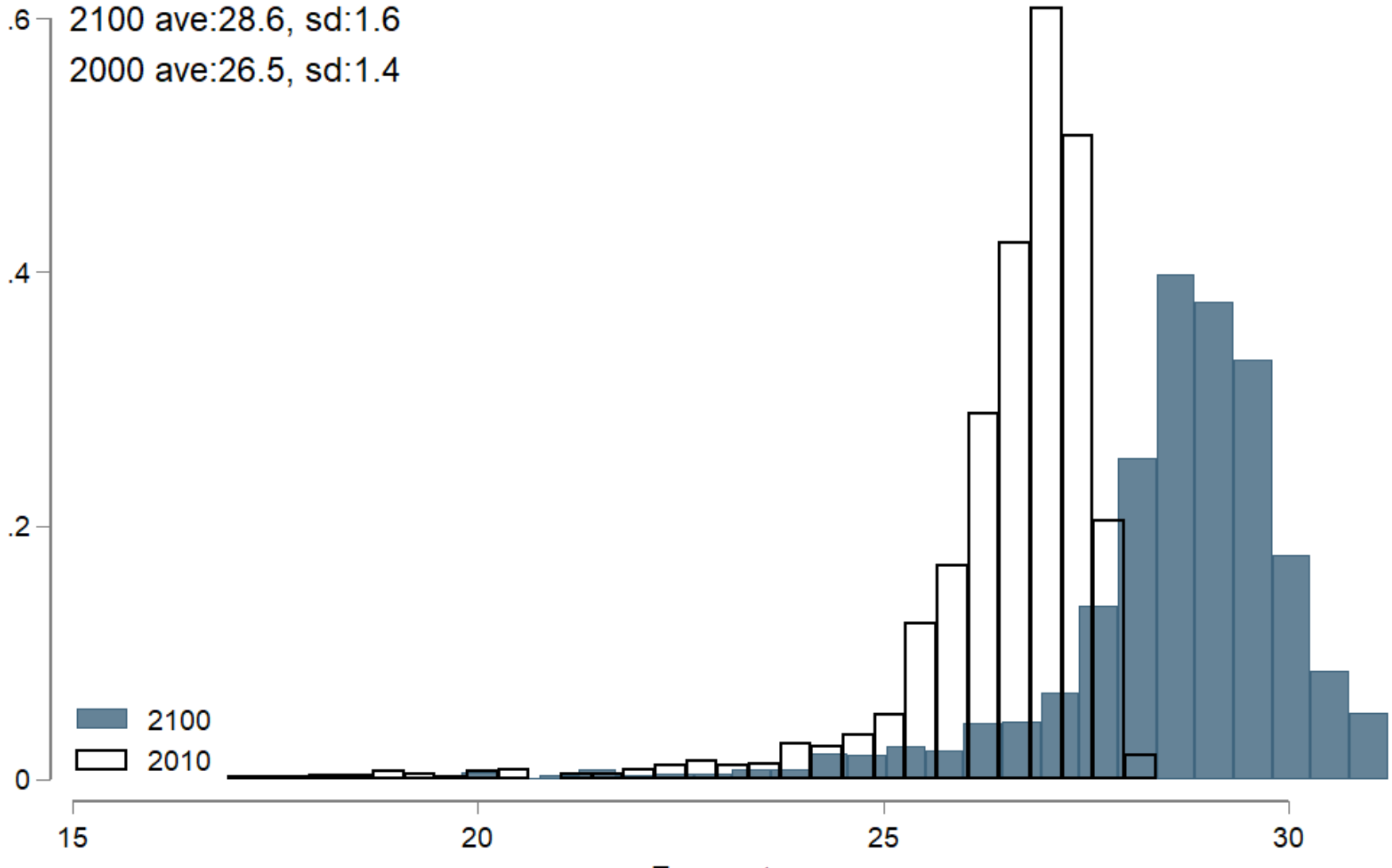
- Ranks 5th in Global Climate Risk Index, 13th most populous country
- Approx. 70% of the population are exposed to multiple hazards



Research Questions (2)

3 **What are the implications for lower-middle income countries?**

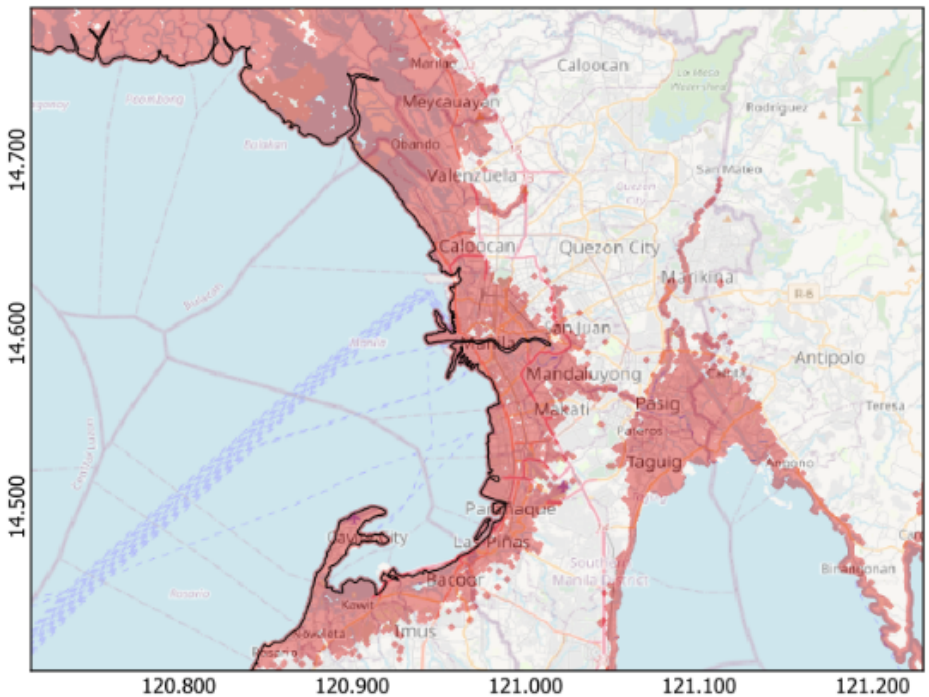
- Rising Temperatures (2010 vs 2100)



Research Questions (2)

3 **What are the implications for lower-middle income countries?**

- 5th longest coastline: 60% of the population live along the coasts
- At 1-meter SLR : 65% of municipalities affected



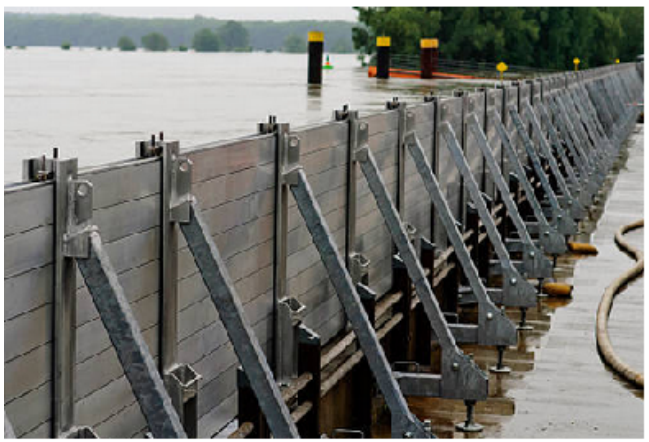
Worst Case Scenario: Metro Manila

Area of 245.56 sq. miles (636 sq.km) for 13 million people

Research Questions (3)

3 **What is the most cost-effective policy that can attenuate losses in the future?**

- Build up coastal resilience: 3 large coastal cities w/ a combined population of 19.7 million



flood walls and land reclaimation

sea dikes

mangroves

Research Questions (3)

3 **What is the most cost-effective policy that can attenuate losses in the future?**

- Place-based policy: Developing land 9,450-hectares 80km away from Metro Manila (US$ 12.9 billion)

Background

- 109 million people with per-capita GDP $\$9,061$
- 70-30% split of low-skilled to high-skilled workers
- 55% in urban areas
- **Internal migration:** 15% have changed residence in last 5 years
- **Climate profile:** Dry season (Dec-May) and wet season (Jun-Nov). Within year variation of 3°C
- **Spatial unit:** Region $\rightarrow$ Province $\rightarrow$ Municipality $\rightarrow$ Village
  - N municipalities: 1,627
  - **Average municipal area:** 180 sq. km $\approx$ 70 sq. miles
  - **Average municipal pop'n:** 62,096 in 2015 Census

Data

Collected at consistent geographic units at the **municipality**

- Temperature, Precipitation
  i. TerraClimate: monthly historical data since 1958
  ii. NASA Earth Exchange - GDDP: monthly projections under RCP 4.5 and RCP 8.5 (IPCC, 2014)
- Population, Migration Flows, Wages
  i. Censuses: 1990, 2000, 2010
  ii. Labor Force Surveys: triennial from 2004 to 2016
  iii. Family Income Expenditure Surveys: triennial from 2003 to 2015
- Amenities:
  i. Various from GIS: Soil quality, elevation, topography, slope, distance to water
  ii. Census village module for endogenous amenities

Reduced-form evidence: climate-induced migration

Did locations with unpredictable climate lose population?

$$y_{nt} = \alpha + \gamma W_{nt} + \beta X_{nt} + \delta_n + \delta_t + \epsilon_{nt},$$

- y_{nt}: out-migration rates in municipality n at year t
- W_{nt}: temperature deviation

$$W_{nt} = \underbrace{C_{nt}}_{\text{period } t \text{ weather}} - \underbrace{E(\mathbf{C}_{n\tau})}_{\text{20-year yearly average}}, \quad \tau \in [t-1, t-20]$$

- X_{nt}: size of prior migrant stocks, lagged population levels
- δ_n: municipal fixed effects
- δ_t: year fixed effects

Reduced-form evidence: climate-induced migration

Did locations with unpredictable climate lose population?

$$y_{nt} = \alpha + \gamma W_{nt} + \beta X_{nt} + \delta_n + \delta_t + \epsilon_{nt},$$

	All	Skilled	Unskilled
Δ Temperature (°C)	0.2384**	0.1645*	0.2443**
	(0.1136)	(0.0846)	(0.1168)
Pseudo R^2	0.541	0.653	0.542
Observations	3,252	3,252	3,252
With lag controls	Y	Y	Y
With basic controls	Y	Y	Y
Year FE (2)	Y	Y	Y
Municipal FE (1626)	Y	Y	Y

Clustered standard errors at municipality-level

$*p < 0.1; **p < 0.05; ***p < 0.01$.

Model Environment

- QSM similar to Ahlfeldt et al. (2015), and Allen and Arkolakis (2018).
- Discrete locations $n, d \in \{1, ...N\}$ that are unique:
  - amenities
  - productivities
  - access to other locations (trade and migration cost)
- Two skill- and sector- groups $s, g \in \{\text{skilled, unskilled}\}$
- **Firms** specialize in one sector s costly trade output across locations.
- **Workers** move from n to d to enjoy location-specific wages and amenities
  - Receives a Fréchet distributed idiosyncratic preference shock $\epsilon_n dg$
  - Fréchet parameter θ^g: nice properties
  - $\theta^{\text{skilled}} < \theta^{\text{unskilled}}$: e.g. Tsivanidis, 2020; Lee 2015; Hsieh et. al. 2016; Galle et. al. 2017

Climate Impacts in Consumer Preferences

Indirect utility of agent i of skill-type g is a function of wages w, prices P, amenities B:

$$V_{ndg}(i) = \frac{B_{dg} w_{dg} \epsilon_{ndgi}}{\mu_{ndg} P_d}$$

Local amenity is defined as:

$$B_{dg} = \overline{B}_{dg} \left(\frac{L_d}{T_d} \right)^{-\eta},$$

- Type-specific allows for heterogeneity in tastes and preference-based sorting.
- $\overline{B}_{dg}$: exogenous component (i.e. climate, topography, distance to coast, soil quality).
- T_d [← SLR impact here] is municipality area $\implies$ affects congestion externalities (η).

Climate Impacts in Firms

- In each location, many firms produce the same differentiated product under perfect competition.
- Firms in sector g only hire workers of skill-type g with production function:

$$Y_{dg} = A_{dg} L_{dg},$$

where A_d^g is the sector-specific productivity in location d:

$$A_{dg} = \overline{A}_{dg} \left(\frac{L_d}{T_d} \right)^{\alpha}. \tag{1}$$

- Climate affects the model through:
  - **Temperature:** $\overline{A}_{dg}$.
  - **Sea-level rise:** agglomeration economies (α) from local density

Climate Elasticities on Fundamental Amenity and Productivity

	Amenity		Productivity	
	(1) Skilled	(2) Low-Skilled	(3) Skilled	(4) Low-Skilled
Δ °C relative to long-run average	-0.4782*	-0.2219	-0.5912**	-0.8801**
	(0.2577)	(0.2013)	(0.2740)	(0.3547)
Pseudo R^2	0.406	0.356	0.417	0.403
Observations	3,252	3,252	3,252	3,252
No. Municipalities	1626	1626	1626	1626
Year Fixed Effects	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y
Controls: Natural Amenities	Y	Y	Y	Y

Clustered standard errors at region-level in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$

Natural amenities include: elevation, slope, soil bulk density, soil water content, latitude, and ruggedness

Counterfactual Procedures

Recover **baseline spatial distribution of exogenous productivities and amenities**: $\{A_{dg}, B_{dg}\}$:

1. Migration gravity: type-specific migration elasticities

Estimation: PPML Migration Gravity

	All	Skilled	Unskilled
Log distance	-1.217***	-1.174***	-1.227***
	(0.042)	(0.049)	(0.043)
Same island	0.259***	0.255**	0.254***
	(0.080)	(0.105)	(0.077)
Same province	1.130***	1.361***	1.085***
	(0.091)	(0.109)	(0.092)
Hometown bias	3.845***	3.893***	3.862***
	(0.113)	(0.127)	(0.115)
Absolute difference in longitude	0.117***	0.029	0.146***
	(0.034)	(0.031)	(0.035)
Absolute difference in latitude	-0.098***	-0.062**	-0.108***
	(0.021)	(0.026)	(0.020)
Origin x Year FE	Y	Y	Y
Dest. x Year FE	Y	Y	Y
N municipality pairs	7,941,387	7,941,387	7,941,387
N municipalities	1,627	1,627	1,627
N years	3	3	3
Wald χ^2	57,727	46,594	57,353
Pseudo R^2	0.824	0.815	0.826

Two-way clustered standard errors in parentheses.$*p < 0.1; **p < 0.05; ***p < 0.01$.

Counterfactual Procedures

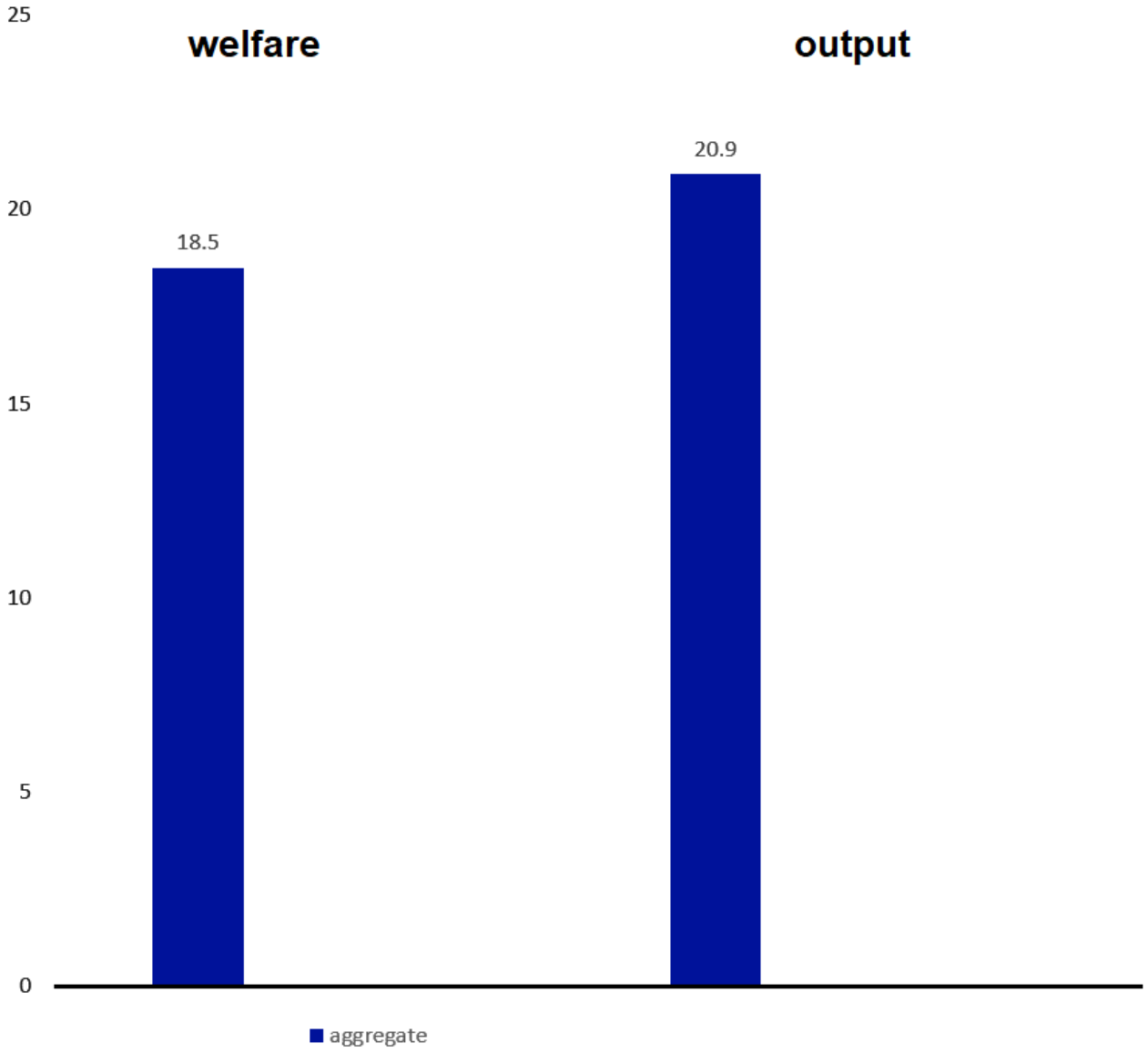
Recover **baseline spatial distribution of exogenous productivities and amenities**: $\{A_{dg}, B_{dg}\}$:

1. Migration gravity: type-specific migration elasticities
2. Calibrated parameters

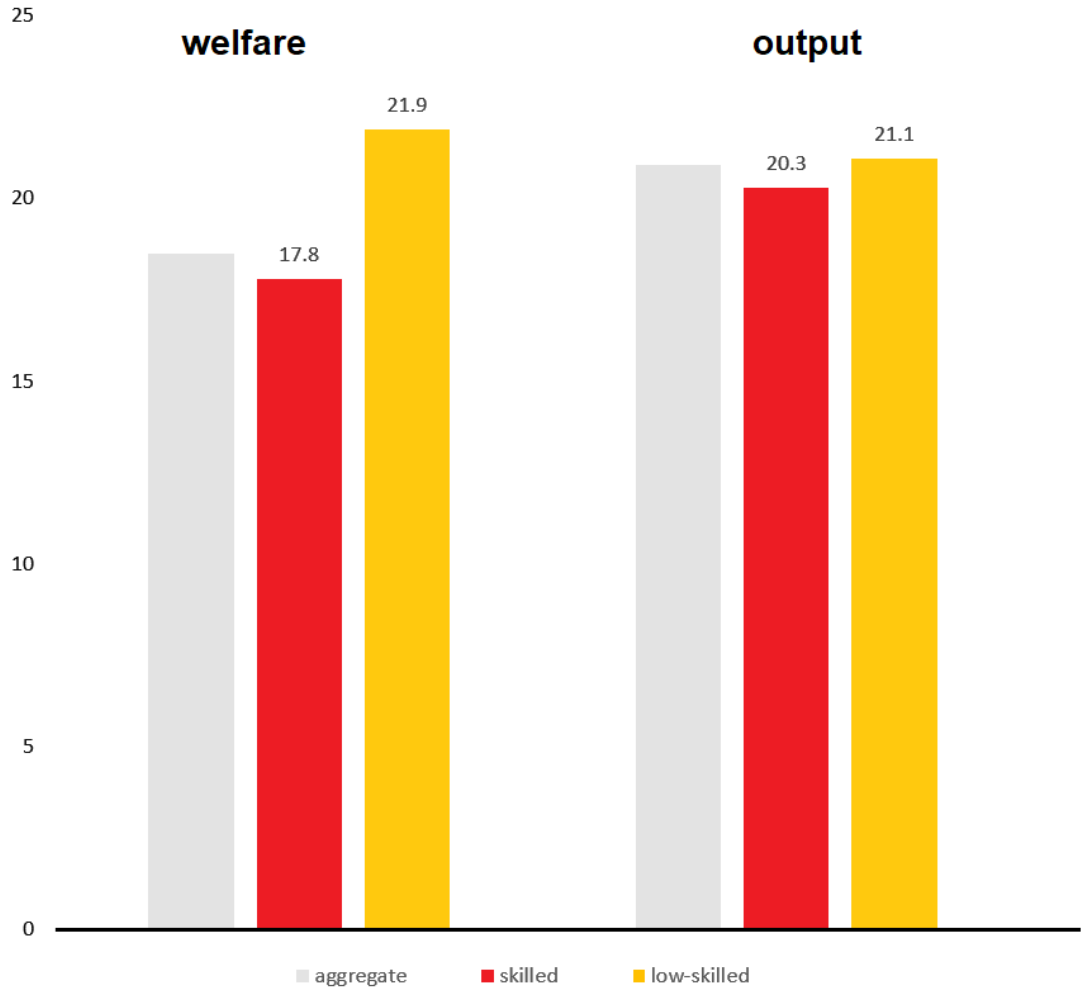
Parameter	Description
$\beta^{ag} = 0.352$	Share parameter for agricultural consumption bundle (FIES 2003,06,09)
$\sigma = 5$	Elasticity of substitution between goods (Allen and Arkolakis, 2014)
$\theta^H = 2.054$	Fréchet parameter (Tsivanidis, 2019)
$\theta^U = 2.840$	Fréchet parameter (Tsivanidis, 2019)
$\eta = -0.10$	Congestion parameter (Ahlfeldt et al., 2015)
$\alpha = 0.076$	Agglomeration Externalities (Chauvin et al., 2017)
$\tau_{nd} = -1$	Trade cost elasticity (Head and Mayer, 2014)

3. Take the model to data (using observed labor flows, wages, output)
4. Plug-in to the model: Inundated land from sea-level rise + municipality temperatures at 2100

New Economic Geography at 2100: % Losses

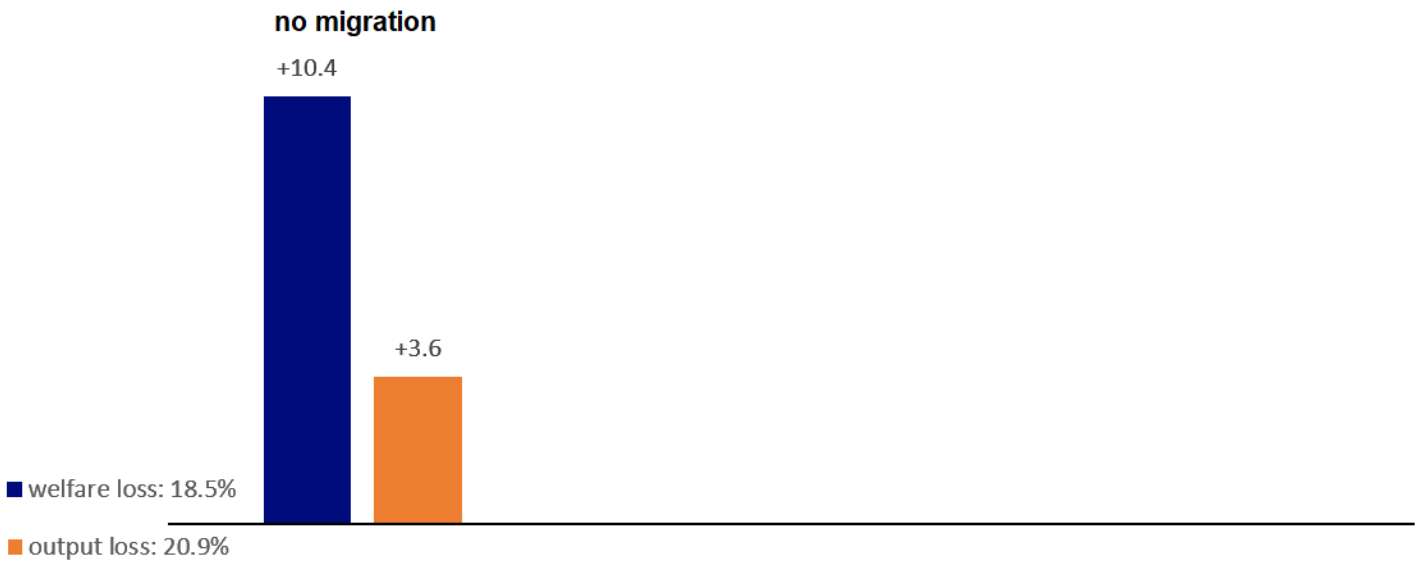


Distributional Effects: % Losses, Low-skilled vs skilled



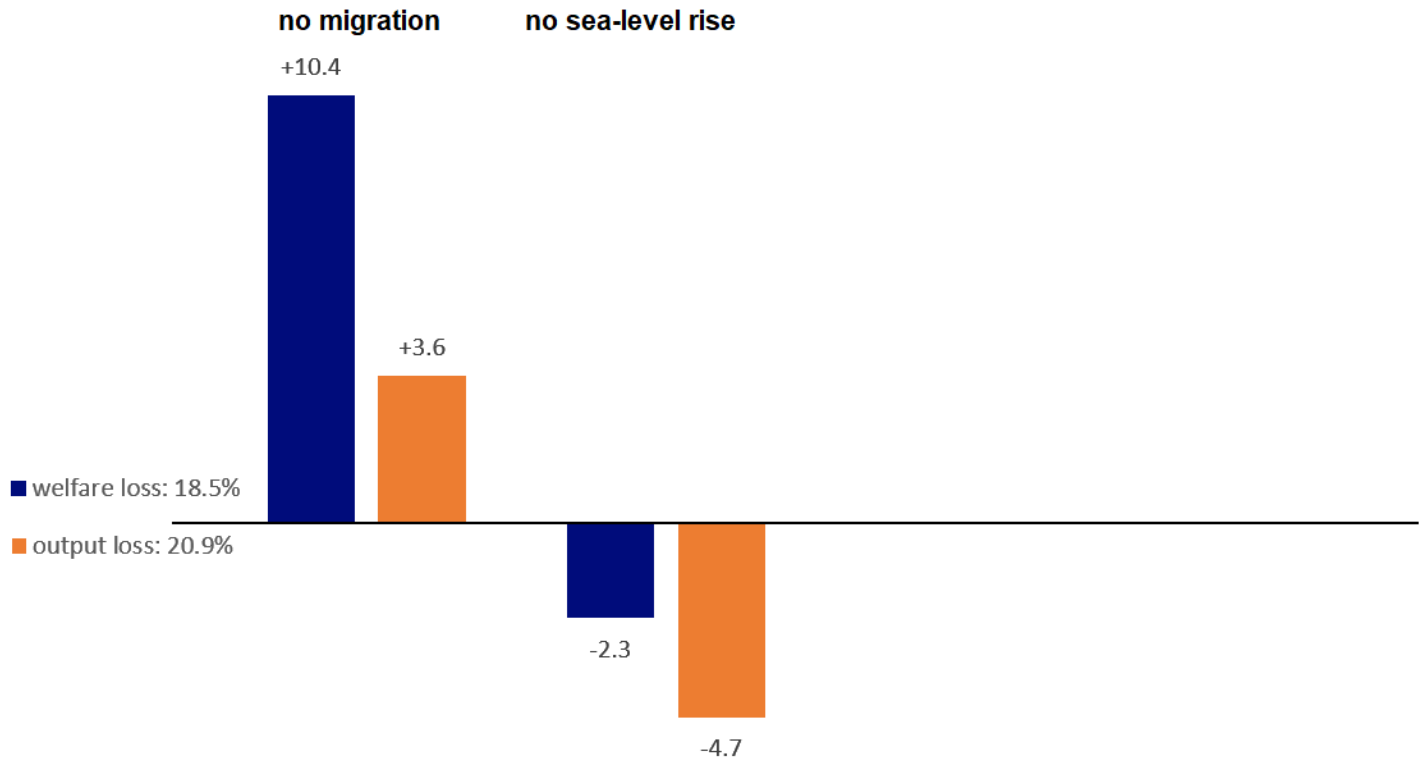
- Movement to *poor* areas: ↑18.9% low-skilled; ↑ skilled ↑12.7%
- **Inequality**: ↑ 5.4%

Δ percentage points relative to baseline losses



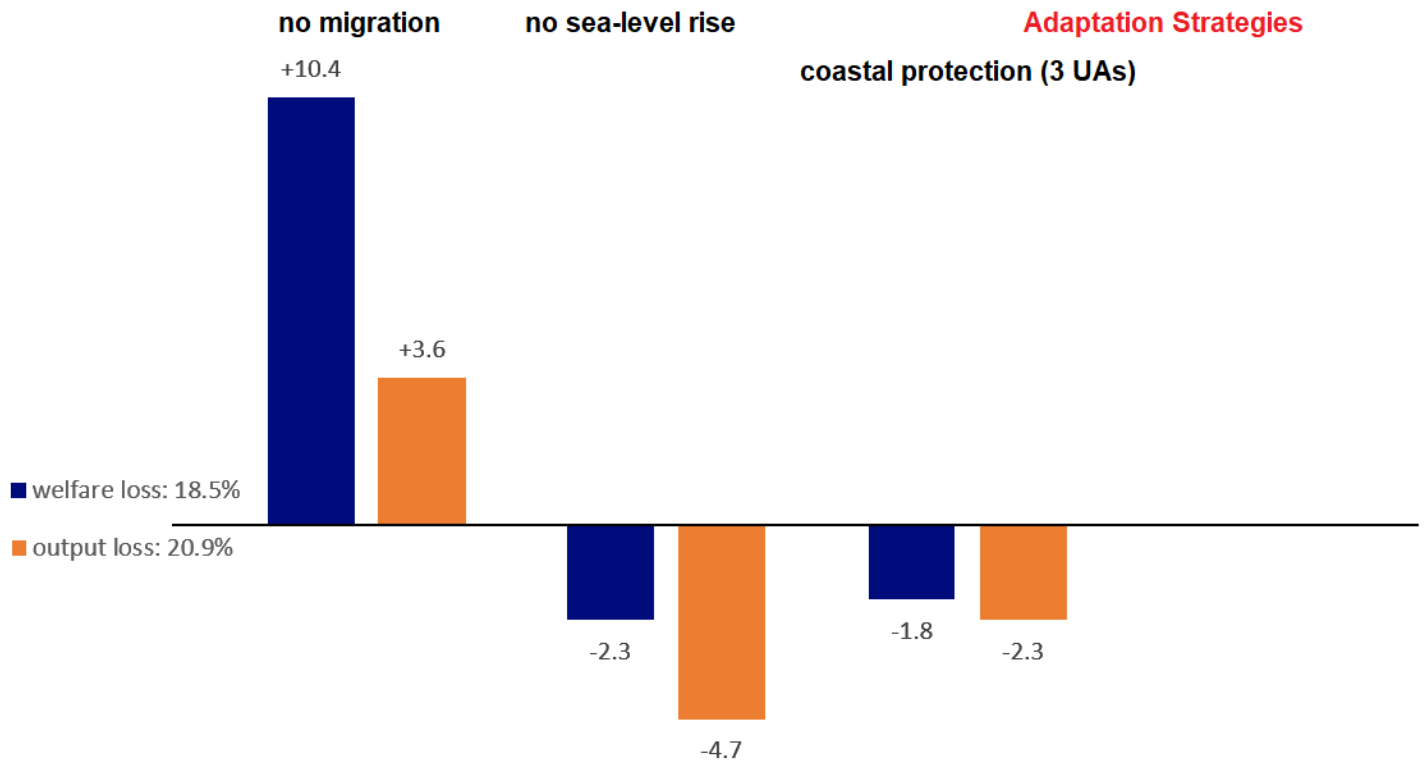
Larger losses from low-skilled sector $\Longrightarrow$ inequality rises to 12.7%

Δ percentage points relative to baseline losses



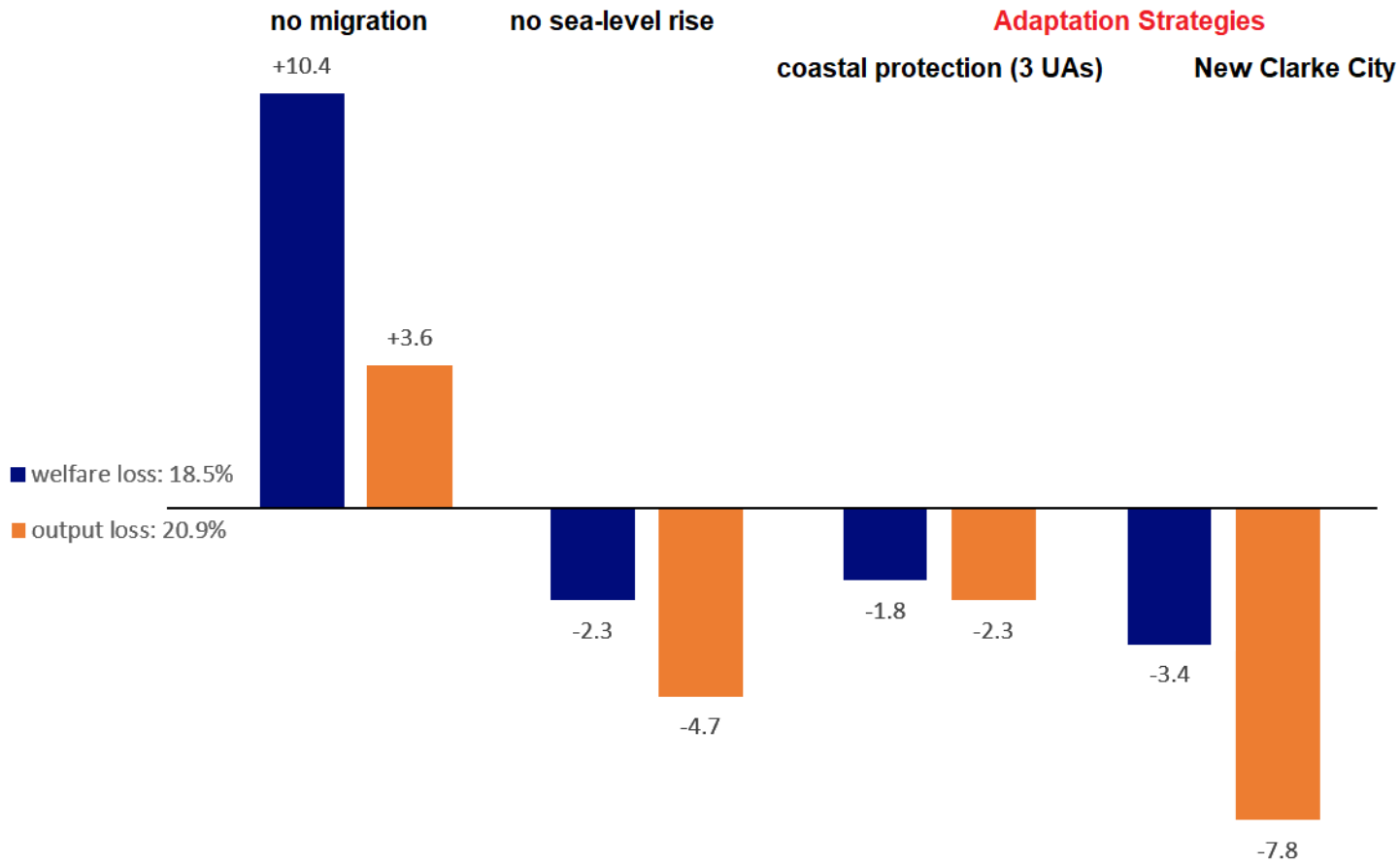
- **Mechanism**: Reduces displacement to *poor* areas, abated by 2% of low-skilled and 5% of skilled workers

Δ percentage points: Adaptation strategies



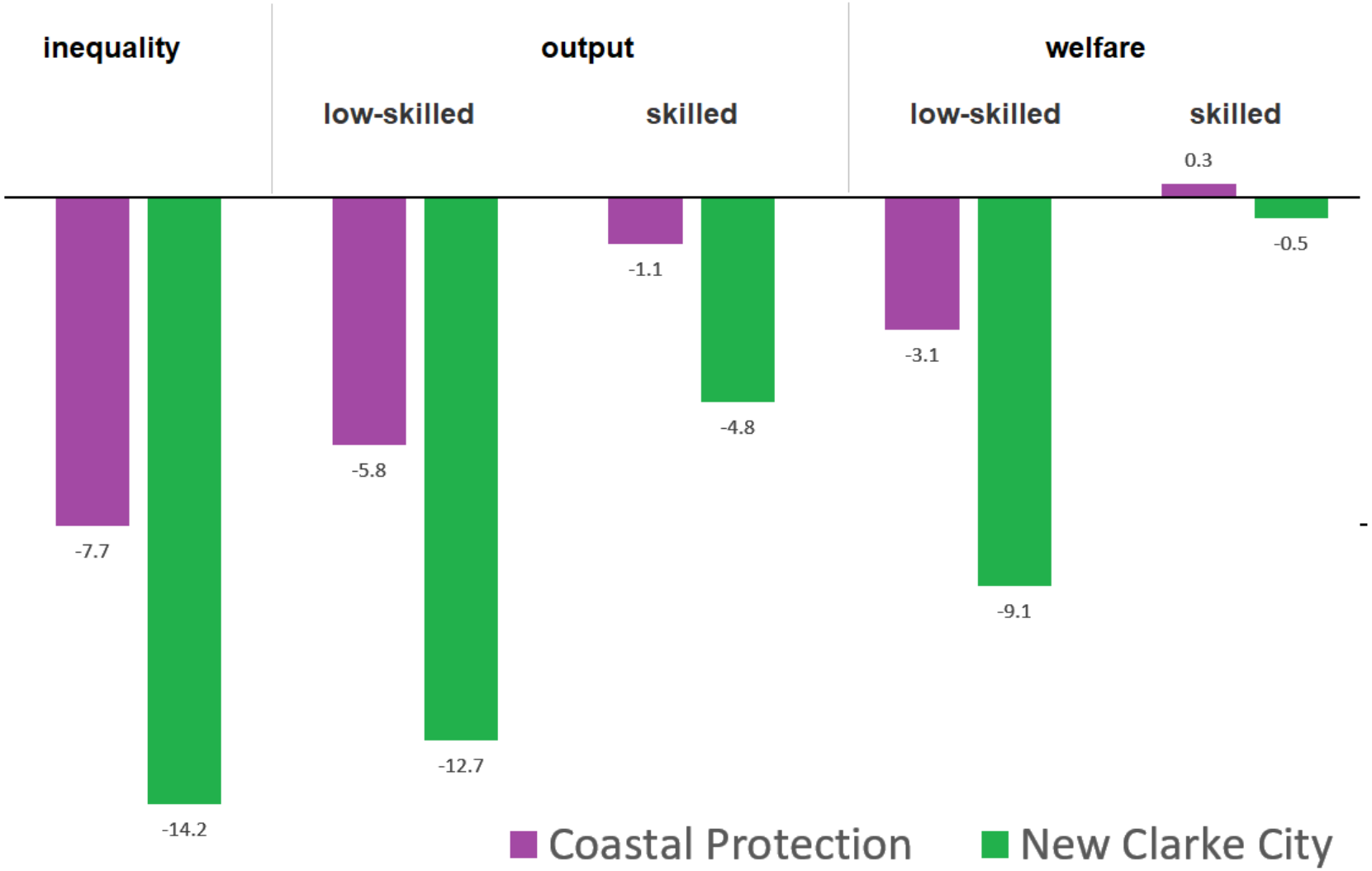
- Protect Metro Manila, Metro Cebu, and Metro Davao: local agglomeration economies from high-density coastal areas are preserved.

Δ percentage points: Adaptation strategies



- Implementation: replicated amenity and productivity values of Metro Manila to new city (NPV cost US$ 12.9 billion)

Distributional Implications of Adaptation Strategies



Evaluating Adaptation Strategies

1. **Coastal Protection**
   - Benefit: US$ 5 billion
   - Buffer cost to protect 1,000 kilometers of coastline: $5 million
     - $ 51,000 per-km using a nature-based apprach (ADB, 2017)
     - $ 2.2 million per-km for engineering approach (Min et al., 2016)
2. **New Clarke City**
   - Capital outlay: US$ 12.9 billion
   - Benefit: US$ 9.8 billion (calculated from output gains of 7.8%)
   - Main concern: Can new places be as productive? Feasible to replicating agglomeration spillovers?

Option 1 is more cost-effective

Summary of Results

1. New climate environment in 2100 $\Longrightarrow$ Δ economic geography
   - Aggregate welfare loss of 18.5%, while output decreases by 20.9%
   - **Extreme no-adjustment case**: $\uparrow$ losses by 10% for welfare, 4.5% for output
   - Effects are driven by rising temperatures as opposed to sea-level rise
2. Distributional effects
   - Inequality rises by 5.4%.
   - **Trade-offs**: largely responds to climate changes to local amenities
   - **Low-skilled-workers**: are sensitive to temperature effects on productivity
3. Policy Evaluation: **New city inland** vs **Coastal Protection**
   - Losses are mitigated by 7% when a new mega-city is generated
   - But introducing costs: coastal protection becomes more attractive

Conclusions

- Quantify GE-effects of temperatures + sea-level rise
- Approx. 20% losses, with burden on low-skilled workers
- Restricting mobility will have dire effects
- Baseline losses can be mitigated with strategic policy interventions.
  - Responsiveness of low-skilled workers to interventions $\implies$ possible $\downarrow$ inequality
  - Gains in narrowing large amenity distortions to erode strong coastal preferences of skilled workers
- Future work: Explore other model assumptions, robustness, sophisticated cost-benefit analysis