

# The Impact of Racial Segregation on College Attainment in Spatial Equilibrium

Victoria Gregory  
St. Louis Fed

Julian Kozlowski  
St. Louis Fed

Hannah Rubinton  
St. Louis Fed

Neighborhood  
A  
B  
C  
Data Unavailable

Stanford Institute for Theoretical Economics  
Frontiers of Macroeconomic Research  
August 23, 2024

*The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of St. Louis or the Federal Reserve System.*

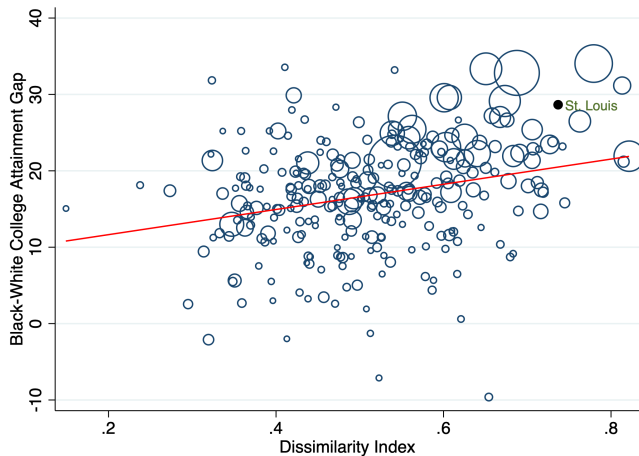
## Black-White College Gap and Racial Segregation

---

- ▶ Large literature arguing that a child's **neighborhood** matters for their adult outcomes (Chetty and Hendren, 2018b; Chetty et al., 2018)
- ▶ Racial and economic **segregation** are predominant features of many American cities
- ▶ **Racial inequality** in exposure to “high-quality” neighborhoods (Bayer et al., 2021)

Do **racial differences** in exposure to **high-quality neighborhoods** explain the **Black-White college gap**?

# Black-White College Gap and Segregation in the US



## College graduation

	US	STL
White, %	44	47
Black, %	23	19
Gap, p.p.	21	28

$$\text{corr}(\text{gap}, \text{dissimilarity}) = 0.43$$

▷ College gap time series

▷ High Correlation between Race and College Enrollment

## Spatial Equilibrium Model with Spillovers and Race

---

- ▶ Spatial equilibrium model of a city with **spillovers** and **racial differences**:

## Spatial Equilibrium Model with Spillovers and Race

---

- ▶ Spatial equilibrium model of a city with **spillovers** and **racial differences**:
  1. **Black-White earnings gap**: Gap in lifetime earnings between Black and White households
  2. **Amenity externalities**: Households care about the racial composition of neighbors  
Fear of discrimination in all White neighborhood, White flight, homophily
  3. **Moving costs**: Vary by race and neighborhood  
Differences in borrowing constraints, discrimination in housing markets, information frictions

## Spatial Equilibrium Model with Spillovers and Race

---

- ▶ Spatial equilibrium model of a city with **spillovers** and **racial differences**:
  1. **Black-White earnings gap**: Gap in lifetime earnings between Black and White households
  2. **Amenity externalities**: Households care about the racial composition of neighbors  
Fear of discrimination in all White neighborhood, White flight, homophily
  3. **Moving costs**: Vary by race and neighborhood  
Differences in borrowing constraints, discrimination in housing markets, information frictions
- ▶ General equilibrium **neighborhood effects**:
  - ▶ Rental markets
  - ▶ Human capital **spillovers**: Peer effects, networks, school quality
  - ▶ **Racial composition**: Matters due to amenity externalities

## Overview of Results

---

1. Model explains 64% of Black-White college gap and the 70% of the segregation in St. Louis
  - ▶ Not targeted: The 3 racial differences go a long way in explaining the data

## Overview of Results

---

1. Model explains 64% of Black-White college gap and the 70% of the segregation in St. Louis
  - ▶ Not targeted: The 3 racial differences go a long way in explaining the data
2. Earnings gap + amenity externalities are crucial for explaining college gap and segregation
  - ▶ No earnings gap:
    - ▶ Raises parental investment and spillovers in Black neighborhood → lower college gap
    - ▶ But amenity externalities still discourage moving → little change in segregation
  - ▶ No amenity externalities:
    - ▶ Households are more integrated → lower segregation
    - ▶ Households of both races exposed to similar spillovers → lower college gap



## Overview of Results

---

1. Model explains 64% of Black-White college gap and the 70% of the segregation in St. Louis
  - ▶ Not targeted: The 3 racial differences go a long way in explaining the data
2. Earnings gap + amenity externalities are crucial for explaining college gap and segregation
  - ▶ No earnings gap:
    - ▶ Raises parental investment and spillovers in Black neighborhood → lower college gap
    - ▶ But amenity externalities still discourage moving → little change in segregation
  - ▶ No amenity externalities:
    - ▶ Households are more integrated → lower segregation
    - ▶ Households of both races exposed to similar spillovers → lower college gap
3. Escaping segregation traps
  - ▶ Spillovers + amenity externalities  $\implies$  multiple equilibria
  - ▶ Evaluate policies that induce households to move to a more integrated equilibrium

## Road Map

---

1. Model
2. Empirical results to quantify the model, calibration, and validation
3. Counterfactual analysis of racial differences
4. Multiple equilibrium

Model

## Model

---

- ▶ Overlapping generations who each live 2 periods
- ▶ Households are of **race**  $r$  in  $\{B, W\}$  which impacts:
  - ▶ **Earnings**: calibrated Black-White earnings gap
  - ▶ **Amenity externalities**: preferences over the racial composition of the neighborhood
  - ▶ **Mobility cost**: additional barriers to moving that depend on race and neighborhood

## Model

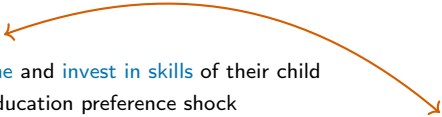
---

- ▶ Overlapping generations who each live 2 periods
- ▶ Households are of **race**  $r$  in  $\{B, W\}$  which impacts:
  - ▶ **Earnings**: calibrated Black-White earnings gap
  - ▶ **Amenity externalities**: preferences over the racial composition of the neighborhood
  - ▶ **Mobility cost**: additional barriers to moving that depend on race and neighborhood
- ▶ 3 **neighborhoods**  $n$  in  $\{A, B, C\}$ , with 3 **equilibrium** characteristics:
  - ▶ Rent:  $p_n$
  - ▶ **Local spillover**:  $X_n$ , college share
  - ▶ **Racial composition**:  $S_{r,n}$ , population share of each race

## Model

- ▶ Overlapping generations who each live 2 periods
- ▶ Households are of **race**  $r$  in  $\{B, W\}$  which impacts:
  - ▶ **Earnings**: calibrated Black-White earnings gap
  - ▶ **Amenity externalities**: preferences over the racial composition of the neighborhood
  - ▶ **Mobility cost**: additional barriers to moving that depend on race and neighborhood
- ▶ 3 **neighborhoods**  $n$  in  $\{A, B, C\}$ , with 3 **equilibrium** characteristics:
  - ▶ Rent:  $p_n$
  - ▶ **Local spillover**:  $X_n$ , college share
  - ▶ **Racial composition**:  $S_{r,n}$ , population share of each race
- ▶ Timing:
  - ▶ Adults choose their **neighborhood**
  - ▶ They decide how much to **consume** and **invest in skills** of their child
  - ▶ The child is born, realization of education preference shock
  - ▶ Child chooses **education level**,  $e$  in  $\{e^L, e^H\}$ , with which they will enter adulthood

## Model

- ▶ Overlapping generations who each live 2 periods
  - ▶ Households are of **race**  $r$  in  $\{B, W\}$  which impacts:
    - ▶ **Earnings**: calibrated Black-White earnings gap
    - ▶ **Amenity externalities**: preferences over the racial composition of the neighborhood
    - ▶ **Mobility cost**: additional barriers to moving that depend on race and neighborhood
  - ▶ 3 **neighborhoods**  $n$  in  $\{A, B, C\}$ , with 3 **equilibrium** characteristics:
    - ▶ Rent:  $p_n$
    - ▶ **Local spillover**:  $X_n$ , college share
    - ▶ **Racial composition**:  $S_{r,n}$ , population share of each race
  - ▶ Timing:
    - ▶ Adults choose their **neighborhood**
    - ▶ They decide how much to **consume** and **invest in skills** of their child
    - ▶ The child is born, realization of education preference shock
    - ▶ Child chooses **education level**,  $e$  in  $\{e^L, e^H\}$ , with which they will enter adulthood
- 

## Adult Problem: Consumption, Investment, and Neighborhood Choices

$$V(r, s, e, n_0, n) = \max_{c, i} \log(c) + \log(A(n, r, S_{r,n})) + \beta \mathbb{E} [\mathcal{V}(r, s', e', n)]$$

subject to

$$\begin{aligned} c + i + p_n + m(r, n_0, n) &= y(r, e, s) \\ \log s' &= \theta_c + \underbrace{\theta_i \log(i)}_{\text{individual}} + \underbrace{\theta_X \log(X_n)}_{\text{neighborhood}} + \varepsilon_s \quad \varepsilon_s \sim N(0, \sigma_s) \\ P(e' = e^H) &= G^e(r, s', n) \end{aligned}$$

- ▶ **Amenity externalities:** neighborhood valuation depends on racial composition,  $S_{r,n}$
- ▶ **Mobility cost:** depends on race, initial neighborhood, neighborhood as adult
- ▶ **Income:** depends on race, education, and skills
- ▶ **Local spillover:** share of college-educated adults,  $X_n$



## Adult Problem: Consumption, Investment, and Neighborhood Choices

$$V(r, s, e, n_0, n) = \max_{c, i} \log(c) + \log(A(n, r, S_{r,n})) + \beta \mathbb{E} [\mathcal{V}(r, s', e', n)]$$

subject to

$$c + i + p_n + m(r, n_0, n) = y(r, e, s)$$

$$\log s' = \theta_c + \underbrace{\theta_i \log(i)}_{\text{individual}} + \underbrace{\theta_X \log(X_n)}_{\text{neighborhood}} + \varepsilon_s \quad \varepsilon_s \sim N(0, \sigma_s)$$

$$P(e' = e^H) = G^e(r, s', n)$$

- ▶ **Amenity externalities:** neighborhood valuation depends on racial composition,  $S_{r,n}$
- ▶ **Mobility cost:** depends on race, initial neighborhood, neighborhood as adult
- ▶ **Income:** depends on race, education, and skills
- ▶ **Local spillover:** share of college-educated adults,  $X_n$

Neighborhood choice:

$$\mathcal{V}(r, s, e, n_0) = \mathbb{E}_\varepsilon \left[ \max_n \{ V(r, s, e, n_0, n) + \varepsilon^n \} \right].$$

$\varepsilon^n$ : neighborhood preference shock drawn from a type 1 extreme value distribution

## Child's Problem: Education Choice

---

$$e = \operatorname{argmax}_{\{e^L, e^H\}} \{ \mathcal{V}(r, s, e^L, n) + \sigma^L, \mathcal{V}(r, s, e^H, n) - \underbrace{(\bar{c} - s)}_{\text{educ. cost}} + \sigma^H \}$$

- ▶ Skill affects: (i) income  $y(r, e, s)$ , and (ii) education cost
- ▶  $\sigma^H, \sigma^L$  are preference shocks drawn from a type 1 extreme value distribution

## Three General Equilibrium Forces

---

- ▶ **Housing:** elastically supplied,  $S_n = \eta_n p_n^\psi$
- ▶ **Local spillovers:**  $X_n$ , share of adults with high education by neighborhood
- ▶ **Amenity externalities:**  $S_{r,n}$ , race shares by neighborhood

▷ Equilibrium Definition

Quantification

## Calibration Strategy

---

Focus on St. Louis MSA

► **Empirical estimates:**

1. Three neighborhoods
2. Moving across neighborhoods
3. Black-White earnings gap
4. Amenity externalities
5. Skills and spillovers

} Sources of racial differences

- **Calibration:** some external and some internal, to match the data
- **Validation:** replicate causal effects from the literature

## 1. Three Neighborhoods

*K*-means clustering of Census tracts:

	All	Cluster A	Cluster B	Cluster C
Population Share	1.00	0.17	0.62	0.21
Black Share	0.20	0.78	0.09	0.07
College Share of Adults	0.28	0.15	0.23	0.53
Income (\$)	57,835	33,273	55,405	84,749
Median House Price (\$)	171,749	82,699	150,060	307,244

Notes: K-means clustering for St. Louis MSA. Data from 2000 Census and (Chetty et al., 2018)

▷ Map

## 2. Moving Across Neighborhoods

---

Additional mobility cost,  $m^B$  for Black households who move out of A (Box-Couillard Christensen 2024)

$$m(r, n_0, n) = \begin{cases} m^B & \text{if } r = B, n_0 = A, n \neq A \\ 0 & \text{o.w.} \end{cases}$$

Captures barriers to moving to a predominantly White area:

- ▶ Discrimination in housing markets
- ▶ Difficulties in obtaining credit

**Target:** Racial difference in probability of staying in A

- ▶ Probability of staying in A is 58% for Black children, while 12.5% for White children (NLSY data)

▷ Details

### 3. Black-White Earnings Gap

- ▶ Mincer regression in NLSY-97:

$$\log(\text{earnings}_i) = \alpha \text{ race}_i + \beta \text{ college}_i + \chi \log(\text{skill}_i) + \delta \text{ gender}_i + \varepsilon_i$$

where skill is measured with ASVAB.

- ▶ In the model:

$$y(r, e, s) = w(r, e) s^\chi$$

	White	Black
earnings, below college	1.00	0.92
earnings, college	1.71	1.58
Return to skill, $\chi$	0.19	0.19

- ▶ Gaps consistent with the literature (Neal and Johnson, 1996; Heckman et al., 2006)

▷ Time series



## 4. Amenity Externalities

Why do amenities depend on racial composition?

- ▶ Homophily, discrimination (Becker and Murphy, 2000)

Functional Form:

- ▶ Penalty on exogenous amenities (Banzhaf and Walsh, 2013):

$$A(n, r, S_{r,n}) = A_n (1 - \varphi_r (S_{r,n} - \gamma_r)^2)$$

- ▶ Utility from exogenous amenities  $A_n$  decreases as racial composition differs from ideal
- ▶  $S_{r,n}$  is the share of population of race  $r$  in  $n$
- ▶  $\gamma_r$  is the “bliss point” for racial composition
- ▶  $\varphi_r$  is a weight on the penalty

## 4. Calibration of Amenity Externalities $\varphi_r (S_{r,n} - \gamma_r)^2$

---

1.  $\gamma_r$ : Survey evidence:  $\gamma_B = 0.5$ ,  $\gamma_W = 0.9$  (Farley et al., 1997; Krysan and Farley, 2002) [▷ Details](#)
2.  $\varphi_r$ : Causal effect of racial composition on neighborhood choice (Caetano and Maheshri, 2021)
  - ▶ If the Black share in a neighborhood rises by 10 p.p., the moving probability:
    - ▶ Increases by 3.5% for rich Black households
    - ▶ Decreases by 2.8% for rich white households
  - ▶ Larger responses to changes in race than in income
  - ▶ Similar findings in the literature Bayer et al. (2004); Bayer and McMillan (2005); Bayer et al. (2017); Boustan (2013); Card et al. (2008)

## 5. Skills and Education

---

### Skills:

$$\log s = \theta_c + \theta_i \log(i) + \theta_x \log(X_n) + \varepsilon_s$$

- ▶ Estimate same regression in the data and model ▶ [Results](#)
- ▶ Target the coefficients  $\theta_i$  and  $\theta_x$
- ▶ Target the rank-rank correlation of income to discipline the variance of  $\varepsilon_s$  Chetty et al. (2014)

## Calibration: Internal Parameters and Targeted Moments

Parameter	Description	Value	Moment	Data	Model
<b>Neighborhoods</b>					
$A_A$	Amenity in A	1.0000	Population neighborhood A	0.1700	0.1150
$A_B$	Amenity in B	1.1894	Population neighborhood B	0.6200	0.6676
$A_C$	Amenity in C	1.2752	Population neighborhood C	0.2100	0.2174
$\eta_A$	Housing supply in A	25.3023	Rent neighborhood A	0.1200	0.1017
$\eta_B$	Housing supply in B	22.6165	Rent neighborhood B	0.2178	0.2248
$\eta_C$	Housing supply in C	1.4118	Rent neighborhood C	0.4460	0.4526
$\kappa$	Shape parameter for location	0.1232	Neighborhood flows	0.4600	0.4200
$m^B$	Additional mobility cost	0.0200	Diff in moving prob for Black HHs	-0.4550	-0.4853
<b>Amenities: Importance of bliss point</b>					
$\varphi_W$	White	0.5492	Migration response to Black share, Black non-college	0.0241	0.0267
$\varphi_B$	Black	0.8740	Migration response to Black share, Black college	0.0345	0.0274
			Migration response to Black share, White non-college	-0.0225	-0.0280
			Migration response to Black share, White college	-0.0283	-0.0278
<b>Skill production</b>					
$\theta_c$	Constant term	0.7884	Mean skills	1.0000	0.9669
$\theta_i$	Investment	0.1579	Reg s on $X_n$ and $i$	0.1510	0.1581
$\theta_X$	Spillovers	0.3081	Reg s on $X_n$ and $i$	0.2984	0.3052
$\sigma_s$	Std. skill shock	0.1916	Rank-rank correlation	0.4130	0.4127
<b>Education</b>					
$\bar{c}$	Education cost level	1.7879	Educational probability	0.4166	0.4624
$\sigma$	Shape parameter education	0.2572	$R^2$ education choice	0.1570	0.1690

[▷ Details: flows](#)
[▷ Policy functions](#)
[▷ External parameters](#)

## Model Validation 1: Moving to Opportunity

### Data: MTO

- ▶ Voucher program increased college attainment (Chetty et al., 2016)
- ▶ Small-scale RCT

### Model:

- ▶ Subsidize rent differences across neighborhoods for households living in A
- ▶ Partial equilibrium exercise, following the small-scale RCT

	Data	Model
Takeup rate (%)	[46.0, 49.3]	52.2
College attainment, treatment-on-the-treated (%)	[ 2.9, 7.6]	15.4
College attainment, intent-to-treat (%)	[ 1.4, 3.7]	8.1

## Model Validation 2: Causal effect of segregation

Data: (Ananat, 2011)

- ▶ Instrument: exogenous variation in segregation from the historical layout of train tracks
- ▶ Measure the causal impact of segregation on college attainment

Model:

- ▶ Eliminate amenity externality, evaluate the response in college attainment
- ▶ Compare general equilibrium

	Data	Model
$\Delta$ college attainment, White	[-0.290, 0.012]	0.200
$\Delta$ college attainment, Black	[-0.520, -0.078]	-0.211

Model: Segregation and College Gap

## Model Explains Segregation and the College Gap

Model generates 64% of the college gap and 70% of the level of segregation

	Data	Model
<b>College attainment</b>		
All, %	0.42	0.46
White, %	0.47	0.50
Black, %	0.19	0.32
College gap, p.p.	0.28	0.18
<b>Black share</b>		
All	0.20	0.20
Neighborhood A	0.78	0.79
Neighborhood B	0.09	0.14
Neighborhood C	0.07	0.06
Dissimilarity Index	0.61	0.43

### 1. Earnings gap:

Higher earnings enable White HH to afford better neighborhoods, invest in kids (Couture et al., 2023)

### 2. Amenity externalities:

Drives White HHs to B and C and Black HHs to A  
Segregation  $\Rightarrow$  lower spillovers for Black  $\Rightarrow$  college gap

### 3. Mobility cost differences:

Reinforces these outcomes

$\rightarrow$  Racial inequality in exposure to high-quality neighborhoods



Sources of College Gap: Earnings Gap, Amenity Externality, Mobility Cost

## No Earnings Gap Counterfactual, $w(B, e) = w(W, e)$

	College gap	Dissimilarity index
<i>Benchmark</i>	0.18	0.43
<b>No Earnings Gap Counterfactual</b>		
<i>General equilibrium</i>	0.10	0.36
<i>Partial equilibrium</i>	0.15	0.38

- ▶ Removing the **Black-White earnings gap** decreases college gap by **8 p.p.** and segregation by **14%**
- ▶ **Direct effect:** Black households use additional income on investment → Increase education
- ▶ **GE effect:** Spillovers in A goes up
- ▶ **Segregation** is not substantially reduced due to amenity externalities and barriers to moving

▷ Investment    ▷ Neighborhood Characteristics Equalization

## Race-Blind Counterfactual: No Amenity Externality, $\varphi_b = \varphi_w = 0$

	College gap	Dissimilarity index
<i>Benchmark</i>	0.18	0.43
<b>Race-Blind Counterfactual</b>		
<i>General equilibrium</i>	0.02	0.04
<i>Partial equilibrium</i>	0.02	0.05

- ▶ Removing **amenity externality** decreases college gap by **16 p.p.** and segregation by **91%**
- ▶ Households reallocate → **lower racial inequality in exposure to high-quality neighborhoods**
- ▶ White and Black households are exposed to similar **spillovers** → reduction of the college gap

▷ Investment

▷ Equal Mobility Cost

## Multiple Equilibria

## Spillovers + Amenity Externality $\Rightarrow$ Multiple Equilibria

	Equilibrium 1	Equilibrium 2
Dissimilarity index	0.43	0.17
College gap	0.18	0.06
Education, neighborhood A	20.03	26.98
Education, neighborhood B	39.12	35.29
Education, neighborhood C	77.10	71.91
SSE	0.02	0.27

### Equilibrium 1:

- ▶ Segregated equilibrium
- ▶ Matches the data

### Equilibrium 2:

- ▶ Integrated equilibrium
- ▶ Lower college gap

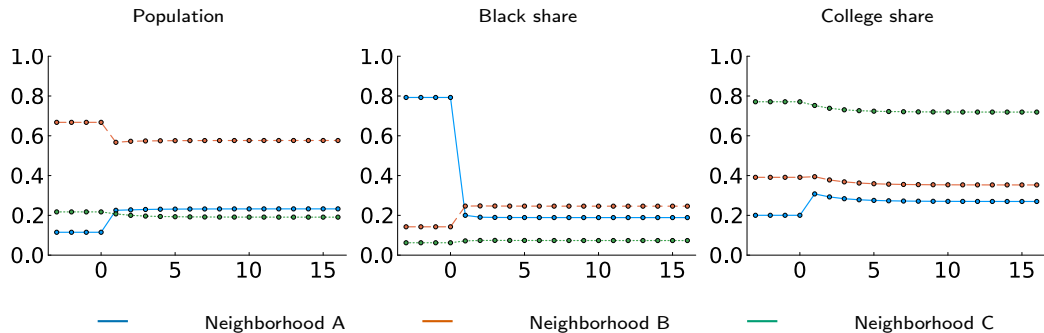
Can the economy coordinate to move from the segregated to the integrated equilibrium?

## Escaping the Segregation Trap

---

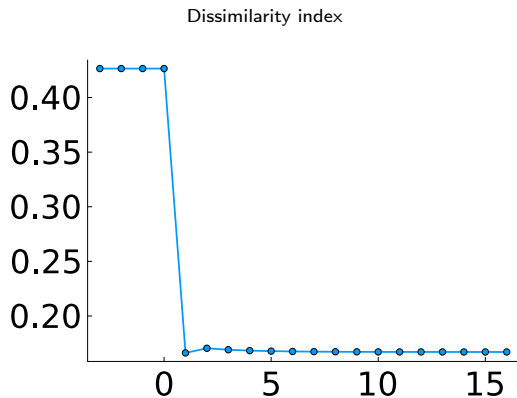
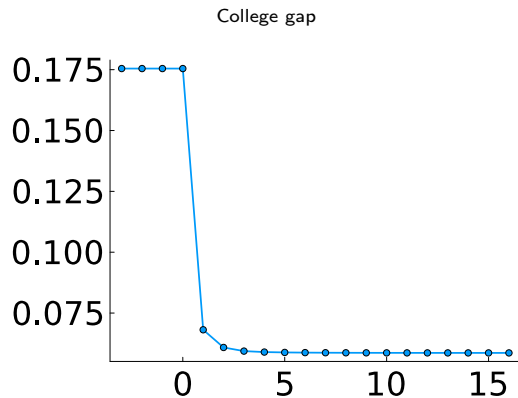
- ▶ Start in segregated equilibrium
- ▶ In  $t = 0$  agents learn that in  $t = \tau$  they will coordinate to be in integrated equilibrium
- ▶ What is the transition path?

## Escaping the Segregation Trap



- ▶ Black households move from A to B, White households from B to A
- ▶ A gains population, B loses
- ▶ Neighborhood C about the same
- ▶ Increase in college share in A
- ▶ Can achieve fast coordination to equilibrium 2, robust for different values of  $\tau$

## Escaping the Segregation Trap



- ▶ Lower college gap and segregation
- ▶ Lower racial inequality in exposure to high-quality neighborhoods



## Place-Based Policies

---

Can government provide incentives to moving and destabilize the segregated equilibrium?

We consider 2 alternative policies:

1. Moving to Opportunity (MTO)

- ▶ Same as before, but in GE
- ▶ Fund vouchers with housing tax

2. Opportunity Zones (OZ)

- ▶ Tax benefits to investors to spur growth in low-income neighborhoods
- ▶ In STL: 71% of opportunity zones are in neighborhood A
- ▶ **Model:** provide transfer to college households living in A, if college attainment in A  $\leq 26\%$

**Opposite incentives:**

- ▶ **MTO:** incentives for low-education households to live in high-education areas
- ▶ **OZ:** incentives for high-educated households to live in low-educated areas

## Place-Based Policies: Outcomes

### OZ:

- ▶ With high enough transfer, the segregated equilibrium is no longer an equilibrium
- ▶ The transfer will never actually be paid, and only the integrated equilibrium remains

	Benchmark	OZ	MTO
Dissimilarity index	0.43	0.17	0.11
College gap	0.18	0.06	0.03
<i>Welfare (C.E.), %</i>			
Aggregate		1.63	1.28
Coefficient of variation		2.49	3.28
Black households		2.61	3.74
White households		1.38	0.66
Non-college households		1.93	1.81
College households		1.26	0.63
Fraction with welfare gains		0.69	0.80

- ▶ Welfare gains are larger and less dispersed in OZ than in MTO

## Conclusion

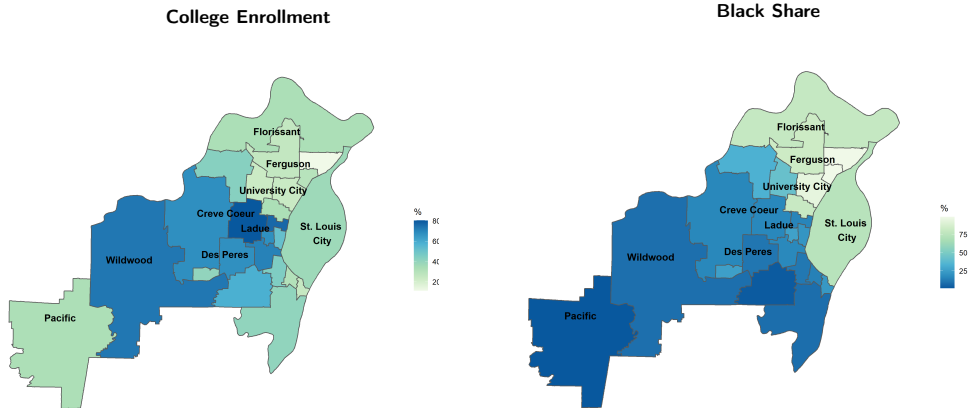
## Conclusion

---

- ▶ Add race to a benchmark model of a city with neighborhood spillovers
- ▶ Model does a good job in replicating the Black-White college gap and segregation
- ▶ Racial segregation affects the exposure to high-quality neighborhoods and the college gap
- ▶ Closing earnings gap impacts college gap, but not segregation
- ▶ Amenity externalities have largest impacts on both
- ▶ There exists a second, more integrated equilibrium with a lower college gap, which can be reached with appropriate government policies

# Appendices

## St. Louis: High Correlation between Race and College Enrollment



$\text{Correlation}(\text{college enrollment}, \text{black share}) = -0.63$

[▷ Back](#)

## Related Literature

---

### ► Empirical literature on racial differences and causes and consequences of segregation

- Neal and Johnson (1996); Cutler and Glaeser (1997); Cameron and Heckman (2001); Card and Rothstein (2007); Boustan (2013); Ananat (2011); Billings et al. (2013); Chetty et al. (2016); Jackson et al. (2016); Hyman (2017); Chetty and Hendren (2018a,b); Graham (2018); Monarrez and Schönholzer (nd); Biasi (2021); Derenoncourt (2022)

### ► Spatial equilibrium models of racial segregation

- Schelling (1969, 1971)
- Sethi and Somanathan (2004); Banzhaf and Walsh (2013); Bayer and McMillan (2005); Bayer et al. (2004); Caetano and Maheshri (2021); Christensen and Timmins (2023)

Do not consider the impact on human capital accumulation

### ► Neighborhood spillovers in human capital accumulation

- Fernandez and Rogerson (1996); Brock and Durlauf (1995); Benabou (1996)
- Fogli et al. (2023); Zheng and Graham (2022); Eckert and Kleineberg (2019); Aliprantis and Carroll (2018); Chyn and Daruich (2022); Gilraine et al. (2023)

Do not consider race

### ► Our contribution: Add race to a spatial model with education and neighborhood spillovers

## Recursive Competitive Equilibrium

A *Recursive Competitive Equilibrium* is characterized by policy functions for the neighborhood choice  $n(r, s, e, n_0)$ , consumption  $c(r, s, e, n_0, n)$ , and investment  $i(r, s, e, n_0, n)$  decisions of the parent, the education choice  $e'(r, s, e, n)$  of the child, value functions  $V(r, s, e, n_0, n)$ , house prices  $\{p_n\}_{n=1}^N$ , local spillovers  $\{X_n\}_{n=1}^N$ , neighborhood racial shares  $\{S_{r,n}\}_{n=1}^N \forall r \in \{B, W\}$ , and an ergodic distribution  $F(r, s, e, n_0, n)$  over race, skills, education, birth neighborhood, and adult neighborhood, which satisfy the following:

1. Household optimization: the policy functions  $n, e', c, i$  solve both the adult's and child's problem.
2. Housing market clearing:

$$\eta_n p_n^\psi = S_n = \int F(dr, ds, de, dn_0, n) \quad \forall n = 1, \dots, N$$

3. Spillover consistency:

$$X_n = \frac{\int F(dr, ds, e^H, dn_0, n)}{\int F(dr, ds, de, dn_0, n)} \quad \forall n = 1, \dots, N$$

4. Location consistency:

$$S_{r,n} = \frac{\int F(r, ds, de, dn_0, n)}{\int F(dr, ds, de, dn_0, n)} \quad \forall n = 1, \dots, N \text{ and } r = \{b, w\}.$$



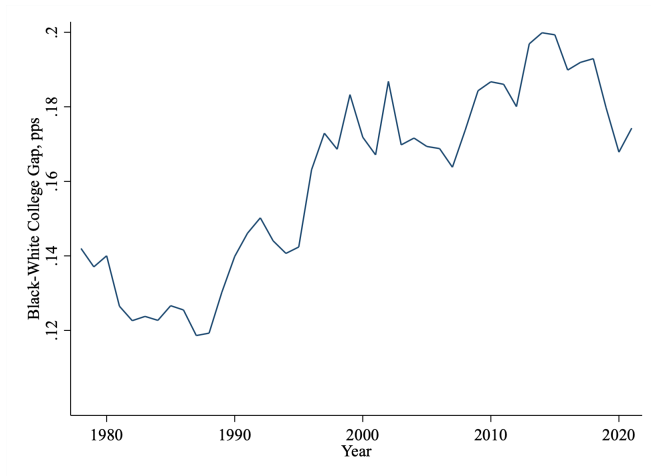
## Intergenerational Transmission

1. **Parental investment:** as transfers between parent and child
  2. **Neighborhood:**
    - ▶ **Spillovers:** living in a high-quality neighborhood is a complementary way of investing in child's skills
    - ▶ **Moving costs:** persistence in neighborhood choice across generations
- ⇒ still have intergenerational persistence in income + education, even without a wealth gap

Data

## Black-White College Attainment Gap

---



## Survey Evidence

Survey evidence from (Farley et al., 1997; Krysan and Farley, 2002)

Attractiveness Ratings of Neighborhoods  
by Racial Composition (Black Respondents)

All Black	20%
Majority Black	23%
50% Black	50%
Majority White	5%
All White	2%

Reasons Blacks Find  
A Neighborhood Most Attractive

Because it is mixed	56%
Positive effects of integration	22%
Better neighborhood characteristics	7%
White hostility	4%
Other	11%

Krysan and Farley (2002)

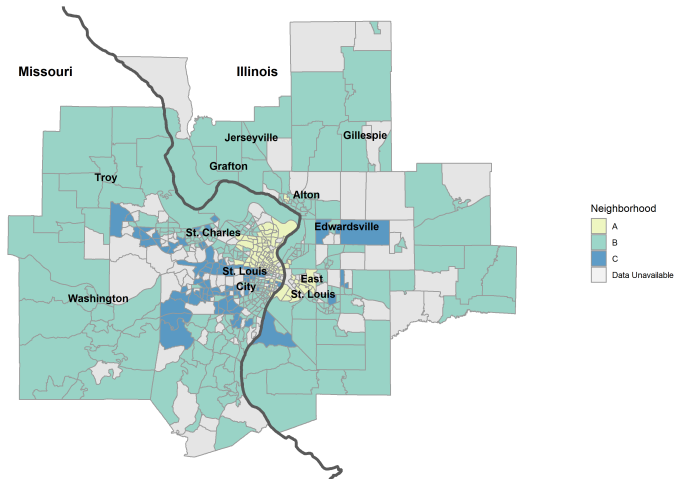
**TABLE 1: Attractiveness Ratings of Neighborhoods by Racial Composition and Rank Order (Black Respondents)**

	First Choice Percent	Second Choice Percent	Third Choice Percent	Fourth Choice Percent	Fifth Choice Percent
All black	20	7	24	32	16
10 black–4 white	23	58	13	6	1
7 black–7 white	50	22	26	1	< 1
2 black–12 white	5	12	34	49	1
All white	2	2	3	12	81
Total	100	100	100	100	100
Sample size	2001	1995	1989	1977	1975

## Black-White Earnings Gap Across Decades

	1980-1989	1990-1999	2000-2009	2010-2019
<hr/>				
<i>St. Louis, Below college</i>				
White	1.000	1.000	1.000	1.000
Black	0.783	0.831	0.875	0.819
<hr/>				
<i>St. Louis, College or above</i>				
White	1.281	1.567	1.632	1.817
Black	1.004	1.302	1.427	1.489
<hr/>				
<i>National, Below college</i>				
White	1.000	1.000	1.000	1.000
Black	0.823	0.893	0.910	0.895
<hr/>				
<i>National, College or above</i>				
White	1.446	1.704	1.802	1.988
Black	1.190	1.522	1.639	1.729

# Neighborhood Segregation



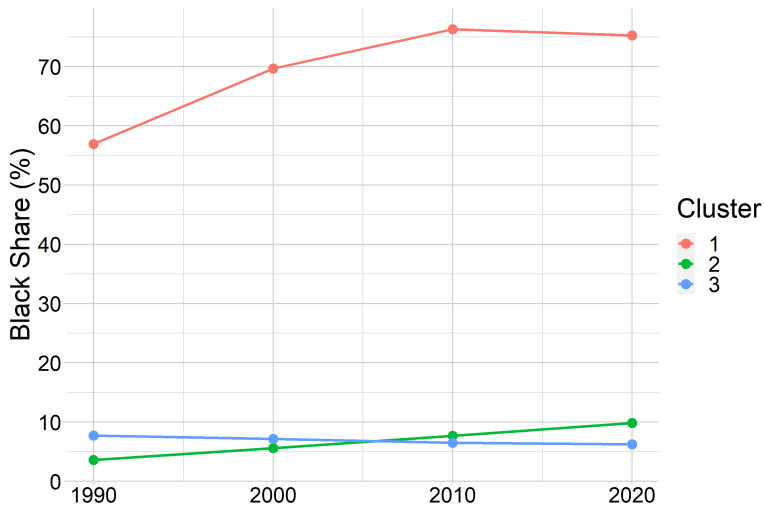
## Clusters:

A: Black & low-income

B: White & middle-income

C: White & high-income

## Black Share by Cluster Over Time





## Parent-Child Neighborhood Transition Matrices

		Adult Neighborhood		
		Cluster A	Cluster B	Cluster C
<b>Child Neighborhood</b>	<b>Black</b>			
	Cluster A	0.580	0.334	0.086
	Cluster B	0.384	0.508	0.108
	Cluster C	0.364	0.423	0.214
<b>Child Neighborhood</b>	<b>White</b>			
	Cluster A	0.125	0.596	0.278
	Cluster B	0.070	0.623	0.306
	Cluster C	0.052	0.452	0.496

▷ [Back](#)

## Neighborhood Flows

- ▶ Cluster Census tracts at the national level
  - ▶ K-means clustering algorithm on race share, income, housing prices, and college share
- ▶ NLSY: See county, race, education → estimate the probability of being in each cluster
- ▶ Compute the probability of moving between clusters between age 17 and 35.
- ▶ Conclusion: take a midpoint of 35% move across clusters

	Sample Restriction	
	50%	75%
Neighborhood flows	.461	.253
Observations	16,364	3,173

## Calibration: External Parameters

Parameter	Description	Value	Source
$\beta$	Discount factor	0.97 <sup>40</sup>	
$\gamma_B$	Bliss points for Black	0.50	Banzhaf and Walsh (2013)
$\gamma_W$	Bliss points for White	0.90	Banzhaf and Walsh (2013)
$w(B, L)$	Relative wage of Black, low education	0.92	Mincer regressions
$w(B, H)$	Relative wage of Black, high education	1.57	Mincer regressions
$w(W, H)$	Relative wage of White, high education	1.71	Mincer regressions
$\chi$	Return to skill	0.18	Mincer regressions
$\psi$	Housing supply elasticity	2.36	Saiz (2010)

▷ [Back](#)

## Skill Formation Estimates

	log(ASVAB)
log(parental transfers)	0.151 (0.0159)
log(county college share)	0.298 (0.0381)
Constant	-1.951 (0.185)
Observations	3,898
$R^2$	0.050

	Bachelor's Degree or More
log(skills)	0.1910 (0.0059)
Constant	0.4200 (0.0074)
Observations	4,997
$R^2$	0.1570

## Dissimilarity Index

---

- ▶ Use dissimilarity index as in Ananat (2011)
- ▶ Dissimilarity index is defined as:

$$\text{seg} = \frac{1}{2} \sum_i^N \left| \frac{Black_i}{Black_{total}} - \frac{White_i}{White_{total}} \right|$$

where N is the number of neighborhoods

- ▶ Measures (Ananat, 2011):  
*“What percent of Blacks (or non-Blacks) would have to move to a different census tract in order for the proportion of Black households in each neighborhood to equal the proportion Black in the city as a whole?”*

## Neighborhood Heterogeneity Matters

---

- ▶ Three GE neighborhood variables: **Spillovers** ( $X_n$ ), **race shares** ( $S_{r,n}$ ), and **rents** ( $p_n$ )
- ▶ What would happen if these are determined at the city, instead of neighborhood, level?

## Neighborhood Heterogeneity Matters

- ▶ Three GE neighborhood variables: **Spillovers** ( $X_n$ ), **race shares** ( $S_{r,n}$ ), and **rents** ( $p_n$ )
- ▶ What would happen if these are determined at the city, instead of neighborhood, level?

	College gap	Dissimilarity Index
Benchmark	0.18	0.43
Equal spillovers	0.03	0.40

- ▶ Equal **spillovers**  $\implies$  lower college gap, but still high segregation
  - ▶ Something else is determining neighborhood choice

## Neighborhood Heterogeneity Matters

- ▶ Three GE neighborhood variables: **Spillovers** ( $X_n$ ), **race shares** ( $S_{r,n}$ ), and **rents** ( $p_n$ )
- ▶ What would happen if these are determined at the city, instead of neighborhood, level?

	College gap	Dissimilarity Index
Benchmark	0.18	0.43
Equal spillovers	0.03	0.40
Equal race shares	0.02	0.04
Equal rents	0.00	0.15
All equal	0.00	0.02

- ▶ Equal **spillovers**  $\implies$  lower college gap, but still high segregation
  - ▶ Something else is determining neighborhood choice
- ▶ Equal **race shares** or **rents**  $\implies$  lower segregation  $\implies$  lower college gap
  - ▶ With equal racial shares, more agreement on neighborhood ranking
  - ▶ With equal rents, Black households less likely to choose A



## Neighborhood Heterogeneity Matters

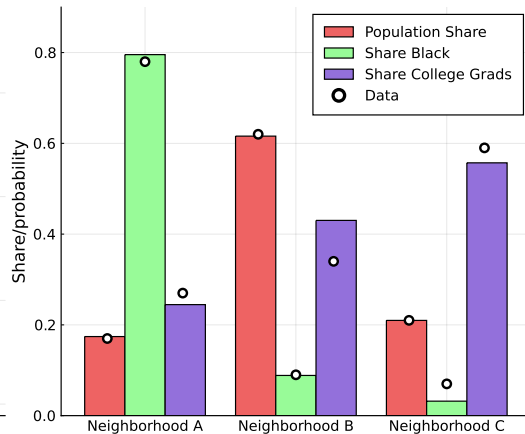
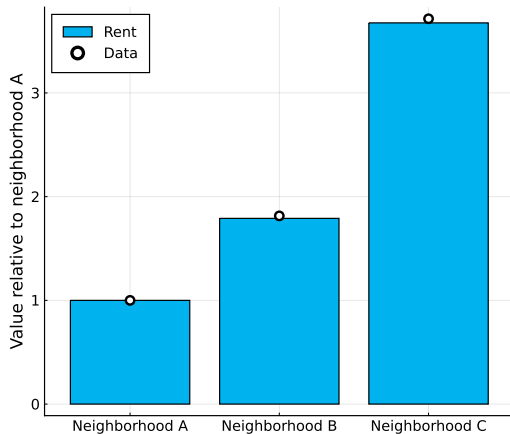
- ▶ Three GE neighborhood variables: **Spillovers** ( $X_n$ ), **race shares** ( $S_{r,n}$ ), and **rents** ( $p_n$ )
- ▶ What would happen if these are determined at the city, instead of neighborhood, level?

	College gap	Dissimilarity Index
Benchmark	0.18	0.43
Equal spillovers	0.03	0.40
Equal race shares	0.02	0.04
Equal rents	0.00	0.15
All equal	0.00	0.02

- ▶ Equal **spillovers**  $\implies$  lower college gap, but still high segregation
  - ▶ Something else is determining neighborhood choice
- ▶ Equal **race shares** or **rents**  $\implies$  lower segregation  $\implies$  lower college gap
  - ▶ With equal racial shares, more agreement on neighborhood ranking
  - ▶ With equal rents, Black households less likely to choose A
- ▶ **Neighborhood heterogeneities implies racial inequality in exposure to high-quality neighborhoods**

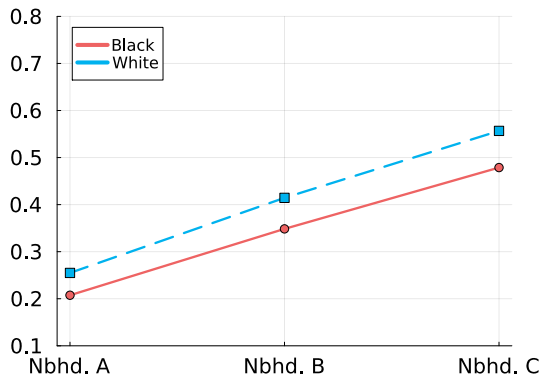
## Quantitative Results

## Baseline: Neighborhood Characteristics

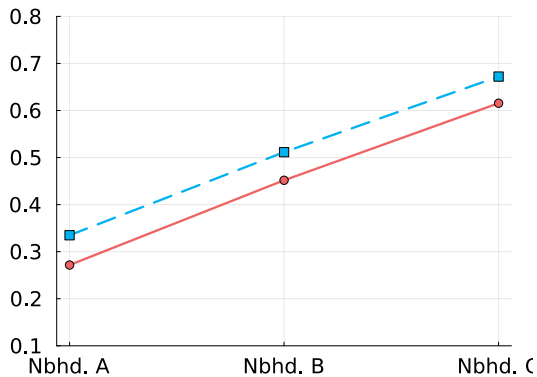


## Benchmark: Probability of Going to College

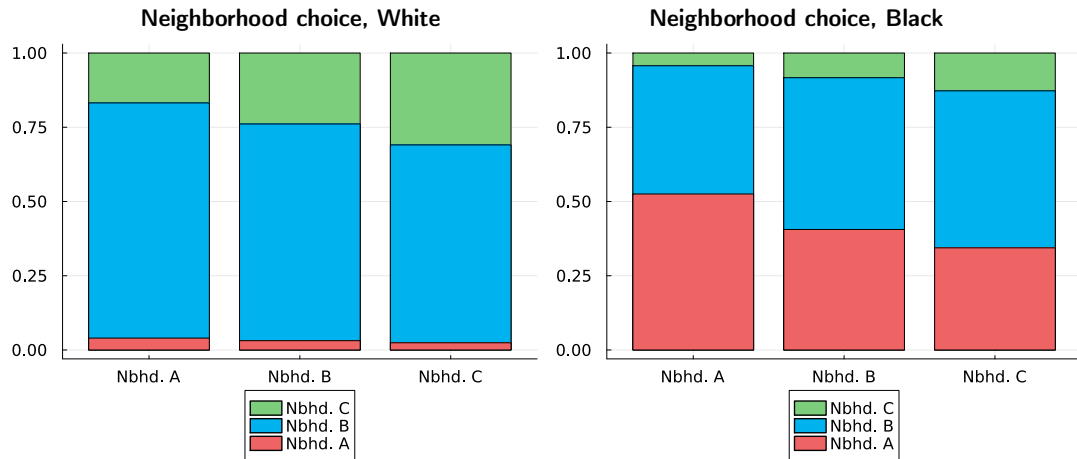
Non-college parents



College parents

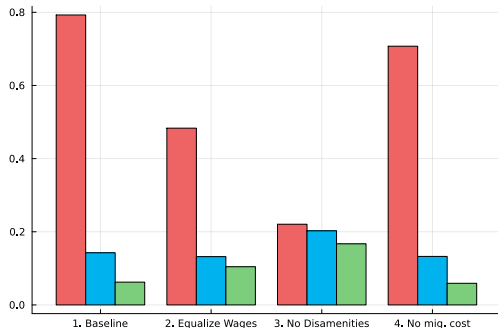


## Benchmark: Policy Rules, Neighborhood Choice

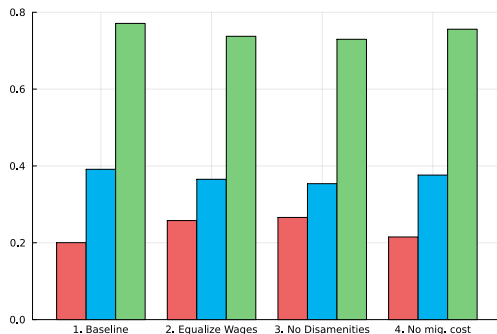


## Neighborhood Characteristics Equalization

**Black share**

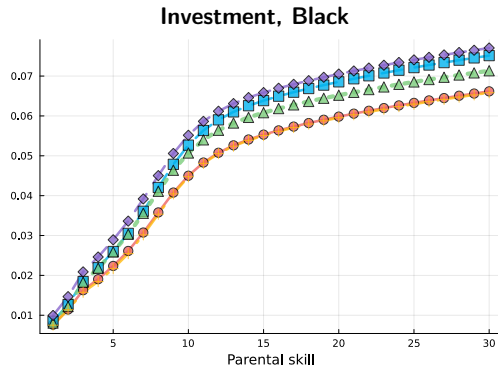
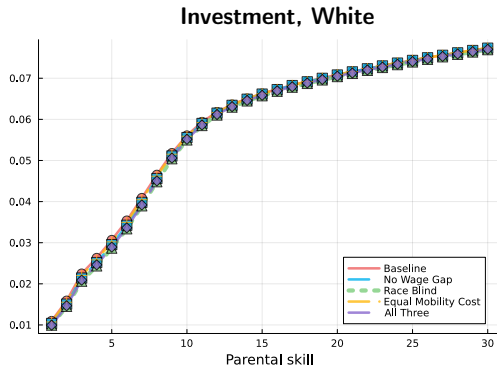


**College share**



▷ [Back](#)

## Equalizing Earnings: Investment is the Primary Driver of the Closing Education Gap



▷ [Back](#)

## Equal Mobility Cost

	College gap	Dissimilarity index
<i>Benchmark</i>	0.18	0.43
<b>Equal Mobility Cost</b>		
<i>General equilibrium</i>	0.17	0.46
<i>Partial equilibrium</i>	0.17	0.41

- ▶ Equalizing mobility costs increases segregation by 57% and decreases college gap by 1 p.p.
- ▶ If cost removed, Black households more likely to live in A
- ▶ Quantitatively minor impacts overall: few households move, leaving exposure to high-quality neighborhoods unchanged
- ▶ GE effects important for segregation index

▷ Investment



## Intergenerational Mobility

	Education Probability			
	Benchmark	No Earnings gap	Race blind	Equal mobility cost
Non-college parent, White	0.43	0.38	0.36	0.41
Non-college parent, Black	0.27	0.30	0.34	0.26
Gap	0.15	0.08	0.01	0.15
College parent, White	0.57	0.53	0.51	0.56
College parent, Black	0.43	0.45	0.50	0.41
Gap	0.14	0.09	0.01	0.15

- Equalization in intergenerational mobility
- Driven by increases in college attainment for Black children, decreases for White children

## References I

---

- [ ] Aliprantis, D. and Carroll, D. R. (2018). Neighborhood dynamics and the distribution of opportunity. *Quantitative Economics*, 9(1):247–303.
- [ ] Ananat, E. O. (2011). The wrong side(s) of the tracks: The causal effects of racial segregation on urban poverty and inequality. *American Economic Journal: Applied Economics*, 3(2):34–66.
- [ ] Banzhaf, H. S. and Walsh, R. P. (2013). Segregation and tiebout sorting: The link between place-based investments and neighborhood tipping. *Journal of Urban Economics*, 74:83–98.
- [ ] Bayer, P., Casey, M., Ferreira, F., and McMillan, R. (2017). Racial and ethnic price differentials in the housing market. *Journal of Urban Economics*, 102(C):91–105.
- [ ] Bayer, P., Charles, K. K., and Park, J. (2021). Separate and unequal: Race and the geography of the american housing market. Technical report, Mimeo., Duke University.
- [ ] Bayer, P. and McMillan, R. (2005). Racial Sorting and Neighborhood Quality. NBER Working Papers 11813, National Bureau of Economic Research, Inc.
- [ ] Bayer, P., McMillan, R., and Rueben, K. (2004). Residential Segregation in General Equilibrium. Working Papers 885, Economic Growth Center, Yale University.
- [ ] Becker, G. and Murphy, K. (2000). *Social Economics: Market Behavior in a Social Environment*. Harvard University Press.

## References II

---

- [ ] Benabou, R. (1996). Equity and efficiency in human capital investment: the local connection. *The Review of Economic Studies*, 63(2):237–264.
- [ ] Biasi, B. (2021). School finance equalization increases intergenerational mobility. *Journal of Labor Economics*.
- [ ] Billings, S. B., Deming, D. J., and Rockoff, J. (2013). School Segregation, Educational Attainment, and Crime: Evidence from the End of Busing in Charlotte-Mecklenburg \*. *The Quarterly Journal of Economics*, 129(1):435–476.
- [ ] Boustan, L. P. (2013). Racial residential segregation in american cities. Technical report, National Bureau of Economic Research.
- [ ] Brock, W. A. and Durlauf, S. N. (1995). Discrete Choice with Social Interactions I: Theory. NBER Working Papers 5291, National Bureau of Economic Research, Inc.
- [ ] Caetano, G. and Maheshri, V. (2021). A unified empirical framework to study segregation. Technical report, Working paper.
- [ ] Cameron, S. V. and Heckman, J. J. (2001). The dynamics of educational attainment for black, hispanic, and white males. *Journal of Political Economy*, 109(3):455–499.
- [ ] Card, D., Mas, A., and Rothstein, J. (2008). Tipping and the Dynamics of Segregation. *The Quarterly Journal of Economics*, 123(1):177–218.

## References III

- [ ] Card, D. and Rothstein, J. (2007). Racial segregation and the black–white test score gap. *Journal of Public Economics*, 91(11):2158–2184.
- [ ] Chetty, R., Friedman, J. N., Hendren, N., Jones, M. R., and Porter, S. R. (2018). The opportunity atlas: Mapping the childhood roots of social mobility. Working Paper 25147, National Bureau of Economic Research.
- [ ] Chetty, R. and Hendren, N. (2018a). The Impacts of Neighborhoods on Intergenerational Mobility I: Childhood Exposure Effects\*. *The Quarterly Journal of Economics*, 133(3):1107–1162.
- [ ] Chetty, R. and Hendren, N. (2018b). The Impacts of Neighborhoods on Intergenerational Mobility II: County-Level Estimates\*. *The Quarterly Journal of Economics*, 133(3):1163–1228.
- [ ] Chetty, R., Hendren, N., and Katz, L. F. (2016). The effects of exposure to better neighborhoods on children: New evidence from the moving to opportunity experiment. *The American Economic Review*, 106(4):855–902.
- [ ] Chetty, R., Hendren, N., Kline, P., and Saez, E. (2014). Where is the land of opportunity? the geography of intergenerational mobility in the united states. *The Quarterly Journal of Economics*, 129(4):1553–1623.
- [ ] Christensen, P. and Timmins, C. (2023). The Damages and Distortions from Discrimination in the Rental Housing Market\*. *The Quarterly Journal of Economics*. qjad029.

## References IV

- [ ] Chyn, E. and Daruich, D. (2022). An equilibrium analysis of the effects of neighborhood-based interventions on children. Technical report, National Bureau of Economic Research.
- [ ] Couture, V., Gaubert, C., Handbury, J., and Hurst, E. (2023). Income Growth and the Distributional Effects of Urban Spatial Sorting. *The Review of Economic Studies*, page rdad048.
- [ ] Cutler, D. M. and Glaeser, E. L. (1997). Are Ghettos Good or Bad?\*. *The Quarterly Journal of Economics*, 112(3):827–872.
- [ ] Derenoncourt, E. (2022). Can you move to opportunity? evidence from the great migration. *American Economic Review*, 112(2):369–408.
- [ ] Eckert, F. and Kleineberg, T. (2019). Can We Save the American Dream? A Dynamic General Equilibrium Analysis of the Effects of School Financing on Local Opportunities. 2019 Meeting Papers 1197, Society for Economic Dynamics.
- [ ] Farley, R., Fielding, E. L., and Krysan, M. (1997). The residential preferences of blacks and whites: A four-metropolis analysis. *Housing Policy Debate*, 8:763–800.
- [ ] Fernandez, R. and Rogerson, R. (1996). Income distribution, communities, and the quality of public education. *The Quarterly Journal of Economics*, 111(1):135–164.
- [ ] Fogli, A., Guerrieri, V., Ponder, M., and Prato, M. (2023). The end of the american dream? inequality and segregation in us cities. Technical report, National Bureau of Economic Research.

## References V

- [ ] Gilraine, M., Graham, J., and Zheng, A. (2023). Public education and intergenerational housing wealth effects. Working Paper 31345, National Bureau of Economic Research.
- [ ] Graham, B. S. (2018). Identifying and estimating neighborhood effects. *Journal of Economic Literature*, 56(2):450–500.
- [ ] Heckman, J. J., Lochner, L. J., and Todd, P. E. (2006). Earnings functions, rates of return and treatment effects: The mincer equation and beyond. *Handbook of the Economics of Education*, 1:307–458.
- [ ] Hyman, J. (2017). Does money matter in the long run? effects of school spending on educational attainment. *American Economic Journal: Economic Policy*, 9(4):256–80.
- [ ] Jackson, C. K., Johnson, R. C., and Persico, C. (2016). The Effects of School Spending on Educational and Economic Outcomes: Evidence from School Finance Reforms. *The Quarterly Journal of Economics*, 131(1):157–218.
- [ ] Krysan, M. and Farley, R. (2002). The residential preferences of blacks: Do they explain persistent segregation? *Social forces*, 80(3):937–980.
- [ ] Monarrez, T. and Schönholzer, D. (n.d.). Dividing lines: Racial segregation across local government boundaries. *Journal of Economic Literature*.

## References VI

---

- [ ] Neal, D. A. and Johnson, W. R. (1996). The role of premarket factors in black-white wage differences. *Journal of Political Economy*, 104(5):869–895.
- [ ] Schelling, T. C. (1969). Models of Segregation. *American Economic Review*, 59(2):488–493.
- [ ] Schelling, T. C. (1971). Dynamic models of segregation. *The Journal of Mathematical Sociology*, 1(2):143–186.
- [ ] Sethi, R. and Somanathan, R. (2004). Inequality and segregation. *Journal of Political Economy*, 112(6):1296–1321.
- [ ] Zheng, A. and Graham, J. (2022). Public education inequality and intergenerational mobility. *American Economic Journal: Macroeconomics*, 14(3):250–82.