Wage Convergence and the Decline after 1980

**Robustness**

1940–1980

1980–2010

Annual wage growth 1940–1980

Annual wage growth 1980–2010

Log hourly wages, 1940

Log hourly wages, 1980

Boston

Chicago

Detroit

Los Angeles

New York

Philadelphia

San Francisco
This Paper: Wage Convergence by Skill Group

Robustness

Annual wage growth 1940−2010

Annual wage growth 1940−1980

Annual wage growth 1980−2010
THIS PAPER

Research Question: What is the Role of Skill-Biased Technical Change (SBTC) on the End of Cross-Cities Wage Convergence?

- **Novel Facts**: Skill premium and migration patterns support differential ends of convergence by skill group

- **Model**: Spatial equilibrium model with heterogeneous skill workers
  - Skill-Biased Technical Shock
  - Agglomeration
  - Migration

- **Structural Estimation**: SBTC explains the majority of the end of wage convergence

- **Other Results**: Implications on quantities ⇒ “Great Divergence” of skills
  - Secular Migration Decline
Contributions

Empirical

- Novel set of facts on the evolution of:
  - regional convergence
  - skill premium
  - migration patterns

Theoretical

- Introduction of heterogeneous skill and endogenous agglomeration in a long-run spatial equilibrium model
  - Structural estimation and identification in a dynamic macro model
  - Quantification of the decline in wage convergence across US cities between 1980 and 2010 due to skill-biased technology and agglomeration forces
**Related Work Contributions**

**Convergence - North/South**  Caselli and Coleman (2002), Barro and Sala-i-Martin (1992), Brown (1993), Berry and Glaeser (2005); Ganong and Shoag (2015);  ⇒  **Quantitative spatial model**

**Skill-Biased Technical Change (SBTC)**  Katz and Murphy (1992), Autor and Dorn (2013), Autor and Dorn (2014), Baum-Snow *et al.* (2015), Burstein *et al.* (2016);  ⇒  **Application to cities and agglomeration forces**


Outline

Empirical Regularities

Model

Estimation

Counterfactuals

Other Results
**Novel Empirical Regularities**

**Fact 1**: Cross-Cities Wage Convergence decreased only among high-skill workers after 1980

- **Fact 2**: \( \uparrow \) share of high skilled workers \( \uparrow \) **skill premium** post 1980, \( \downarrow \) **skill premium** pre 1990

- **Fact 3**: \( \uparrow \) initial share of high skill workers \( \uparrow \) probability of getting high skill **migrants** over time

**Take-away**: *Supply* forced dominated by *demand* forces over time
FACT 2: SKILL PREMIUM OVER TIME AND ACROSS SPACE

\[ \ln \left( \frac{\hat{W}^H_{jt}}{\hat{W}^L_{jt}} \right) = \alpha_t + \sum_{t=1970}^{2010} \beta_t \ln \left( \frac{H_{jt}}{L_{jt}} \right) + f_{t \text{MSA}} + f_{t \text{year}} + \epsilon_{jt} \]
**Fact 3: High-Skill Migrants to High-Skill Locations**

\[ 1 \left( \text{Migrant} \right)_{ijt} = \alpha_t + \beta_1 (H_{ijt}) + \gamma \frac{H_{jt}}{L_{jt}} + \sum_{t=1963}^{2013} \delta_t 1(H_{ijt}) \ast \left( \frac{H_{jt}}{L_{jt}} \right) + \Gamma X_{ijt} + \mu_{ijt} \]
**Main Idea**

- Before 1980, technology diffusion was skill neutral $\Rightarrow$ push for convergence
- **Skill-biased technology** shifted the demand for skills nationally
- Endogenous **agglomeration** economies of skill pushed sorting where the concentration of initial skills was higher
- High-skill migrate more to high skill places
- Higher match of high skilled workers to high-skilled locations
- Wages diverge
Outline

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Other Results
**Key Ingredients**

- Heterogeneous Demand for skills
- Migration
- Agglomeration

**Other Mechanisms**

- Housing
**Model Environment**

**Space**
- $J$ locations

**Workers**
- 2 types: high-skilled and low-skilled
- Workers decide in which location to live
- Preferences over:
  - tradable and non-tradable housing
  - exogenous amenities and endogenous amenities
  - utility loss from moving
  - i.i.d. preference shock
- Supply labor inelastically

**Firms**
- Tradable: CES production with intermediates inputs
- A set of non-tradable intermediates
  - CES production function with high and low-skilled workers
- Housing sector
- Productivities depend on:
  - skill and population agglomeration
  - skill-biased technology
  - technology diffusion process
Outline

Empirical Regularities

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Other Results
Objective: Identifying agglomeration and amenities

Challenges:
- Separate endogenous agglomeration and amenities from local productivity and local amenities
- Keep into account the path dependence in technology diffusion

Solution: Instrumental approach isolating local changes in supply from changes in demand

- Changes in supply through housing regulation and land unavailability
- Changes in demand through routinization shock by skills
# Parameters Estimated and Used for Calibration

\[
E[\Delta \xi_{kdjt} \Delta Z_{jt}] = 0
\]

### Supply

<table>
<thead>
<tr>
<th>Moments</th>
<th>Parameter</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>spillover on skill for H: ( \gamma^H )</td>
<td>0.616[0.231]</td>
</tr>
<tr>
<td></td>
<td>spillover on skill for L: ( \gamma^L )</td>
<td>-0.185[0.117]</td>
</tr>
<tr>
<td></td>
<td>spillover on population for H: ( \phi^H )</td>
<td>-0.137[0.088]</td>
</tr>
<tr>
<td></td>
<td>spillover on population for L: ( \phi^L )</td>
<td>-0.111[0.047]</td>
</tr>
<tr>
<td></td>
<td>( \frac{1}{1-\rho} ) elasticity of substitution between H and L: ( \rho )</td>
<td>0.531[0.310]</td>
</tr>
<tr>
<td></td>
<td>elasticity on SB: ( \lambda )</td>
<td>-0.014[0.062]</td>
</tr>
</tbody>
</table>

### Demand

\[
E[\Delta A_{kdjt} \Delta Z_{jt}] = 0
\]

| | Elasticity to local prices: \( \theta \) | 0.503[0.107] |
| | Elasticity to population: \( \gamma^p \) | 0.679[0.130] |
### Externally Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of Services: $v$</td>
<td>0.2</td>
<td>Serrato and Zidar (2016)</td>
</tr>
<tr>
<td>Subsistance level of Housing: $\bar{O}$</td>
<td>0.25</td>
<td>Ganong and Shoag (2015)</td>
</tr>
<tr>
<td>Elasticity of Supply Housing: $\mu$</td>
<td>0.4</td>
<td>Ganong and Shoag (2015)</td>
</tr>
<tr>
<td>Share of technology: $\gamma_2$</td>
<td>0.99</td>
<td>Desmet et al. (2016)</td>
</tr>
<tr>
<td>Migration costs: $\sigma^L$ and $\beta^L$</td>
<td>-.065 and -.861</td>
<td>Notowididgo (2013)</td>
</tr>
<tr>
<td>Migration costs: $\sigma^H$ and $\beta^H$</td>
<td>-.066 and -1.044</td>
<td>Notowididgo (2013)</td>
</tr>
</tbody>
</table>
Model vs Data: Wage Convergence $\beta$ $\beta_H$ $\beta_L$

Estimate rolling 30-year window $\beta_t$ for the following equation:

$$\Delta w_{jt} = \alpha + \hat{\beta}_t w_{jt-30} + \epsilon_{jt}$$
Model vs Data: Wage Convergence $\beta_H$ and $\beta_L$

Estimate rolling 30-year window $\beta_{Ht}$ for the following equation for $H$:

$$\Delta w_{kjt} = \alpha + \hat{\beta}_{kt} w_{kjt-30} + \epsilon_{kjt}, \quad \forall k \in \{H, L\}$$
OUTLINE

EMPIRICAL REGULARITIES

MODEL

ESTIMATION

COUNTERFACTUALS

OTHER RESULTS
Decomposing the Decline in Wage Convergence β

Proceed stepwise:

1. Simulate counterfactual convergence rate with no agglomeration;

2. Remove SBTC;

3. Remove Housing;

4. Remove Migration Costs;
Decomposing the Decline in Wage Convergence $\beta$

No Agglomeration
Decomposing the Decline in Wage Convergence $\beta$

No SBTC
Decomposing the Decline in Wage Convergence $\beta$

No Housing
DECOMPOSING THE DECLINE IN WAGE CONVERGENCE $\beta$

No Migration

![Graph showing wage convergence with various scenarios: full, no Agg, No SBTC, No Housing, No Migr. Cost. The x-axis represents years from 1980 to 2010, and the y-axis represents a range of values from -4.5 to -0.5. Each scenario is represented by a different line or marker, indicating how each factor affects wage convergence.](image-url)
Outline

Empirical Regularities

Model

Estimation

Counterfactuals

Other Results
Other Results

Wages
- Wage Dispersion
- Real Wage Convergence

Migration
- "Great Divergence" in Skill Ratio
- Sorting of Migrants
- Migration Decline
Cities’ Wage Dispersion in the Last 30 Years

**Data:** Cities’ Wage dispersion increased 100% from 1969 to 2009 (Hsieh and Moretti (2015))

**Model:** Cities’ Wage dispersion increased by:

Take-away: Cities’ Wage dispersion increased only among high-skilled workers and mostly because of SBTC.
Real Wages Convergence

Total

High Skill

Low Skill

\[\beta^R \text{ data}, \quad \beta^R \text{ model}, \quad \beta^{RH} \text{ data}, \quad \beta^{RH} \text{ model}, \quad \beta^{RL} \text{ data}, \quad \beta^{RL} \text{ model}\]
"The Great Divergence" in the Skill Ratio $\frac{H}{L}$: Data
"The Great Divergence" in the Skill Ratio $\frac{H}{L}$: Model vs Data

$$\log \left[ \frac{H_{jt}}{L_{jt}} / \frac{H_{j,\tau}}{L_{j,\tau}} \right] \frac{1}{(t - \tau)} = \alpha + \hat{\beta}_{t}^{\text{skill}} \log \frac{H_{j,\tau}}{L_{j,\tau}} + \epsilon_{jt}$$

![Graph showing the comparison between skill data and model over years from 1950 to 2010.](image)
**Model: Extra Sorting over Time**

\[ \Delta H_{jt} = \alpha + \sum_{t=1941}^{1970} \delta^H_t \ln W_{Hjt} + \epsilon_{jt} \]

![Graph showing the model](image_url)
What is happening to regional convergence in other countries and across countries over time?
AVERAGE REGIONAL CONVERGENCE WITHIN OTHER COUNTRIES

- Estimate rolling 20 and 30-year window $\beta_t$ for the following equation in GDP per capita in each country:

$$\Delta GDP_{jt} = \alpha + \hat{\beta}_t GDP_{jt-30} + \epsilon_{jt}$$

- Plot average $\hat{\beta}_t$

Note: This figure shows the average of the $\beta$ estimates for the countries in the sample with rolling 20-year (30-year) windows on the left (right) plot.
Regional Convergence Across Countries

- Estimate rolling 20 and 10-year window $\beta_t$ for the following equation in GDP per capita:

$$\Delta GDP_{jt} = \alpha + \hat{\beta}_t GDP_{jt-30} + \epsilon_{jt}$$
CONCLUSIONS AND FUTURE DIRECTIONS

Spatial Equilibrium Model that several key moments and changes in the last 30 years:
- Regional Convergence in wages
- Increase in wage dispersion
- Great Divergence of skills
- Secular decline of migration

Key elements: Interaction Skill-biased technical change and agglomeration
- explain jointly 80% of the decline in regional convergence

What happens across countries? Preliminary results suggest:
- regional wage convergence decreasing within countries;
- but increasing across countries

Extension to Cross-country convergence and decline
ROBUSTNESS CONVERGENCE

- Adjusted Wages
- Rent Adjusted
- Table Convergence
- Rolling Convergence
- Rent adjusted Convergence
- Adjusted Convergence by Skill
- Table Convergence by Skill
- Rolling skill convergence
- Industry control
Computationally Adjusted Wages
Convergence
Annual wage growth 1940–1980

Annual wage growth 1980–2010

No col_degree  BA degree

No col_degree  BA degree
Rolling Wages Convergence

β convergence estimate

ROLLING WAGES CONVERGENCE BY SKILL GROUP

**Figure:** High Skill

**Figure:** Low Skill
Table: Wage Convergence Rates

<table>
<thead>
<tr>
<th></th>
<th>(1) $\Delta w_{40-80}^{pw}$</th>
<th>(2) $\Delta w_{80-10}^{pw}$</th>
<th>(3) $\Delta w_{40-80}$</th>
<th>(4) $\Delta w_{80-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log wages, 1940</td>
<td>-0.0112***</td>
<td>-0.0144***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-10.90)</td>
<td>(-16.81)</td>
<td></td>
<td></td>
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<tr>
<td>Log wages, 1980</td>
<td>-0.0000389</td>
<td>-0.00852*</td>
<td>-0.00852*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.02)</td>
<td>(-2.57)</td>
<td></td>
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</tr>
<tr>
<td>Constant</td>
<td>0.000360*</td>
<td>0.00145***</td>
<td>-1.37e-09</td>
<td>-0.0000229</td>
</tr>
<tr>
<td></td>
<td>(2.29)</td>
<td>(4.90)</td>
<td>(-0.00)</td>
<td>(-0.09)</td>
</tr>
</tbody>
</table>

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
### Wage Convergence over Time by Skill Group

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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<tbody>
<tr>
<td></td>
<td>No,'40-'80</td>
<td>Yes,'40-'80</td>
<td>No,'80-'10</td>
<td>Yes,'80-'10</td>
</tr>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Log hourly wage, 1940</td>
<td>-0.0123***</td>
<td>-0.0141***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000862)</td>
<td>(0.00117)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log hourly wage, 1980</td>
<td>-0.0169***</td>
<td>-0.00791***</td>
<td>0.000609</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00174)</td>
<td>(0.00212)</td>
<td>(0.000212)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No,'40-'80</td>
<td>Yes,'40-'80</td>
<td>No,'80-'10</td>
<td>Yes,'80-'10</td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log hourly wage, 1940</td>
<td>-0.0143***</td>
<td>-0.0205***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000866)</td>
<td>(0.00106)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log hourly wage, 1980</td>
<td>-0.0200***</td>
<td>-0.00791***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00163)</td>
<td>(0.00203)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| N             | 132          | 131          | 247          | 246          |
FACT 2

\[
\ln \left( \frac{\hat{w}^H_{jt}}{\hat{w}^L_{jt}} \right) = \alpha_t + \sum_{t=1940}^{2010} \beta_t \ln \left( \frac{H_{jt}}{L_{jt}} \right) 1(\text{time} = t) + f_{\text{MSA}} + f_{\text{year}} + \epsilon_{jt}
\]
CONVERGENCE FOR LOW HOUSING ELASTICITY CITIES

MAIN INGREDIENTS
Worker of type $k \in \{H, L\}$ that lives in $i$ decides which location $j$ to pick and solve the following problem:

$$V_k(j, \zeta_i') = \max_{j'} \left[ \frac{V_{ikj'}}{m_k(j,j')} + \beta E \left( \frac{V(j', \zeta_{i''})}{m_k(j,j')} \right) \right]$$

where $m(j, j')$ are the migration costs assumed to be separable such that

$$m_k(s, j) = m_{k1}(s) \cdot m_{k2}(j)$$

$$V_k(j, \zeta_i') = \frac{1}{m_{k1}(j)} \max_{j'} \left[ \frac{V_{ikj'}}{m_{k2}(j')} \right]$$
**WORKERS UTILITY MAXIMIZATION**

Indirect utility function for agent $i$ of type $k$ that lives in city $j$ at time $t$:

$$V_{ikjt} = \max_{T_{jt}, N_{jt}} [\theta \log(T_{kjt}) + (1 - \theta)(\nu \log(N_{kjt}) + (1 - \nu)\log(O_{kjt} - \bar{O}_{kjt}) + A_{jt} + \gamma^{p}(H_{jt} + L_{jt}) + \zeta_{ijt}]$$

s.t. $T_{jt} + N_{jt}P_{jt} + O_{jt}R_{jt} = W_{kjt}$

Assumption: $\zeta_{ij}$ follows a Gumbell distribution (Mc Fadden [1973]) $\implies$

$$H_{jt} = \frac{\exp(\delta_{Hjt} / m_{H2}(j))}{\sum_{s} \exp(\delta_{Hst} / m_{L2}(s))}$$

$$L_{jt} = \frac{\exp(\delta_{Ljt} / m_{L2}(j))}{\sum_{s} \exp(\delta_{Lst} / m_{L2}(s))}$$

where

$$\delta_{kjt} = \left[ \theta \log(W_{kjt} - R_{jt}\bar{H}) + (1 - \theta)(1 - \nu)\log((1 - \theta)(1 - \nu)\frac{W_{kjt}}{R_{jt}} + \bar{O}) + (1 - \theta)\nu \log((1 - \theta)\nu \frac{W_{kjt} - R_{jt}\bar{O}}{P_{Njt}}) + A_{jt} + \gamma^{p}\log(H_{jt} + L_{jt}) \right]$$
**Change in Variable for $Y^T$**

$$Y_j^{T\rho} = \left( H_j^{\gamma_H-\rho-1}(L_{Nj} + L_{Tj})^{-\gamma_H} W_{Lj} L_j^{T\rho} + W_{Hj} L_j^{\gamma_H} (L_{Nj} + L_j^T)^{-\gamma_H} W_{Lj} L_j^{T\rho-1} \right) \left( H_j + L_j \right)^{\gamma_H - \gamma_L} \frac{W_{Hj} (L_{Nj} + L_j^T)^{\rho-1+\gamma_H-\gamma_L} + W_{Lj} H_j^{\rho-1+\gamma_H-\gamma_L}}{W_{Hj} L_j^{T\rho}}$$
Housing $HD$ (following Ganong and Shoag (2015)):

$$HD_{jt} = R_{jt}^{l\mu}$$
where $x_j$ relates to MSA characteristics such as population
## Estimation Results with Housing

<table>
<thead>
<tr>
<th></th>
<th>Supply</th>
<th>Demand</th>
<th>Housing</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.820***</td>
<td>$\beta^w$</td>
<td>4.4***</td>
</tr>
<tr>
<td>$\gamma_H$</td>
<td>0.285***</td>
<td>$\beta^r$</td>
<td>-0.6***</td>
</tr>
<tr>
<td>$\gamma_L$</td>
<td>0.004</td>
<td>$\beta^A$</td>
<td>5.9***</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.447***</td>
<td>$\beta^{HL}$</td>
<td>-4.1***</td>
</tr>
<tr>
<td>$\gamma_P$</td>
<td>0.312***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Get residuals $\Delta w_{Hjt, TFP}, \Delta w_{Ljt, TFP}$ of the equation:

$$
\Delta w_{Hjt, res} = \Delta w_{Hjt} - \Delta \hat{w}_{Hjt} - \left[ (1 - \hat{\rho}) \Delta \ln \hat{Y}_{Tjt} + (\hat{\rho} - 1) \Delta \ln H_{jt} + \hat{\gamma}_H \Delta \ln \left( \frac{H_{jt}}{L_{jt}} \right) + \hat{\gamma} \Delta \ln (H_{jt} + L_{jt}) + \hat{\lambda}^H \Delta S_{Hj, t-10} \right]
$$

$$
\Delta w_{Ljt, res} = \Delta w_{Ljt} - \Delta \hat{w}_{Ljt} - \left[ (1 - \hat{\rho}) \Delta \ln \hat{Y}_{Tjt} + (\hat{\rho} - 1) \Delta \ln L_{jt} + \hat{\gamma}_L \Delta \ln \left( \frac{H_{jt}}{L_{jt}} \right) + \hat{\gamma} \Delta \ln (H_{jt} + L_{jt}) + \hat{\lambda}^L \Delta S_{Lj, t-10} \right]
$$

$$
\Delta w_{Ljt, res} = \Delta w_{Ljt} - \left( \hat{\alpha} \Delta \ln Y_{Njt} + \hat{\lambda}^L \Delta S_{Lj, t-10} \right)
$$
Model Estimation: Location Decision

- Estimate average utility $v_j^H$ and $v_j^L$ with log-likelihood estimation (BLP [2002]);
- Generate moment conditions:

\[ \Delta \alpha_{jt}^k = \Delta \delta_{jt}^k - \beta^{kw} \Delta w_{jt}^k - \beta^{ks} \Delta p_{jt}^s - \beta^{kA} \Delta A_{jt} - \gamma_p \Delta (H_{jt} + L_{jt}), \quad \forall k \in \{H, L\} \]

- Identification:

\[ E[\Delta \alpha_{jt}^k \Delta Z_{jt-10}^k] = 0, \quad \forall k \in \{L, H\} \]
Model Estimation: GMM

Moment Conditions

\[\Delta \xi_{jt}^H = \Delta w_{jt}^H - ((1 - \rho)\Delta \ln Y_{jt}^g + (\rho - 1)\Delta \ln H_{jt} + \gamma_H \Delta \ln \left(\frac{H_{jt}}{L_{jt}}\right) + \gamma \Delta \ln (H_{jt} + L_{jt}) - \beta_{HH}^{H} \Delta SB_{jt-10}^H - \beta_{HL}^{H} \Delta SB_{jt-10}^L)\]

\[\Delta \xi_{jt}^L = \Delta w_{jt}^H - ((1 - \rho)\Delta \ln Y_{jt}^g + (\rho - 1)\Delta \ln L_{jt}^g + \gamma_L \Delta \ln \left(\frac{H_{jt}}{L_{jt}}\right) + \gamma \Delta \ln (H_{jt} + L_{jt}) - \beta_{LH}^{L} \Delta SB_{jt-10}^H - \beta_{LL}^{L} \Delta SB_{jt-10}^L)\]

\[\Delta \xi_{jt}^S = \Delta w_{jt}^L - \alpha \Delta \ln Y_{jt}^s - \beta_{LS}^{L} \Delta SB_{jt-10}^L\]

- Identification:

\[E[\Delta \xi_{jt}^k \Delta Z_{jt-10}^k] = 0 \quad \forall \ k \in \{L^g, L^s, H\}\]
\[ \Delta \hat{\zeta}_{kjt} = constant + \beta \hat{\zeta}_{kjt} + \epsilon_{jt}, \quad \forall k \in H, L \]

**1940-1980** State level

**1980-2010** City Level
## Structural Residual Convergence

<table>
<thead>
<tr>
<th>$\hat{\beta}^{1940-1980}$</th>
<th>(-0.014****)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No SBTC</td>
<td>-0.0126***</td>
<td>-0.0033***</td>
<td>-0.0136***</td>
</tr>
<tr>
<td>No Spillover</td>
<td>-0.0145***</td>
<td>-0.0012***</td>
<td>-0.0165***</td>
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## Decomposing the Wage Convergence

<table>
<thead>
<tr>
<th>$\hat{\beta}$ convergence (not population weighted)</th>
<th>$\geq$ Coll. Degree</th>
<th>$&lt;$ Coll. Degree</th>
</tr>
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<tbody>
<tr>
<td><strong>Data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wage Convergence rate: $\hat{\beta}_{1980-2010}$</td>
<td>-0.00243</td>
<td>-0.0189***</td>
</tr>
<tr>
<td>Wage Convergence rate: $\hat{\beta}_{1940-1980}$</td>
<td>-0.0196***</td>
<td>-0.0142***</td>
</tr>
<tr>
<td><strong>Model 1980-2010</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Model</td>
<td>0.00123</td>
<td>-0.01548***</td>
</tr>
<tr>
<td>No SBTC</td>
<td>-0.0112***</td>
<td>-0.0128***</td>
</tr>
<tr>
<td>No Spillover</td>
<td>-0.0192***</td>
<td>-0.01695***</td>
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</table>
Reduced Form Conditional Convergence on the Shock

\[ \Delta^{1980-2010} w_{jt} = \beta^o + \beta w_{jt} + \alpha^Z \Delta Z_{jt}^{RSH} \]
### Table: Convergence Rates and SBTC

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>Log hourly wages 1980</td>
<td>-0.0000389</td>
<td>-0.00657*</td>
<td>-0.00802*</td>
<td>-0.00912*</td>
<td>-0.0105*</td>
</tr>
<tr>
<td></td>
<td>(-0.02)</td>
<td>(-2.59)</td>
<td>(-2.16)</td>
<td>(-2.13)</td>
<td>(-2.30)</td>
</tr>
<tr>
<td>\textit{RSH_H} 1980</td>
<td>0.0160*</td>
<td>0.0188</td>
<td>0.0182</td>
<td>0.0201</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.40)</td>
<td>(1.62)</td>
<td>(1.39)</td>
<td>(1.47)</td>
<td></td>
</tr>
<tr>
<td>\textit{RSH_L} 1980</td>
<td>0.0406***</td>
<td>0.0220</td>
<td>0.0258</td>
<td>0.0233</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.44)</td>
<td>(1.12)</td>
<td>(1.22)</td>
<td>(1.07)</td>
<td></td>
</tr>
<tr>
<td>\textit{RSH_H} 1970</td>
<td>0.0183*</td>
<td>0.0184*</td>
<td>0.0200*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.41)</td>
<td>(2.25)</td>
<td>(2.37)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{RSH_L} 1970</td>
<td>0.0342*</td>
<td>0.0411*</td>
<td>0.0464*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.00)</td>
<td>(2.13)</td>
<td>(2.22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{RSH_H} 1950</td>
<td></td>
<td></td>
<td></td>
<td>-0.00162</td>
<td>-0.00258</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>(-0.51)</td>
<td>(-0.78)</td>
</tr>
<tr>
<td>\textit{RSH_L} 1950</td>
<td>-0.000279</td>
<td>0.00213</td>
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<tr>
<td></td>
<td>(-0.03)</td>
<td>(0.23)</td>
<td></td>
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</tbody>
</table>

\textit{t} statistics in parentheses

* \( p < 0.05 \), ** \( p < 0.01 \), *** \( p < 0.001 \)
RIGHT TO WORK LAWS BY STATE

Number of States that Passed the 'Right to Work Laws'

Year Range

'40−'50 '51−'60 '61−'70 '71−'80 '81−'90 '91−'00 '01−'10 '11−'15

Adjusted
### Table: Convergence Rates by College Degree and IT

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Log hourly wages 1980</td>
<td>-0.0000389</td>
<td>0.00593**</td>
<td>-0.0126***</td>
</tr>
<tr>
<td></td>
<td>(-0.02)</td>
<td>(2.95)</td>
<td>(-10.58)</td>
</tr>
<tr>
<td>IT</td>
<td>0.00656***</td>
<td>0.00538***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(13.49)</td>
<td>(16.54)</td>
<td></td>
</tr>
<tr>
<td>col_degree</td>
<td></td>
<td></td>
<td>0.0106***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(19.85)</td>
</tr>
</tbody>
</table>

- *t* statistics in parentheses
- *p* < 0.05, **p* < 0.01, ***p* < 0.001
## First-Stage Instrumental Regression

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$\Delta \hat{Z}^H_{j, t-10}$</td>
<td>3.046***</td>
<td>3.643***</td>
<td>2.852***</td>
<td>4.418***</td>
<td>3.062***</td>
<td>3.043***</td>
</tr>
<tr>
<td></td>
<td>(0.620)</td>
<td>(1.024)</td>
<td>(0.632)</td>
<td>(1.118)</td>
<td>(0.719)</td>
<td>(0.737)</td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \hat{Z}^L_{j, t-10}$</td>
<td>1.021***</td>
<td>0.891**</td>
<td>0.850***</td>
<td>2.483***</td>
<td>2.535***</td>
<td>2.511***</td>
</tr>
<tr>
<td></td>
<td>(0.341)</td>
<td>(0.344)</td>
<td>(0.285)</td>
<td>(0.531)</td>
<td>(0.527)</td>
<td>(0.591)</td>
</tr>
<tr>
<td>N</td>
<td>144</td>
<td>119</td>
<td>270</td>
<td>249</td>
<td>283</td>
<td>283</td>
</tr>
</tbody>
</table>
MODEL VS DATA: WAGE CONVERGENCE $\beta$
MODEL VS DATA WAGE CONVERGENCE $\beta_H$ AND $\beta_L$

$\beta_H.pdf$ $\beta_H.png$ $\beta_H.jpg$ $\beta_H.mps$ $\beta_H.jpeg$ $\beta_H.jbig2$ $\beta_H.jb2$ $\beta_H.PDF$ $\beta_H.PNG$ $\beta_H.JPG$
\[
\ln \left( \frac{\hat{H}_{jt}}{\hat{L}_{jt}} \right) = \alpha_t + \sum_{t=1940}^{2010} \beta_t \ln \left( \frac{H_{jt}}{L_{jt}} \right) 1 \left( \text{time} = t \right) + f_{\text{MSA}} + f_{\text{year}} + \epsilon_{jt}
\]
This figure reports the standardized coefficient $\beta$ of the regression

$$\text{Migration Premium}_{t,i} = \alpha + \beta \ln(\text{wage})_{t,i} + \epsilon$$

run for each MSA.
### First Stage Regression SBTC

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<td></td>
</tr>
<tr>
<td>$\Delta \hat{Z}_{L,j, \ t - 10}$</td>
<td>1.021***</td>
<td>0.891**</td>
<td>0.850***</td>
<td>2.483***</td>
<td>2.535***</td>
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<td></td>
<td>(0.341)</td>
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This figure reports the standardized coefficient $\beta$ of the regression

$$\text{Migration Premium}_{t,i} = \alpha + \beta \ln(\text{wage})_{t,i} + \epsilon$$

run for each MSA.
Model vs Data: Migration Rates

High Skilled

Low Skilled
CROSS-COUNTRY CONVERGENCE AND THE DECLINE

CONCLUSIONS

Start at 1970, Datasource = Penn World Table, Number of Country = 156
MODEL: SORTING IMPLICATIONS

\[ \Delta H_{jt} = \alpha + \sum_{t=1941}^{1970} \delta^H_t \ln W_{Hjt} \]
Mechanism with 2 Cities

Main Idea

Detroit

San Francisco
MECHANISM WITH 2 CITIES

**Main Idea**

**Detroit**

**San Francisco**
MECHANISM WITH 2 CITIES

**Main Idea**

**Detroit**

**San Francisco**
Worker of type \( k \in \{ H, L \} \) that lives in \( j \) decides which location \( j' \) to pick and solve the following problem:

\[
V_k(j, \zeta^t_i) = \max_{j'} \left[ \frac{V_{ikj'}}{m_k(j,j')} + \beta E \left( \frac{V(j', \zeta''_i)}{m_k(j',j'')} \right) \right]
\]

Indirect utility function for agent \( i \) of type \( k \) that lives in city \( j \) at time \( t \):

\[
V_{ikj't} = \max_{T_{kj't}, O_{kj't}} \left[ \theta \log(T_{kj't}) + (1 - \theta) \log(O_{kj't} - \bar{O}_{kj't}) + A_{j't} + \gamma^p (H_{j't} / L_{j't}) + \zeta_{ij't} \right]
\]

s.t. \( T_{kj't} + N_{kj't} P_{Nj't} = W_{kj't} \)
WORKERS UTILITY MAXIMIZATION

Assumption: $m_k(j, j')$ are separable such that

$$m_k(j, j') = m_{k1}(j) \ast m_{k2}(j')$$

Assumption: $\zeta_{ij}$ follows a Type-I Extreme Value distribution (McFadden [1973])

$$H_{jt} = \frac{\exp(\delta_{Hjt})}{\sum_s \exp(\delta_{Hst})}$$

$$L_{jt} = \frac{\exp(\delta_{Ljt})}{\sum_s \exp(\delta_{Lst})}$$

where

$$\delta_{kjt} = \theta \log (W_{kjt} - R_{jt} \bar{O}) + (1 - \theta) \left[ \log \left( (1 - \theta) \frac{W_{kjt}}{R_{jt}} + \bar{O} \right) + A_{kjt} + \gamma_p \log \left( \frac{H_{jt}}{L_{jt}} \right) \right]$$

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Tradable $T$ sector:

$$T_{jt} = \left( \sum_{d} \mu_{d} Y_{djt}^{\alpha} \right)^{1/\alpha}$$
Y_{djt} = \left[ \eta_{Ldjt} L_{djt}^\rho + \eta_{Hdjt} H_{djt}^\rho \right]^{\frac{1}{\rho}}, \quad \forall j = \{1, \ldots, N\}

- Productivity Process:

\[ \eta_{Hdjt} = \left( \frac{H_{jt}}{L_{jt}} \right)^{\gamma^H} \left( L_{jt} + H_{jt} \right)^{\phi^H} S_{Ht}^{\lambda^H} \exp(\xi_{Hdjt}) \]  \hspace{1cm} (1)

\[ \eta_{Ldjt} = \left( \frac{H_{jt}}{L_{jt}} \right)^{\gamma^L} \left( L_{jt} + H_{jt} \right)^{\phi^L} S_{Lt}^{\lambda^L} \exp(\xi_{Ldjt}) \]  \hspace{1cm} (2)

\[ \xi_{kdjt} = \xi_{kdjt-1} \left( \int_s \omega(j, s) \xi_{kdst-1} \right)^{1-\gamma^2} \]

convergence force
Model: Wage Equations

Wages for $H$ and $L$ are given by:

$$W_{Hjt} = p_{djt} \eta_{Hdj} \left[ \eta_{Ldj} L_{djt}^\rho + \eta_{Hdj} H_{djt}^\rho \right]^{\frac{1}{\rho} - 1} H_{djt}^{\rho - 1}$$  \hspace{1cm} (3)

$$W_{Ljt} = p_{djt} \eta_{Ldj} \left[ \eta_{Ldj} L_{djt}^\rho + \eta_{Hdj} H_{djt}^\rho \right]^{\frac{1}{\rho} - 1} L_{djt}^{\rho - 1}$$  \hspace{1cm} (4)
Housing Sector

- Housing $HD$ (following Ganong and Shoag (2015)):

$$HD_{jt} = R^{l\mu}_{jt}$$
**Equilibrium Definition**

**Definition** The equilibrium consists of a set of allocations \( \{\{L_{djt}, H_{djt}\}^D_{d=1}\}^J_{j=1} \) and a set of prices \( \{\{P_{djt}\}^D_{d=1}, R_{jt}\}^J_{j=1} \), wages \( \{W_{Hjt}, W_{Ljt}\}^J_{j=1} \), such that given \( \{\{\xi_{Ldj0}, \xi_{Hdj0}\}^D_{d=1}\}^J_{j=1} \), a set of parameters normalizing \( P_{jt} = P_t = 1 \) and \( \sum_j (L_{jt} + H_{jt}) = 1 \) in each time period \( t \):

1. Given a set of migration costs and idiosyncratic preferences, workers choose location and consumption to maximize utility;
2. Firms maximize profits;
3. Labor markets clear;
4. The non-tradable intermediates markets clear in every city, \( \forall j \in J \) and \( \forall d \in D \);
5. Final good market \( T \) clears;
6. Housing market clears.
DATA AND ESTIMATION STRATEGY

  ▶ Wages, Education, City, Rents, Population;

▶ Estimation method: GMM

▶ Parameters:
  1. parameters of labor demand $p^d = \{\rho, \gamma^H, \gamma^L, \phi^H, \phi^L, \lambda^H, \lambda^L\}$;
  2. parameters of labor supply $p^s = \{\theta, \gamma^p\}$;
  3. productivity shocks $\xi_{kjt}, \forall k$;
  4. amenities $A_{kjt}, \forall k$;

▶ Moment Construction:
  1. Exploit geographic variation in $S_{kt}, \Delta S_{kjt}, \forall k$ using ”routinization” index as in Autor and Dorn [2013]
  2. Wages Changes Residual: $\Delta \xi_{kdjt} = \Delta w_{kdjt} - \Delta w_{kdjt}^{model}, \forall k$;
  3. Utility Changes Residuals: $\Delta A_{kjt} = \Delta \delta_{kjt} - \Delta \delta_{kjt}^{model}, \forall k$;
Measure $\Delta S_{kjt}$: Local Effect of Technology (Autor and Dorn [2013]) based on Routinization task intensity $RTI$ of the occupations $\omega$:

$$
\Delta S_{kjt-10} = \sum_{\omega=1}^{\Omega} \left( \frac{k_{\omega jt}}{k_{jt}} - \frac{k_{\omega,j,t-10}}{k_{j,t-10}} \right) 1(RTI_{\omega} > RTI_{P66}) \quad \forall k \in \{H, L\}
$$

Instruments:

1. “Bartik-like” (Autor and Dorn [2013])

$$
\Delta \tilde{S}_{kj,t-10} = \sum_d (k_{d,-j,t} - k_{d,-j,t-10}) (R_{d,j,t-10}) \quad \forall k \in \{H, L\}
$$

Intuition: national component interacted with local component of routinization at industry level $R_{d,j,t-10}$

2. Housing regulations and land availability: (Saiz [2010])

- land use regulation index: $reg_{jt}$
- land unavailability index: $uvan_{jt}$

Define the set of instruments $Z$:

$$
\Delta Z_{jt} = \begin{bmatrix}
\Delta \tilde{S}_{Lj,t-10} & \Delta \tilde{S}_{Lj,t-10}reg_{jt} & \Delta \tilde{S}_{Lj,t-10}unav_{jt} \\
\Delta \tilde{S}_{Hj,t-10} & \Delta \tilde{S}_{Hj,t-10}reg_{jt} & \Delta \tilde{S}_{Lj,t-10}unav_{jt}
\end{bmatrix}
$$