

Unbalanced Growth Across Sectors and Space

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- How has such a distribution changed over time?

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- How is economic activity by broad sector distributed across space?
- How has such a distribution changed over time?
- How do different kinds of places (cities, small towns, rural areas) contribute to aggregate economic growth?
- How have such contributions changed over time?
- What is the geospatial distribution of human capital?
- How does this drive the geospatial distribution of aggregate output across sectors?
- How has the changing geospatial distribution of human capital contributed to unbalanced structural change across sectors and space?

- A series of different growth decompositions exploring together ...
 - i. How the composition of sectoral income has changed both across places and over time;
 - ii. How the composition of human capital has changed over time;
 - iii. How both the place-based composition of sectoral income and human capital impact aggregate income growth.

- Rural regions benefited from first structural transition from ag. to manu. b/c ag. wages rose quickly leading to rural tech. adoption from diffusion (Eckert and Peters 2022).

National Income Across Sectors

Growth Accounting by Sector

National income is the sum of sectoral income:

$$Y_t = \sum_{i \in \mathcal{I}} Y_{it} \quad (1)$$

Let $\sigma_{it}^Y = Y_{it}/Y_t$ be the share of income in period t from sector i . Gross income growth is

$$g_t^Y = \sum_{i \in \mathcal{I}} g_{it}^Y \sigma_{i,t-1}^Y \quad (2)$$

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⇒ Provides a simple means to decompose which sector growth is coming from and how ... new growth? high starting share? both?

Growth Accounting by Sector

Let $i \in \mathcal{I} := \{A, G, HS, LS\}$ (i.e., agriculture, goods, high-skill services, and low-skill services a la Fang and Herrendorf (2021)). Industries by Sector Fraction of growth attributable to sector i is $\sigma_{it}^Y = (g_{it}^Y \sigma_{i,t-1}^Y) / g_t^Y$.

Table 1: Aggregate Growth Decomposition by Sector, 2003-2023

Sector	g_i^Y	$\sigma_{i,2003}^Y$	$g_i^Y \sigma_{i,2003}^Y$	$\sigma_{i,2023}^Y$	$g_i^Y - 1$	Avg. Annual
Ag	1.887	0.013	0.024	0.010	0.887	0.031
Goods	1.843	0.240	0.442	0.191	0.843	0.030
LS	2.266	0.320	0.725	0.313	1.266	0.040
HS	2.636	0.428	1.128	0.486	1.636	0.047
Total			2.318		1.318	0.037

National Income Across Space

Growth Accounting Across Space (Aggregate)

National income is the sum of spatial income:

$$Y_t = \sum_{j \in \mathcal{J}} Y_{jt} \quad (3)$$

Let $\sigma_{jt}^Y = Y_{jt}/Y_t$ be the share of income in period t from place j . Gross income growth is

$$g_t^Y = \sum_{j \in \mathcal{J}} g_{jt}^Y \sigma_{j,t-1}^Y \quad (4)$$

Growth Accounting Across Space (Per Capita)

Let $\sigma_{jt}^N = N_{jt}/N_t$ be the share of population in period t from place j . National income per capita is the sum of weighted spatial income per capita:

$$y_t = \sum_{j \in \mathcal{J}} y_{jt} \sigma_{jt}^N \quad (5)$$

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Per capita growth must account for unbalanced population changes across space:

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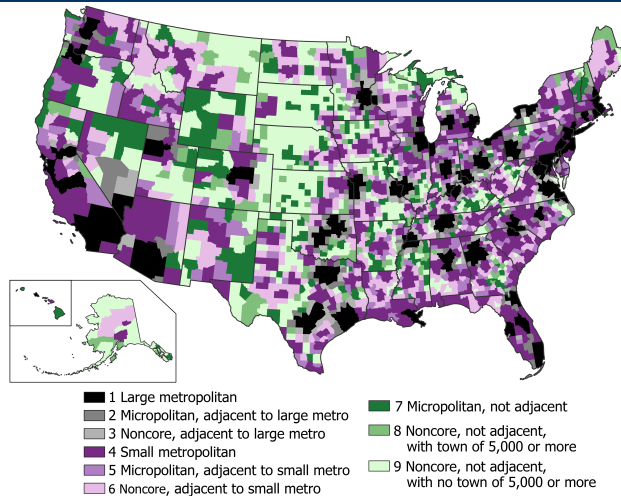
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⇒ Places with relatively fast growing N_t (i.e., $g_{jt}^{\sigma^N} = \sigma_{jt}^N / \sigma_{j,t-1}^N > 1$) will contribute more to per capita growth, all else equal.

2024 Urban Influence Codes

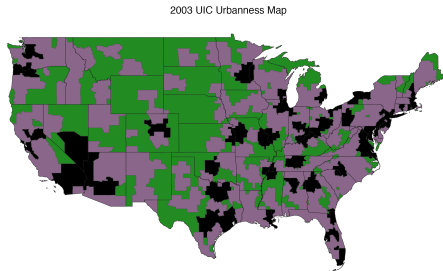


Note: Urban Influence Codes are also available for the county-equivalents of U.S. territories not shown in the map: American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands. Metropolitan and micropolitan statistical areas are based on the U.S. Office of Management and Budget's 2023 delineations of core based statistical areas. Counties are classified as 'adjacent' to a metro area if they are physically adjacent and at least 2 percent of their workforce commutes to the central counties of the physically adjacent metro area. Source: USDA, Economic Research Service using data from the Office of Management and Budget and U.S. Department of Commerce, Bureau of the Census.

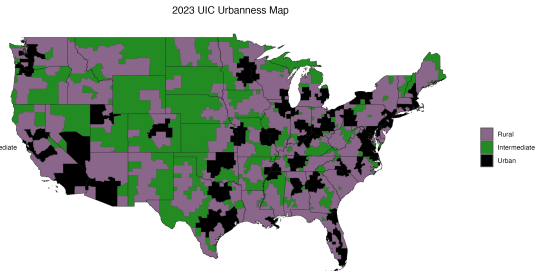
Urban Influence Codes (UIC's) ... What Are They?

- 2 kinds of metropolitan areas (> 1 million, $UIC = 1$; < 1 million $UIC = 4$);
- Micropolitan counties are divided into three categories based on their adjacency to metro areas of different sizes (adjacency $\Rightarrow > 2\%$ of workforce commutes to physically adjacent metro) ... ($UIC \in \{2, 5, 7\}$);
- Noncore counties have $< 50,000$ people and are $UIC \in \{3, 6, 8, 9\}$ classified by adjacency (or lack thereof).

Three Types of American Places



(a) 2003



(b) 2023

Figure 1: Define places as $j \in \mathcal{J} := \{U, I, R\}$ (i.e., urban is UIC 1-3, intermediate is UIC 4-6, rural is UIC 7-9).

Table 2: Aggregate Growth Decomposition by Place, 2003-2023

Place	g_j^Y	$\sigma_{j,2003}^Y$	$g_j^Y \sigma_{j,2003}^Y$	$\sigma_{j,2023}^Y$	$g_j^Y - 1$	Avg. Annual
U	2.467	0.674	1.662	0.717	1.467	0.044
I	2.035	0.293	0.596	0.257	1.035	0.034
R	1.785	0.034	0.060	0.026	0.785	0.028
Total			2.318		1.318	0.037

Table 3: Per Capita Growth Decomposition by Place, 2003-2023

Place	g_j^y	$g_j^{\sigma^N}$	$\sigma_{j,2003}^Y$	$g_j^y g_j^{\sigma^N} \sigma_{j,2003}^Y$	$\sigma_{j,2023}^Y$	$g_j^y - 1$	Avg. Annual
U	1.999	1.068	0.674	1.439	0.717	0.999	0.034
I	1.881	0.936	0.293	0.515	0.257	0.881	0.031
R	2.058	0.751	0.034	0.052	0.026	1.058	0.035
Total				2.006		1.006	0.031

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⇒ Rural catch up offset by relative population decline.

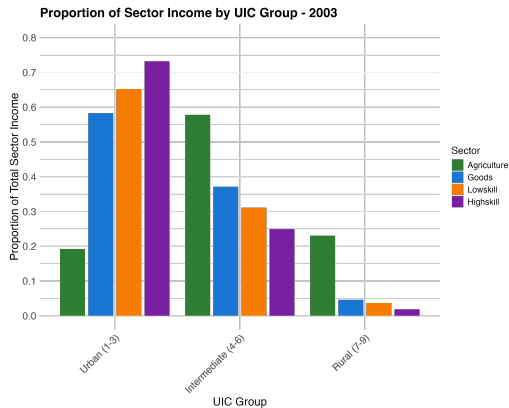
⇒ Urban share of agg. GDP ↑ *because* of relative urban population increases.

Sectors Across Space

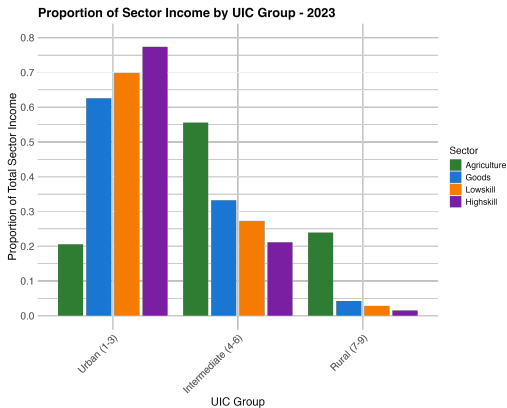
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 - ⇒ While GDP and GDP per capita is growing in all places, are sectors growing at different rates in different places?
 - ⇒ How do differential rates of sectoral growth contribute to urban acceleration relative to other areas?

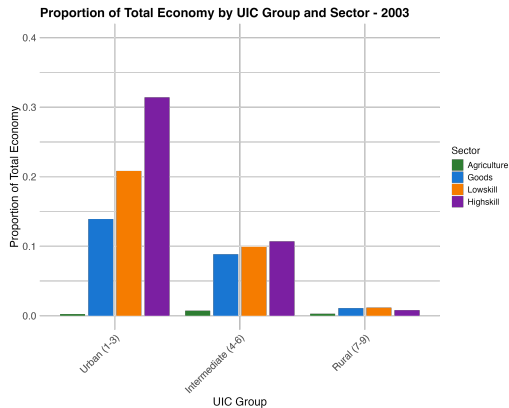


(a) 2003

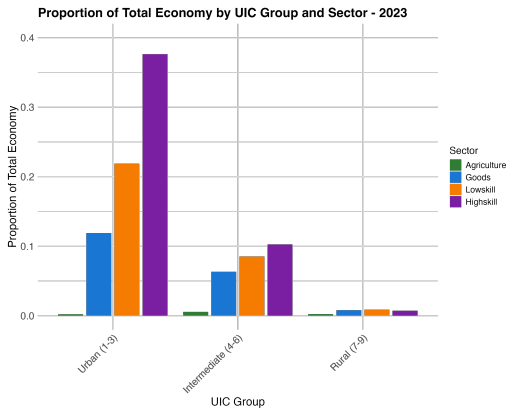


(b) 2023

Figure 2: Fractions of sector i GDP by place. All colors sum to unity.



(a) 2003



(b) 2023

Figure 3: Sector/place fractions of total GDP. All columns sum to unity.

Aggregate:

$$Y_t = \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} Y_{ijt} \quad (7)$$

$$g_t^Y = \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} g_{ijt}^Y \sigma_{ij,t-1}^Y \quad (8)$$

Per capita:

$$y_t = \sum_{j \in \mathcal{J}} \sigma_{jt}^N \sum_{i \in \mathcal{I}} y_{ijt} \quad (9)$$

$$g_t^y = \sum_{j \in \mathcal{J}} g_{jt}^{\sigma^N} \sum_{i \in \mathcal{I}} g_{ijt}^y \sigma_{ij,t-1}^Y \quad (10)$$

Table 4: Aggregate Growth Decomposition by Sector/Place, 2003-2023

Sector	$(g_{ij}^Y)(\sigma_{ij,2003}^Y)$			Totals
	U	I	R	
Ag	$(2.014)(0.002)=0.005$	$(1.816)(0.007)=0.013$	$(1.960)(0.003)=0.006$	0.024
Goods	$(1.960)(0.141)=0.277$	$(1.679)(0.088)=0.147$	$(1.648)(0.011)=0.018$	0.442
LS	$(2.396)(0.212)=0.507$	$(2.048)(0.097)=0.198$	$(1.707)(0.012)=0.020$	0.725
HS	$(2.743)(0.318)=0.874$	$(2.347)(0.101)=0.238$	$(2.025)(0.008)=0.016$	1.128
Totals	1.662	0.596	0.060	2.318

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- HS just in U contribution to growth $>$ than Ag, G, and LS across all places

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- HS growth fast in all regions
- HS just in U contribution to growth $>$ than Ag, G, and LS across all places
- Goods and LS are bigger contributors to R growth despite fast HS growth because they have starting shares of R output

Table 5: Shares of Within Region Growth

	U	I	R
Ag	0.003	0.022	0.094
Goods	0.167	0.247	0.302
LS	0.305	0.332	0.333
HS	0.526	0.399	0.270

Table 5: Shares of Within Region Growth

	U	I	R
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LS	0.305	0.332	0.333
HS	0.526	0.399	0.270

- Svcs. drive $> 50\%$ of growth within all regions.
- Goods a bigger driver of growth in I and R than U

Table 6: Shares of Within Sector Growth

	U	I	R
Ag	0.205	0.557	0.238
Goods	0.626	0.333	0.041
LS	0.700	0.273	0.028
HS	0.775	0.211	0.014

Table 6: Shares of Within Sector Growth

	U	I	R
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Goods	0.626	0.333	0.041
LS	0.700	0.273	0.028
HS	0.775	0.211	0.014

- Svcs. growth driven by *U*.
- Goods growth driven by *U* and *I*.

Table 7: Per Capita Growth Decomposition by Sector/Place, 2003-2023

Sector	$(g_{ij}^y)(\sigma_{ij,2003}^Y)$			Totals ^b
	U	I	R	
Ag	(1.632)(0.002)=0.004	(1.678)(0.007)=0.012	(2.260)(0.003)=0.007	0.021
Goods	(1.588)(0.141)=0.224	(1.551)(0.088)=0.136	(1.900)(0.011)=0.021	0.382
LS	(1.941)(0.212)=0.411	(1.893)(0.097)=0.183	(1.969)(0.012)=0.023	0.627
HS	(2.223)(0.318)=0.708	(2.169)(0.101)=0.220	(2.334)(0.008)=0.019	0.976
$g_j^{\sigma^N}$	1.068	0.936	0.751	
Totals ^a	1.439	0.515	0.052	2.006

$$^a g_j^{\sigma^N} \sum_i g_{ij}^y \sigma_{ij,2003}^Y, \forall j; \quad ^b \sum_j g_j^{\sigma^N} g_{ij}^y \sigma_{ij,2003}^Y, \forall i$$

Human Capital Across Space

Adult Population by Education/Human Capital Levels

How has variation in the adult population by educational attainment contributed to population growth both nationally and in different kinds of places?

Let $\mathcal{K}$ be the set of human capital types. National population is the sum of spatial population across human capital types:

$$N_t = \sum_{j \in \mathcal{J}} \sum_{k \in \mathcal{K}} N_{jkt} \quad (11)$$

Decomposing pop. growth in spatial human capital:

$$g_t^N = \sum_{j \in \mathcal{J}} \sum_{k \in \mathcal{K}} g_{jkt}^N \sigma_{jk,t-1}^N \quad (12)$$

Table 8: Population Growth Decomposition by Human Capital/Place, 2000-2023

Education	$(g_{jk}^N)(\sigma_{jk,2000}^N)$			Totals
	U	I	R	
Less than HS	$(0.775)(0.106)=0.082$	$(0.617)(0.076)=0.047$	$(0.467)(0.014)=0.006$	0.136
HS or Equiv.	$(1.252)(0.146)=0.182$	$(1.090)(0.120)=0.131$	$(0.915)(0.021)=0.019$	0.332
Some Coll.	$(1.340)(0.153)=0.204$	$(1.281)(0.105)=0.134$	$(1.099)(0.016)=0.018$	0.357
Bach or >	$(1.924)(0.155)=0.298$	$(1.661)(0.079)=0.132$	$(1.312)(0.010)=0.013$	0.443
Totals	0.767	0.444	0.056	1.267

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- Growth in U driven by college grads.
- Growth in I and R driven by HS grads and some college.

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- Population growth overall driven by **U** and Bachelor's Degrees or >.
- Growth in **U** driven by college grads.
- Growth in **I** and **R** driven by HS grads and some college.
- College grads only 23% of the 2023 **R** pop, but they are 38% of pop in **U**.
- 3% of all college grads live in **R**, but 67% live in **U**.

A Simple Production Function

Period t GDP by Sector i and Place j (Linear Production)

$$Y_{ijt} = A_{ijt}N_{jt} \quad \text{with} \quad y_{ijt} = A_{ijt} \quad (13)$$

$$(14)$$

Period t GDP by Sector i and Place j (Linear Production)

$$Y_{ijt} = A_{ijt} N_{jt} \quad \text{with} \quad y_{ijt} = A_{ijt} \quad (13)$$

TFP is a function of the place's human capital mix, $\mathbf{e}_{jt}$, and a sector-specific orthogonal component, z_{ijt} :

$$A_{ijt}(\mathbf{e}_{jt}, z_{ijt}) = z_{ijt} \prod_{k \in \mathcal{K}} e_{kjt}^{\gamma_{ikt}}, \quad (14)$$

where $\mathcal{K}$ is the set of different human-capital types (i.e., high school, some college, college, etc.).

Estimating $A_{ijt}(e_{jt}, z_{ijt})$

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- y_{ijt} is per capita income (of residents) by sector $i \in \{A, G, HS, LS\}$ in county j from BEA (2025).
- e_{kjt} is the fraction of the population at education level k for $k \in \{\text{High School, Some Coll., Bach. or } >\}$ (USDA 2025).

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- e_{kjt} is the fraction of the population at education level k for $k \in \{\text{High School, Some Coll., Bach. or } >\}$ (USDA 2025).
- Income data available from 2001-2023, while education data available for 2000 and 2019-23 (avg.).
 - Drop counties that have ≤ 0 income in any sector (8.7% and 15.6% dropped).
- Estimate 2 separate models for $t \in \{2003, 2023\}$, using “closest” education estimates by year.
- Avoids effects of biz cycles and COVID to focus on long-run comparisons.

Separate SUR's by Period, Equations by Sector (Zellner 1962)

Four equations in 2 different SUR's, independently estimated for $t \in \{2003, 2023\}$:

$$\begin{aligned}\ln y_{ijt} &= \beta_{it} + \sum_{k \in \mathcal{K}} \gamma_{ikt} \ln e_{kjt} + \epsilon_{ijt} \\ \ln z_{ijt} &= \beta_{it} + \epsilon_{ijt}, \quad \forall i \in \{A, G, HS, LS\},\end{aligned}\tag{15}$$

with $\mathcal{K} := \{\text{High School, Some Coll., Bach. or } >\}$.

Table 9: 2003 SUR Regression Estimates, $N = 2812$

Sector	β_{it}	High School	Some Coll.	Bach. or >	R^2
Ag	4.584 (0.985)	0.126 (0.198)	1.762 (0.166)	-1.786 (0.110)	0.128
Goods	2.503 (0.630)	1.177 (0.127)	-0.470 (0.106)	1.015 (0.070)	0.070
LS	5.733 (0.306)	0.074 (0.061)	-0.103 (0.052)	0.885 (0.034)	0.300
HS	3.812 (0.571)	0.012 (0.115)	-0.410 (0.096)	1.800 (0.064)	0.337

Table 10: 2023 SUR Regression Estimates, $N = 2605$

Sector	β_{it}	High School	Some Coll.	Bach. or >	R^2
Ag	0.430 (1.569)	0.489 (0.238)	2.643 (0.208)	-1.508 (0.152)	0.181
Goods	4.168 (0.911)	0.622 (0.138)	-0.086 (0.121)	0.791 (0.088)	0.040
LS	8.171 (0.469)	-0.284 (0.071)	-0.148 (0.062)	0.670 (0.045)	0.267
HS	6.675 (0.826)	-0.406 (0.125)	-0.601 (0.109)	1.626 (0.080)	0.375

Productivity Drivers of Growth by Sector and Place

- Take the estimated education coefficients from the micro data models.
- Use them, along with broad, place-specific educational data and income data to compute $\hat{z}_{ijt}$, $\forall j \in \{U, I, R\}$, $\forall t \in \{2003, 2023\}$.
- Decompose growth due to human capital vs. other, place-specific characteristics.

Decomposing Growth in Sector i & Place j Income by Productivities

$$y_{ijt} = z_{ijt}(\epsilon_{ijt})E_{it}(\mathbf{e}_{jt}) \quad (16)$$

$$\Rightarrow g_{ij}^y = g_j^{\sigma^N} g_{ij}^z g_{ij}^E \quad (17)$$

$$\text{with } g_{ij}^z = \exp\{\beta_{i,2023} - \beta_{i,2003} + \epsilon_{ij,2023} - \epsilon_{ij,2003}\} \quad (18)$$

$$\text{and } g_{ij}^E = \prod_{k \in \mathcal{K}} g_{ijk}^e \quad (19)$$

$$\text{where } g_{ijk}^e = \frac{e_{kj,2023}^{\gamma_{ik,2023}}}{e_{kj,2003}^{\gamma_{ik,2003}}} \quad (20)$$

Income Dependence on Place, Sector, and Education

Questions:

- How would per-capita income change if educational talent were distributed equally across places, examining both 2003 and 2023 separately?
- As an extension, what would this do to the place-based sectoral composition and aggregate growth?

Let ϕ_{kt} be the national fraction of N_t with educational attainment k . We want to compute:

$$\tilde{y}_{ijt} = \hat{z}_{ijt} \hat{E}_{it}(\phi_t) \quad (21)$$

$$\tilde{Y}_{ijt} = N_{jt} \tilde{y}_{ijt} \quad (22)$$

Appendix Slides

- **County-Level Income Data:** All County-Level income data was acquired from the CAINC5N public dataset from the BEA. This data included (NA) values, indicating no data available, and (D) values, indicating withheld data as a result of privacy concerns. All non-numeric values were treated as zero when aggregating to avoid incorrect estimations of unavailable data.
- **UIC Codes:** Unlike the current 9-step code, the 2003 codes followed a 12-step coding system. In all plots and analyses, the 12 categories were re-binned into the 9-step system using crosswalks provided by the USDA ERS.

- **Agriculture** — Farm earnings; Forestry, fishing, and related activities.
- **Goods** — Construction; Manufacturing; Mining, quarrying, and oil and gas extraction.
- **Low-skill Services** — Transportation and warehousing; Retail trade; Wholesale trade; Utilities; Accommodation and food services; Administrative and support and waste management and remediation services; Other services (except government and government enterprises).
- **High-skill Services** — Information; Educational services; Real estate and rental and leasing; Health care and social assistance; Arts, entertainment, and recreation; Finance and insurance; Professional, scientific, and technical services; Management of companies and enterprises.

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