Are Big Cities Important for Economic Growth?

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Are big cities important for economic growth? I

- US income per capita increased by about a factor of 6 between 1900 and 2010. Wages increase by 4-8% when city size doubles and patents by 6-20%. How important are these effects for explaining the growth in income?
- Google scholar reports 272,000 articles in response to the keywords "urban agglomeration economies". Have these 272,000 articles explained the entire 6-fold increase in income? How many times?
- Agglomeration effects operate on city productivity, innovation, and human capital. These quantities enter the economy in different ways, not easily summarized by a city size elasticity. How do we think about their importance?

What we do I

- Use four established structural relationships,
  - City size and and output, “static productivity”.
  - City size and and human capital.
  - City size and research output (patents), “research productivity”.
  - Research output and productivity growth.
- Data describing population and patents for 1850-2020, output for 2010.
- Evaluate output in counterfactual US with no city $>$ 1m (also 100k, 50k) and compare to 2010 .

What we do II

Steps: For a counterfactual system of cities,

- Evaluate effect of change in static productivity on aggregate output in 2010.
- Evaluate effect of change in research productivity on research output (patents) by decade for 1900-2010.
- Aggregate decadal changes in patents into changes in national productivity level in 2010.

We rely on three ‘tricks’;

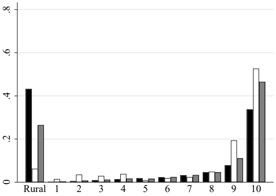
1. particular, simple sets of counterfactual cities.
2. out of equilibrium counterfactuals (as in growth accounting).
3. look at output, not welfare.

Data

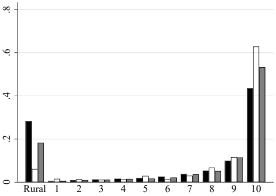
- 275 MSAs plus 'rural'.
- County level population 1850, 1900-2020.
- BEA County level output data 2000-2020 (imputed 1900-2000).
- CUSP patent data, 1850-2014.
- National productivity (TFP) series.

When analyzing output we focus on 2010. When analyzing patents and productivity, we consider 1900-2010 by decade.

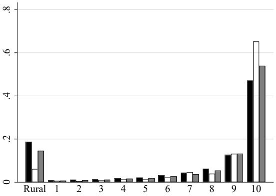
Distribution of population, output and patents by city size



1900



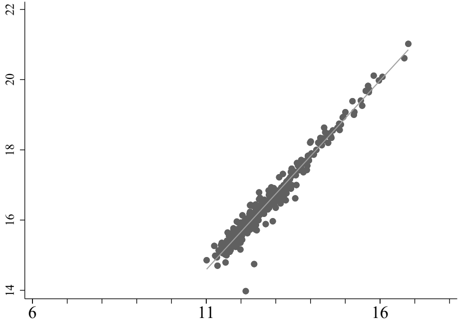
1950



2010

- Black $\sim$ population. Gray $\sim$ output. White $\sim$ patents.
- Output and patents are concentrated in the largest cities. Patenting is more concentrated than output. Output is more concentrated than population. Big cities become more important over time.
- In 2010 52 MSAs $> 1m$; 59% population, 66% output, 78% patents.

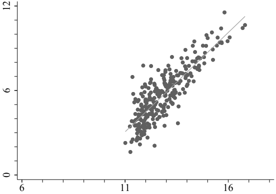
ln(Output) vs. ln(Population)



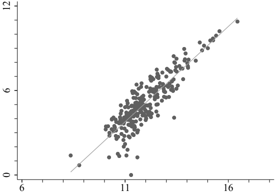
2010; $\beta = 1.08(0.013)$

- BEA output data and census population data.
- People are more productive in big cities (or people in big cities are more productive.)

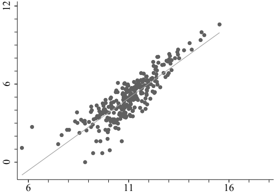
ln(Patents) vs. ln(Population)



2010; $\beta = 1.41(0.053)$



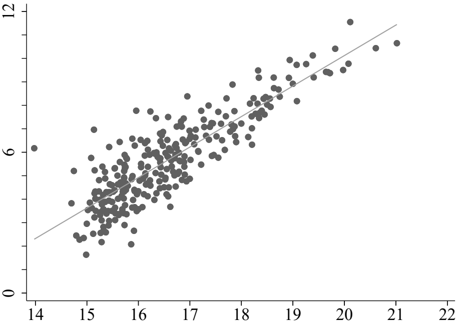
1950; $\beta = 1.3(0.046)$



$\beta = 1.11(0.041)$.

- CUSP patent data, census population.
- The relationship between patents and population is stronger and noisier than between output and population. It becomes weaker as we go back in time.

ln(Patents) vs. ln(Output)



2010; $\beta = 1.29(0.047)$

- CUSP patent data, BEA output data.
- Patents and output are also strongly related, though some cities are quite specialized in output or patents.

Output and static productivity effects I

Notation:

$$
\begin{aligned}
i, t &\sim \text{MSA, decade} \\
Y_{it},\ Y_t &\sim \text{MSA } i\text{, national output in year } t \\
K_{it} &\sim \text{capital} \\
L_{it} &\sim \text{population/Labor} \\
h_{it}^{Y} &\sim \text{human capital per person in output sector} \\
\ell_{it}^{Y} &\sim \text{share of labor used for output} \\
\gamma &\sim \text{capital share of output} = 0.33
\end{aligned}
$$

City level TFP is

$$A_{it} = \widehat{A}_{it}\bar{A}_t\widetilde{A}_{it} = \widehat{A}_{it}\bar{A}_t L_{it}^{\sigma_A}$$

$\bar{A}_t \sim$ Productivity. $\widehat{A}_{it} \sim$ noise. $\widetilde{A}_{it} = L_{it}^{\sigma_A} \sim$ static productivity.

Output and static productivity effects II

MSA output is

$$Y_{it} = A_{it} \left(K_{it}\right)^{\gamma} \left(h_{it}^{Y} \ell_{it}^{Y} L_{it}\right)^{1-\gamma}.$$

Capital is freely mobile,

$$\frac{Y_{it}}{K_{it}} = \frac{Y_t}{K_t} \quad \text{for all } i$$

(some algebra) $\Longrightarrow$

$$Y_{it} = A_{it}^{1/(1-\gamma)} \left(\frac{K_t}{Y_t}\right)^{\gamma/(1-\gamma)} h_{it}^{Y} \ell_{it}^{Y} L_{it}$$

$\Longrightarrow$ aggregate output,

$$Y_t = \left(\frac{K_t}{Y_t}\right)^{\gamma/1-\gamma} \sum_{i} A_{it}^{1/(1-\gamma)} h_{it}^{Y} \ell_{it}^{Y} L_{it}.$$

Counterfactuals I

- All cities the same, but for cities $L_{it}^{base} > L_{max}$ reduce agglomeration economies to those of a city with $L_{it}^{alt} = L_{max}$.
- Divide all cities $L_{it}^{base} > L_{max}$ into 'daughter cities' with population $L_{it}^{alt} = L_{max}$, conserving population.
- In this case

$$A_{it}^{base} = \widehat{A}_{it}\bar{A}_t(L_{it}^{base})^{\sigma_A}$$
$$A_{it}^{alt} = \widehat{A}_{it}\bar{A}_t(L_{it}^{alt})^{\sigma_A}$$
$$\text{(some algebra)} \Longrightarrow Y_t^{alt} = \sum_i Y_{it}^{base}\left(\frac{A_{it}^{alt}}{A_{it}^{base}}\right)^{1/(1-\gamma)}$$

- Need $K_t/Y_t = K_t^{base}/Y_t^{base} = K_t^{alt}/Y_t^{alt}$. This is true if both cases are on a balanced growth path.

Counterfactuals II

Dividing by Y_t^{base} gives

$$\frac{Y_t^{alt}}{Y_t^{base}} = \sum_i \frac{Y_{it}^{base}}{Y_t^{base}} \left(\frac{A_{it}^{alt}}{A_{it}^{base}}\right)^{1/(1-\gamma)}$$
$$= \sum_i \frac{Y_{it}^{base}}{Y_t^{base}} min\left(1, \left(\frac{L_{max}}{L_{it}}\right)^{\sigma_A/(1-\gamma)}\right).$$

We calculate the change in output relative to the observed case, using only information on realized city level output, realized city level productivity, and counterfactual city population.

Human Capital

- If we suppose that human capital is subject to urban scale effect σ_h, then we get

$$\frac{Y_t^{alt}}{Y_t^{base}} = \sum_i \frac{Y_{it}^{base}}{Y_t^{base}} min \left(1, \left(\frac{L_{max}}{L_{it}} \right)^{\frac{\sigma_A}{1-\gamma} + \sigma_h} \right) \quad (1)$$

- We can treat human capital by scaling up σ_A in the formulation without human capital scale effects.
- N.B.: Human capital is fixed, not like regular capital.

Estimates of σ_A and σ_h

σ_A	σ_h	Source	Data
3.7%	1.2%	Combes et al. [2008]	French, Ind. wages, 1976-98
2.2%	2.9%	De la Roca and Puga [2017]	Spanish, Ind. wages, 2004-9
4.5%	3.1%	Duranton and Puga [2023]	US, Ind. wages, ca. 1979-2020
4.1%	.	Glaeser and Gottlieb [2008]	US, Ind. wages, 2000
5.2%	.	Ciccone and Hall [1996]	US, State output, 1988
13%	.	Glaeser and Gottlieb [2009]	US, MSA output, 2000

Note: Various estimates of the static scale effect, σ_A and the human capital scale effect, σ_h from the literature.

Output in 2010 for three counterfactual size caps and values of σ_A.

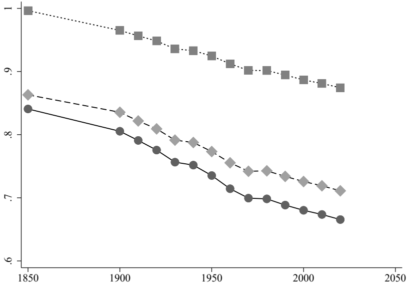
σ_A	$L_{max} = 1m$	$L_{max} = 100k$	$L_{max} = 50k$
0.04	0.94	0.84	0.82
0.08	0.88	0.72	0.68
0.12	0.83	0.62	0.57

- Share of total output relative to the 2010 BEA data, by L_{max} and σ_A,

$$\frac{Y_t^{alt}}{Y_t^{base}} = \sum_i \frac{Y_{it}^{base}}{Y_t^{base}} min\left(1, \left(\frac{L_{max}}{L_{it}}\right)^{\sigma_A/(1-\gamma)}\right).$$

- Rural population is as an extra MSA with output constant across cases.
- If $\sigma_A = 0.08$ then capping city size at $L_{max} = 1$m reduces output 2010 by 12%.

Counterfactual shares of total output



- City sizes are capped at 1m (squares), 100k (diamonds), and 50k (circle).
- Baseline output imputed from the BEA data for 2000 and population data.
- $\sigma_A = 0.08$ and capital share $\gamma = 0.33$.
- Cities are more important for output over time as they get larger.

Patents and research productivity I

Notation

$$
\begin{aligned}
R_{it} &\sim \text{Research output (latent)} \\
h_{it}^{R} &\sim \text{human capital per research worker} \\
(1-\ell_{it}^{Y}) &\sim \text{Share of population working in research} \\
L_{it} &\sim \text{Total population} \\
P_{it} = \mu_t R_{it} &\sim \text{research output to observed patents}
\end{aligned}
$$

We can write production of research output as

$$R_{it} = B_{it} h_{it}^{R} (1-\ell_{it}^{Y}) L_{it}$$

where TFP at research is

$$
\begin{aligned}
B_{it} &= \widehat{B}_{it} \bar{B}_t \widetilde{B}_{it} \\
\widetilde{B}_{it} &= L_{it}^{\sigma_B}.
\end{aligned}
$$

Patents and research productivity II

This structure is like output and we can calculate counterfactual research output analogously,

$$\frac{R_t^{alt}}{R_t^{base}} = \sum_i \frac{R_{it}^{base}}{R_t^{base}} min\left(1, \left(\frac{L_{max}}{L_{it}}\right)^{\sigma_B}\right)$$

- Moretti [2021] $\Longrightarrow \sigma_B = 0.06$ (panel data).
- Carlino et al. [2007] $\Longrightarrow \sigma_B = 0.20$ (cross-section).

Patents for 2000-9 for counterfactual size caps and values of σ_B.

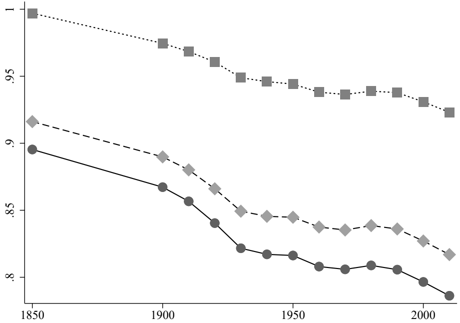
σ_B	$L_{max} = 1m$	$L_{max} = 100k$	$L_{max} = 50k$
0.06	0.93	0.83	0.80
0.20	0.82	0.58	0.52

- Share of total patents during 2000-2009 relative totals reported in the CUSP data Berkes [2018], by L_{max} and σ_B,

$$\frac{R_t^{alt}}{R_t^{base}} = \sum_i \frac{R_{it}^{base}}{R_t^{base}} min\left(1, \left(\frac{L_{max}}{L_{it}}\right)^{\sigma_B}\right)$$

- Rural population is treated as an extra MSA with patents constant across scenarios.
- Cities are more important for patenting than for output.

Counterfactual shares of total patents



- Counterfactual patents as a fraction of actual patents reported in CUSP when city sizes are capped at 1m (squares), 100k (diamonds), and 50k(circles). Calculations assume $\sigma_B = 0.06$.
- Cities are more important for patenting over time as they get larger.

National productivity I

- Recall

$$Y_{it} = \widehat{A}_{it}\bar{A}_t\widetilde{A}_{it}\left(K_{it}\right)^{\gamma}\left(h_{it}^{Y}\ell_{it}^{Y}L_{it}\right)^{1-\gamma}.$$

- We want to relate the evolution of $\bar{A}_t$ to research output (patents), which we can calculate for counterfactual systems of cities.
- Semiconductors per chip grew 35%/year since the early 1970s. 18 times as many people now work on making semiconductors. The contribution of one worker to growth in semiconductors per chip has declined by 7% year [Bloom et al., 2020].
- Measure 'research output' with patents. This lets us adjust the output of a worker for the productivity of their location. We want 'efficiency workers' to Bloom et al.'s 'workers'.

National productivity II

- Assume (following [Bloom et al., 2020]).

$$\Delta \bar{A}_t / \bar{A}_t = \alpha R_t^{\lambda} \bar{A}_t^{-\beta}$$
$$\implies \bar{A}_t^{\text{base}} = \bar{A}_{t-1}^{\text{base}} + \alpha (R_{t-1}^{\text{base}})^{\lambda} (\bar{A}_{t-1}^{\text{base}})^{1-\beta}$$

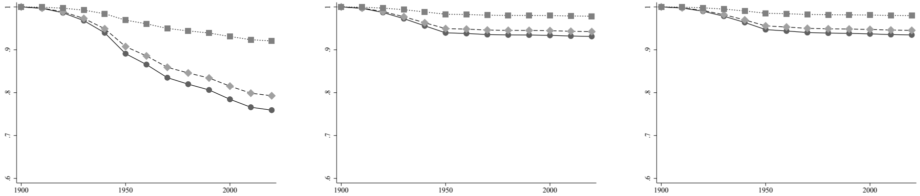
- Use national productivity data reporting $\bar{A}_t^{\text{base}}$, $t = 1900, .., 2010$ [Gordon, 2017] to solve for R_{t-1}^{base}.
- Assume $\bar{A}_1^{\text{alt}} = \bar{A}_1^{\text{base}} = 1$, calculate counterfactual $\bar{A}_1^{\text{alt}}$,

$$\bar{A}_t^{\text{alt}} = \bar{A}_{t-1}^{\text{alt}} + \alpha (R_{t-1}^{\text{base}} \frac{R_t^{alt}}{R_t^{base}})^{\lambda} (\bar{A}_{t-1}^{\text{alt}})^{1-\beta}$$

for $t = 1900, .., 2010$.

- $\lambda \sim$ 'duplication of effort'. $\beta \sim$ 'frontier moves'.

Counterfactual trajectories of national productivity



$\lambda = 1,\ \beta = 0$ $\lambda = 1,\ \beta = 3.1$ $\lambda = 0.75,\ \beta = 2.4.$

- Recall,

$$\Delta \bar{A}_t / \bar{A}_t = \alpha R_t^{\lambda} \bar{A}_t^{-\beta}$$

- Counterfactual productivity, $\bar{A}_t^{alt} / \bar{A}_t^{base}$, by decade for three different counterfactuals and $\sigma_B = 0.06$.
- City size caps 1m (squares), 100k (diamonds), and 50k(circles).
- Changes in patents are not important for productivity $\Longrightarrow$changes in city size are not important for productivity.

$\bar{A}_{alt}/\bar{A}_{base}$ for $L_{max} = 1,000,000$

Parameters	$\sigma_B = .06$	$\sigma_B = .20$
$\lambda = 1$ and $\beta = 3.1$	.979	.935
$\lambda = .75$ and $\beta = 2.4$	.980	.939
$\lambda = 1$ and $\beta = 0$	.924	.790

- Each cell reports the ratio of the time-specific component of aggregate productivity, $\bar{A}$, for the year 2010 in the case where maximum city size is limited to one million, relative to the base case in which city size is not limited.
- The relationship between research output and productivity mutes the effects of city size on research output.

Big cities and the growth of *output* I

- Recall

$$Y_{it} = \widehat{A}_{it} \bar{A}_t \widetilde{A}_{it} \left(K_{it}\right)^{\gamma} \left(h^Y_{it} \ell^Y_{it} L_{it}\right)^{1-\gamma}.$$

- We have calculated the evolution of $\frac{\bar{A}^{alt}_t}{\bar{A}^{base}_t}$ and $\frac{\widetilde{A}^{alt}_{i2010}}{\widetilde{A}^{base}_{i2010}}$.
- Multiplying static productivity effect and productivity effect for 2010, we get the total effect on output of the change to counterfactual systems of cities for 2010.

Big cities and the growth of *output* II

	$\sigma_B = 0.06$			$\sigma_6 = 0.20$		
Parameters	$\sigma_A = .04$	$\sigma_A = .08$	$\sigma_A = .12$	$\sigma_A = .04$	$\sigma_A = .08$	$\sigma_A = .12$
$\lambda = 1.00$ and $\beta = 3.1$	0.917	0.863	0.816	0.877	0.825	0.780
$\lambda = 0.75$ and $\beta = 2.4$	0.919	0.865	0.817	0.880	0.829	0.783
$\lambda = 1$ and $\beta = 0$	0.866	0.815	0.770	0.741	0.697	0.658

- Counterfactual output as a share of realized output in 2010, $L_{max} = 1m$.
- The best estimates of λ, β, σ_A, σ_B probably put us in the highlighted cells.
- Most of the decline is due to the static productivity effect, σ_A.
- Increasing income by a factor of 6 between 1900 and 2010 $\Longrightarrow g = 1.63\%$.
- Increasing income by a factor of $6 \times 0.86 \Longrightarrow g = 1.49\%$.

Conclusion

- Under a counterfactual where no city larger than 1m is allowed (top 52/275 MSAs), the decrease in output is less than 14% for the most defensible parameter estimates.
- Most of the effect is due to the static effect of city size on TFP, not the effect of size on research productivity.
- This does not suggest that big cities are playing an important role in the growth process.

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