Empirics of Agglomeration Effects

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Empirical analysis of agglomeration effects

- *Agglomeration effect* is the effect of city size/population density
  - Often, we use *agglomeration economies* to represents the beneficial agglomeration effects. This lecture mainly focuses on this.
  - Another terminology note: *agglomeration forces* represent the beneficial agglomeration effects, while *congestion forces* represent the negative agglomeration effects.
- I first review the empirics of agglomeration effects on various outcomes
  - Following Ahlfeldt and Pietrostefani's (2019 JUE) survey article
- I then briefly discuss the literature on *path dependence* as quasi-experimental evidence of agglomeration economies
- I close with pointing out some taxonomy of agglomeration forces, focusing particuarly on the three types of microfoundations of agglomeration economies
  - Learning
  - Matching
  - Sharing

Ahlfeldt and Pietrostefani: "The Economics of Density"

- A comprehensive review paper about the agglomeration effect on various outcomes.
  - See Rosenthal and Strange (2004 Handbook of Regional and Urban Economics) for a more classic literature review.
- Agglomeration effects are measured by the regressions like:

$$\ln y_i = \alpha + \beta \underbrace{\ln \frac{P_i}{A_i}}_{\text{Log population density}} + \epsilon_i$$

  where P_i is population of location i and A_i is the geographical area. y_i is some outcome variable (e.g., wages, productivity, amenities)
- Before turning to the result of the meta study, let me point out some empirical challenges to the above specification
  - Some papers reviewed by AP addresses these issues, while others are not.

Empirical issue 1: Endogeneity of population density

$$\ln y_i = \alpha + \beta \ln \frac{P_i}{A_i} + \epsilon_i$$

- Population density affects y_i, but y_i might also affect population density (reverse causality)
  - Example: If y_i is the wage rate, then more people choose to live in a location with higher wages.
- How to address the endogeneity? No definitive solution, but many things have been done:
  - Include observable worker and city characteristics
  - Including location and worker fixed effects
  - Instrumental variables for addressing correlation between city characteristics and density:
    - Past population (Ciccone and Hall 1996 AER)
    - Bedrock quality for development suitability (Rosenthal and Strange 2008 JUE).
    - Soil fertility (Combes Duranton, Gobillon 2010 Book Chapter)
  - Quasi-experiment (e.g., Greenstone, Hornbeck, Moretti 2010 JPE)
- See Combes, Duranton, Gobillon (2011 JEG) for more discussions.

Empirical issue 2: Density vs city size

- Both population density and city size (total city population) are plausible way to measure urbanity
  - Some agglomeration economies might take place at a city level (e.g., accumulation of new ideas at workplace)
  - But others may happen at a more local level, so that density matters (e.g., local shoppiong environments)
- Some studies have attempted to disentangle these two, but difficult as these two are highly correlated
- In practice, using either population density and city size often leads to similar conclusions
  - We can "convert" the density effect to the city size effect
  - Ahlfeldt and Pietrostefani reports that the elasticity of density with respect to total city population is 0.43.
  - Therefore, using density would provide the coefficient about twice as large as city size
- Takeaway: it is not always straightfoward to measure "urbanity" in the data.[1] Be careful!
  - But do not panic too much: different urbanity definitions usually lead to similar conclusions

[1] Indeed, there is a recent JUE special issue dedicated to this:
https://www.sciencedirect.com/journal/journal-of-urban-economics/vol/125/suppl/C

Agglomeration effects on various outcomes

- Evidence of agglomeration forces
  - Positive effects of density on productivity (wages, patents)
  - Positive effects on amenities (goods variety, local public spending)

- Evidence of congestion forces (housing rents, pollution, traffic congestion)

Table 6
Recommended elasticity estimates by category.

ID	Elasticity	Value	Comment
1	Wage	0.04	Citation-weighted mean in review, roughly in line with Melo et al. (2009). 0.08 for non-high-income countries. Net of selection effects, elasticity estimates about halve (Combes and Gobillon 2015).
2	Patent intensity	0.21	Citation-weighed mean in review, in line with original analysis of OECD data.
3	Rent	0.15	Citation-weighed mean in review. In line with evidence from the US (dedicated analysis based on Albouy and Lue, 2015 data). Estimated elasticity increases in density (original meta-analysis) and is 0.21 for France (Combes et al., 2018).
4	Vehicle miles travelled (VMT) reduction	0.06	Citation-weighted mean in review, roughly in line with Duranton and Turner (2018) and Ewing and Cervero (2010).
5	Variety value (price index reduction)	0.12	Dedicated analysis on request using data from Couture (2016), in line with Ahlfeldt et al. (2015).
6	Local public spending	0.17	Citation-weighted mean in review, roughly in line with dedicated high-quality paper (Carruthers and Ulfarsson 2003).
7	Inter-quintile wage gap reduction	−0.035	Original analysis of OECD data[a]. −0.057 for the US. US estimate in line with dedicated high-quality paper (Baum-Snow et al., 2017) (Section 3 in Supplementary material 1).
8	Crime rate reduction	0.085	Dedicated analysis on request (Tang 2015), in line with original analysis of OECD non-US city data. Dedicated high-quality paper (Glaeser and Sacardote) and original analysis suggest a negative value for the US.
9	Green density	0.28	Original analysis of OECD data (evidence base non-existent)
10	Pollution reduction	−0.13	Dedicated high-quality paper (Carozzi and Roth 2018). In line with Borck and Schrauth (2018) and original analysis of OECD data
11	Energy use reduction	0.07	Citation-weighted mean in review
12	Average speed	−0.12	Citation-weighted mean of two (no further evidence) high-quality papers (Duranton and Turner 2018; Couture et al., 2018)
13	Car use reduction	0.05	Citation-weighted mean in review
14	Mortality rate reduction	−0.09	Dedicated paper (Reijneveld et al., 1999)
15	Self-reported well-being	−0.0037	Only direct estimate in literature (Glaeser et al., 2016). In line with original analysis of OECD data

“Path dependence” approach for agglomeration economies

- The regression of population density on outcome variables is suggestive of agglomeration forces, but endogeneity issues remain
- A more indirect but quasi-experimental approach for testing agglomeration forces is the “path dependence” approach
- This approach aims to test for the presence of multiple equilibria in the spatial economy
- Looks at a historical event that impacts population distribution.
  - If a shock to the population distribution does not have a persistent impact, indicative of unique equilibrium
  - If a shock to the population distribution has a persistent impact, it indicates multiple equilibria

Agglomeration forces and multiple equilibria

	Location A	Location B
Location A	$f+A, f+A$	$f, 0$
Location B	$0, f$	A, A

- When agglomeration forces are strong ($A > f$), multiple equilibra exist
- If a historical shock moves the situation from (A, A) to (B, B), then it would "lock-in" and things never go back to (A, A)
- Hence, path dependence is indicative of agglomeration forces.

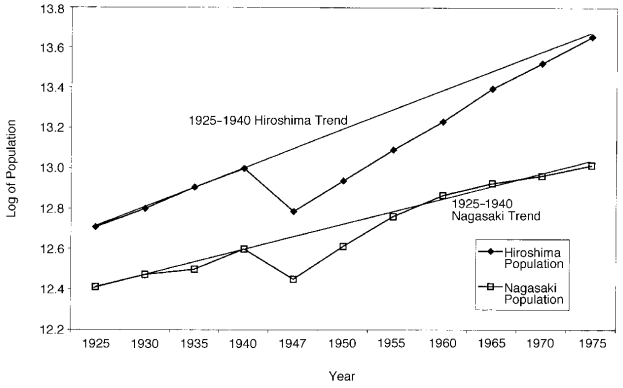
Agglomeration forces and multiple equilibria

	Location A	Location B
Location A	$f+A, f+A$	$f, 0$
Location B	$0, f$	A, A

- When agglomeration forces are weak ($f > A$), the equilibrium is unique
- Even if a historical shock moves the situation from (A, A) to (B, B), things would go back to (A, A) because (B, B) is not an equilibrium
- Hence, path independence seems to imply weak agglomeration forces

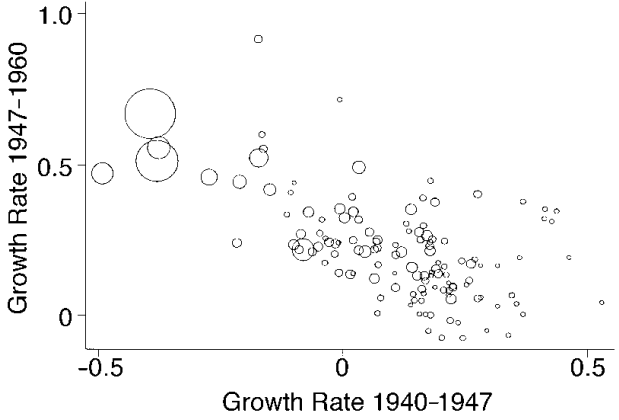
Davis and Weinstein (2002 AER)

- Indiscriminate air-raid bombing on Japanese cities by the US during World-War II
  - It had a huge effect on population distribution across cities
- Does this "bombing shock" have a persistent impact?
  - Maybe not. Look at the population trend of Hiroshima and Nagasaki that experienced atomic bombing



Davis and Weinstein (2002 AER)

- Almost perfect recovery by 1960. Strong path independence result
- DW interprets this as evidence favoring the importance of fundamental characteristics of cities, not agglomeration forces



Bleakley and Lin (2012 QJE)

- Davis and Weinstein (2002) spawned the literature that investigates the persistent impact of historical events on spatial distribution of economic activities
- Many subsequent studies found evidence of path dependence, in contrast to Davis and Weinstein (2002)
  - See Lin and Rauch (2023 RSUE) for a recent review.
- I discuss Bleakley and Lin (2012), which is one of the most influential studies among the ones finding path dependence

Bleakley and Lin (2012 QJE)

- When river transportation was important (-19th century), cities tend to be formed where the river rapidly falls
  - Need for overland hauling or *portage*.
- Cities tended to locate along the "fall lines"
  - Combined with water power plants, which were very important in the past but much less today.
- This no longer matters as river transportation got obsolete
  - Railways are alternative (c.f., Donaldson and Hornbeck 2016 AER)

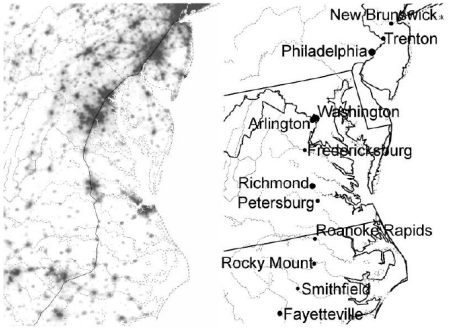


FIGURE IV
Fall-Line Cities from North Carolina to New Jersey

The map in the left panel shows the contemporary distribution of economic activity across the southeastern United States measured by the 2003 nighttime lights layer from NationalAtlas.gov. The nighttime lights are used to present a nearly continuous measure of present-day economic activity at a high spatial frequency. The fall line (solid) is digitized from *Physical Divisions of the United States*, produced by the U.S. Geological Survey. Major rivers (dashed gray) are from NationalAtlas.gov, based on data produced by the U.S. Geological Survey. Contemporary fall-line cities are labeled in the right panel.

Bleakley and Lin (2012 QJE)

- Indeed, population density is higher exactly at the fall line, *even today*
- Past positive shock to population density persists even today
  - Evidence of multiple equilibria $\rightarrow$ agglomeration forces matter

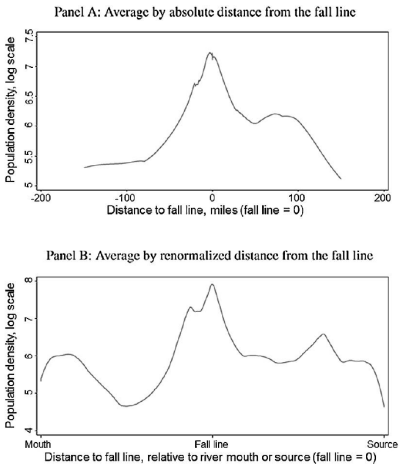


FIGURE III
Population Density in 2000 along Fall-Line Rivers

Takeda and Yamagishi (2024 JPE R&R)

- Taken at a face value, DW suggests that agglomeration forces are unimportant, while BL suggests agglomeration forces are important
  - How can we reconcile these two findings?
- Takeda and Yamagishi: Agglomeration forces are important, but path independence can happen even when agglomeration forces are strong.
  - Expectations about the future may select the recovery equilibrium, among multiple equilibria that include no-recovery equilibrium.
- Revisits the path independence result of Hiroshima, but focuses on the population and employment distribution *within* Hiroshima
  - Rapid recovery of the destroyed city center just in five years of the atomic bombing
  - Since the city is small and already developed, fundamental location characteristics are likely homogeneous within the city

Takeda and Yamagishi (2024 JPE R&R)

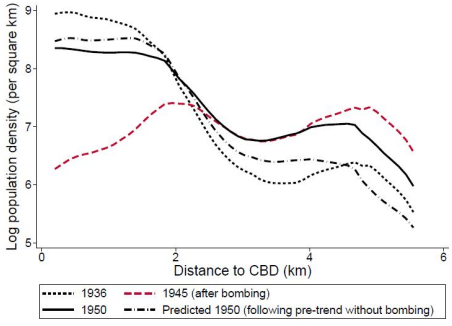
	Location A	Location B
Location A	$f+A, f+A$	$f, 0$
Location B	$0, f$	A, A

- Even if there are two equilibria ($A > f$) and the historical shock shifts the economy to (B, B), the economy may again shift to (A, A) if people expect that the (A, A) equilibrium is selected
- Motivated by this idea, TY develops a dynamic QSE model and estimates A and f by extending the approach of Ahlfeldt, Redding, Sturm, Wolf (2015)
  - They find relatively strong agglomeration forces (A), while location fundamentals (f) are relatively homogeneous within the city
  - The homogeneous f is also consistent with their reduced-form evidence

Takeda and Yamagishi (2024 JPE R&R)

- Using newly-digitized data, TY documents the recovery of city structure just in five years (path independence).

Figure 3: Population density by distance to city center

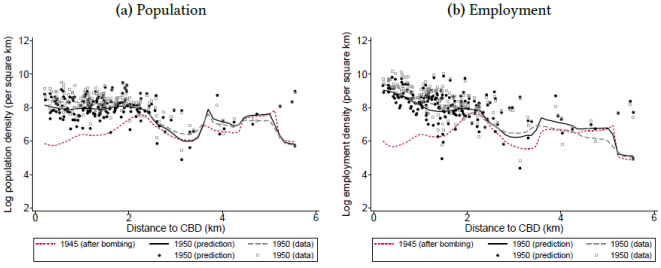


Note: The figure shows the local polynomial regression of log population density on distance to the CBD for different years. To eliminate the effect of changes in the total population, we normalize the total population each year to 100,000. The predicted population distribution of 1950 is computed based on the 1936 population distribution, assuming that each block experienced annual population growth rate equal to the pre-war (1933–1936) rate.

Takeda and Yamagishi (2024 JPE R&R)

- In a counterfactual analysis, the calibrated QSE model can successfully predict the fast recovery of central Hiroshima
  - The calibrated model can predict such rapid recovery
- The model thus can explain the striking path independence result

Figure 5: Recovery of population and employment: Endogenous part explained by our model

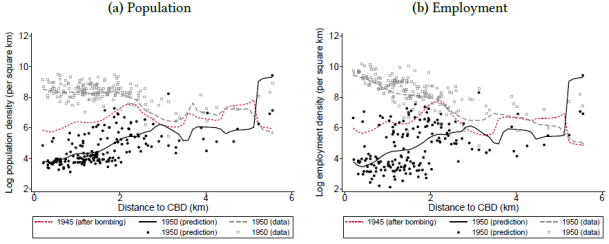


Note: Each figure overlays observed log population density (Panel a) and employment density (Panel b) with local polynomial regressions using each on distance from the CBD. We estimate three separate regressions: the 1945 population and employment densities (small dashed line); the observed 1950 population and employment densities (long dashed line); and the 1950 population and employment densities inferred under the counterfactual scenario in which we exclude the structural error components of amenities and productivity (solid line). Each dot represents a block, with different colors for the predicted density and the observed density.

Takeda and Yamagishi (2024 JPE R&R)

- In the second counterfactual analysis that shuts down the agglomeration forces, the model no longer predicts the recovery
- Importance of agglomeration forces
  - Reconciling DW (2002) and BL (2012) by highlighting that path independence can happen even when agglomeration forces are important

Figure 6: Population and employment distributions with no agglomeration forces

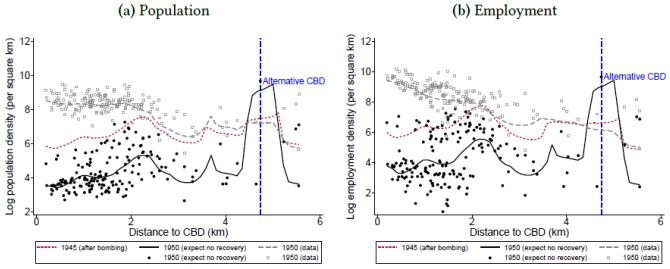


Note: Each figure overlays log population density (Panel a) and employment density (Panel b) with local polynomial regressions of each on distance from the CBD. We run three separate regressions: one for the observed 1945 population and employment densities (small dashed line), one for the observed 1950 population and employment densities (long dashed line), and one for the inferred 1950 population and employment densities when we shut down agglomeration forces in both productivity and amenities (solid line). Each dot represents a block, with different colors for the predicted density and the observed density.

Takeda and Yamagishi (2024 JPE R&R)

- The model also has another equilibrium in which the city center fails to recover
- The selection of recovery equilibrium is important
  - Role of "optimistic expectations" as an equilibrium selection device

Figure 7: Population and employment distribution in an alternative equilibrium



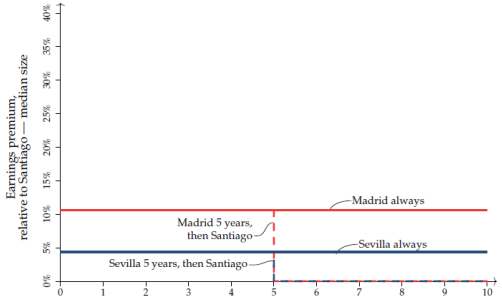
Note: Each figure plots log population density (Panel a) and employment density (Panel b) with local polynomial regressions of each on distance from the CBD. We run three separate regressions: one for the observed 1945 population and employment densities (small dashed line), one for the observed 1950 population and employment densities (long dashed line), and one for the inferred 1950 population and employment densities in an alternative equilibrium (solid line) when people expect that the pre-war CBD will not recover and an alternative block located at the vertical dashed line will grow. Each dot represents a block, with different colors for the predicted density and the observed density. The location with growing population and employment density is labeled "alternative CBD".

Microfoundations of agglomeration economies

- We have seen the importance of agglomeration forces
- What is the underlying mechanism behind agglomeration forces?
- Useful categorization by Duranton and Puga (2004 Handbook of Regional and Urban Economics)
  - Learning: People learn faster in cities, leading to faster productivity growth
  - Matching: Workers and firms find better partners in cities
  - Sharing: People can share indivisible/non-congestable goods (goods variety, public goods etc) in cities
- We briefly discuss recent empirical evidence of each mechanism
  - Overall, we have evidence that all three mechanisms matter, depending on contexts
  - Various theoretical foundations behind each mechanism have been considered. See Duranton and Puga (2004).

Learning: De la Roca and Puga (2017 RES)

- Regressing individual wages on city fixed effects, using Spanish panel data
  - Larger cities, like Madrid (1st) and Sevilla (4th) have larger wage premium
- If we literally take the city fixed effects model, a worker moving from a small city (Santiago) to Madrid will immediately lose their wage premium



Panel (b) Profiles not allowing for learning benefits of bigger cities

FIGURE 3
Earnings profiles relative to median-sized city

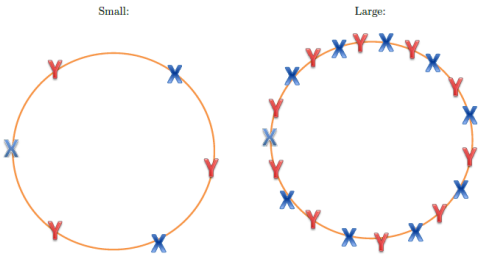
Learning: De la Roca and Puga (2017 RES)

- However, in the data, wage growth is faster in larger cities and the wage premium is (largely) portable to smaller cities
- Consistent with faster accumulation of human capital (= learning) in cities
- Drawback: De la Roca and Puga do not directly observe learning, but infer its importance from wage data
  - See Yamagishi (2024 JEG R&R) for a recent attempt to directly analyze learning in cities

Matching: Moretti and Yi (2024 wp)

- In a larger market, there are various types of workers and firms
- Therefore, we expect that the "mismatch" between workers (X) and firms (Y) should be smaller in larger cities
  - Each individual can find a better-matching partner in a larger city
  - See Helsley and Strange (1990 RSUE), Sato (2001 JUE), and Papageorgiou (2022 AEJ Macro) for more theoretical discussions.

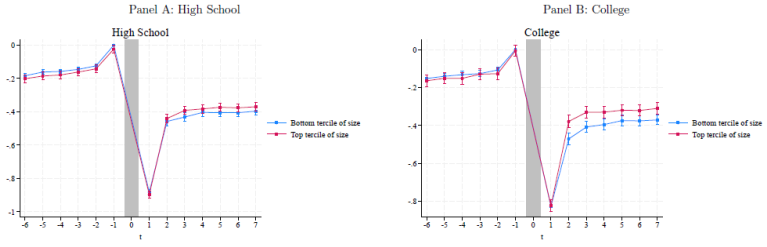
Figure 1: An Example of a Large and a Small Labor Market



Matching: Moretti and Yi (2024 wp)

- After workers lose their jobs, they find a new job faster in larger markets
  - Also higher earnings and lower probability of moving-out
- Consistent with faster job matching process and better matching quality in cities

Figure 2: Employment



Notes: This figure plots the conditional probability of employment for a worker from 6 quarters before involuntary displacement to 7 quarters after displacement. The shaded area highlights the quarter when the relevant closure occurs. These estimates come from the specification in equation (3). Plot whiskers show 95% confidence intervals from standard errors clustered at the CZ-level based on CZ residence at $t = -1$.

Sharing: Handbury and Weinstein (2015 RES)

- Do urban areas have higher goods price levels?
  - We often here things like "Tokyo's restaurants are expensive"
- Handbury and Weinstein points out two key points:
  - We should compare the same products (should be Kewpie Mayonnaise vs Kewpie Mayonnaise, not just Mayonnaise vs Mayonnaise)
  - We should correct for the number of goods available across cities (see figure)

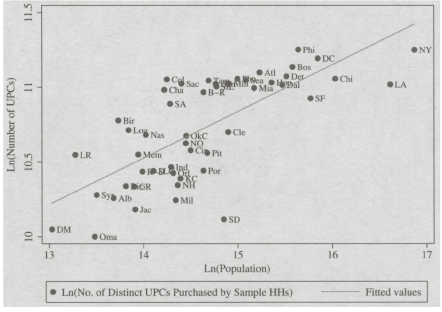


FIGURE 3

Log number of distinct UPCs in each city sample versus log city population

Notes: (1) Numbers on plots reference the market ID of the city represented, as listed in Table A.1.

Sharing: Handbury and Weinstein (2015 RES)

- Theoretically, a larger city should have more number of available goods.
- For instance, in Redding's (2016) model we have seen, the number of goods M_i is proportional to population size L_i
  - "Sharing" is happening here! When there are larger population, there is more demand.
  - This larger demand supports more firms' entry, leading to the "sharing" of goods variety
- More goods variety then lowers prices because people love more variety
  - In Redding's model (or the CES utility models more generally), the price index is defined as $P_n = \left[\sum_{i \in N} \int_0^{M_i} p_{ni}(j)^{1-\sigma} dj\right]^{\frac{1}{1-\sigma}}$
  - Larger M_n leads to lower P_n

Sharing: Handbury and Weinstein (2015 RES)

- Using the US barcode data, correcting for goods variety kills the result that prices are more expensive in larger cities (top-right figure)
- Adjusting for purchaser and store heterogeneity, prices are now lower in larger cities (bottom-right figure).
  - Accounting for the tendency that "big cities have different (less price sensitive) consumers purchasing different (more expensive) varieties of products in different (more expensive) stores.
- Lower price in larger cities is consistent with spatial economic models like Redding (2016)

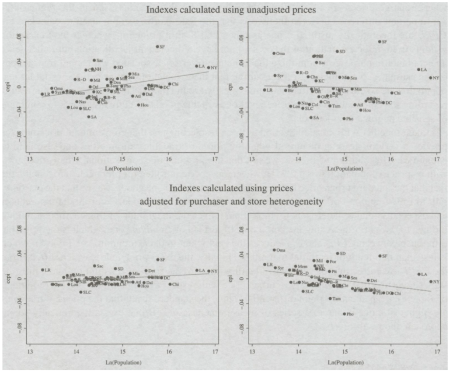


FIGURE 12
City price indexes versus log city population
Notes: (1) Acronyms on plots reference the city represented, as listed in Table A.1. (2) City price indexes are normalized to be mean zero.

Urban diversity vs Specialization

- Marshall vs Jacobs arguments about sources of agglomeration economies: specialization vs urban diversity
- Marshall highlights that the benefit of many people specializing in a particular industry
  - Sharing inputs in production
  - Labor market pooling of similar workers
  - Spillovers of specialized knowledge
- Jacobs highlight the benefit of urban diversity:
  - Creation of new ideas through the exchange of various ideas
  - Broadly speaking, the availability of diverse consumption goods may also correspond to such Jacobs' idea
- Which type of agglomeration forces matter more depend on contexts
- See Rosenthal and Strange (2004 Handbook of Regional and Urban Economics) for details
  - Note, however, that these are not necessarily conflicting notions. See Faggio, Silva, Strange (2017 REStat)

Geographical scope of agglomeration economies

- We have seen that agglomeration economies exist, but what is the spatial reach of this?
  - In Ahlfeldt, Redding, Sturm, Wolf (2015) there was a spatial decay parameter.
  - We would like to review more evidence on this
- Overall, evidence suggests that the spatial scope of agglomeration economies is fairly narrow
  - Recent exception: Giroud, Lenzu, Maingu, Mueller (2024 ECMA)
- Some key papers:
  - Arzaghi and Henderson (2008 RES)
  - Ahlfeldt, Redding, Sturm, Wolf (2015 ECMA)
  - Liu, Rosenthal, Strange (2018 JUE)
  - Baum-Snow, Gendron-Carrier, Pavan (2024 AER)
- See Rosenthal and Strange (2020 Journal of Economic Perspectives) for a relatively new survey on this issue.

Taking stock

- We have seen empirical studies of agglomeration effects
- There are various studies using simple regression of population density on various outcome variables
- We have also seen the path-dependence approach for testing the importance of agglomeration forces
- We discussed three major microfoundations of agglomeration forces
  - Learning
  - Matching
  - Sharing
- We finally touched upon Marshall vs Jacobs arguments and the spatial scope of agglomeration forces.
- We later unpack housing market a bit more in depth, a major congestion forces.
  - The balance of agglomeration forces and congestion forces determines the spatial distribution of economic activities.