Vertical Density and Agglomeration Economies

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Revisions of the paper will be available at:
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I. Introduction

A. Context: density in urban economics:

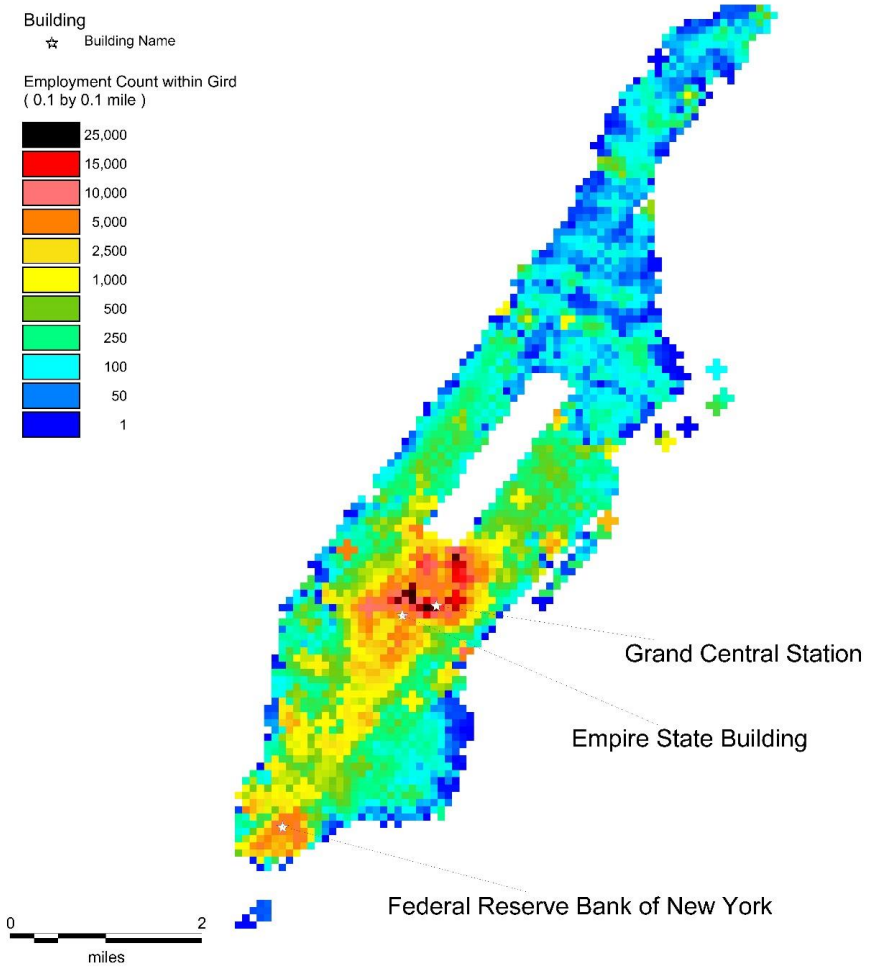
1. Cities exist because density is valuable.

2. Cities are defined by density.

3. Foundational research on urban spatial structure focuses on density: Clark (1951), Muth (1961, 1969), and Mills (1970).

4. <u>This research is entirely horizontal in focus</u>.

Figure 0. Employment Density in Manhattan



B. Cities are not flat, but urban and real estate economists have acted as if they were.

1. Monocentric model: variable capital to land ratios generate variation within and between cities in building heights.

2. All activity at a particular distance from the city center is treated as taking place at ground level.

3. The standard model thus largely ignores what takes place within a building.

4. A prior paper (Liu et al, 2016) estimates vertical rent gradients (which are shown to be nonmonotonic) and characterizes vertical spatial structure (significant variation).

C. Current thinking about vertical density.

1. Decreasing within a building (Ascher, 2011).

2. Explanation: access.

3. Liu et al (2016) shows other forces are at work.

D. This paper considers vertical density.

1. The primary focus will be on the tall buildings that make up a city's business district.

2. The analysis is guided by a theoretical model that extends standard economic analysis by considering verticality.

3. A building is truly "long and narrow" in the sense of Solow and Vickrey (1971).

4. The paper's results on density are interesting in their own right, relevant to real estate, and important for the light that they shed on familiar urban economic phenomena.

E. Context revisited:

1. Vertical transportation costs matter.

    a. An IBM (2010) survey shows that an office tenant spends 22.25 minutes in or waiting for elevators in a business day.

    b. Compare this to the median one-way commute of 24 minutes (Rosenthal and Strange, 2011).

2. Office sector matters.

    a. As an asset market: bigger than corporate bonds.

    b. For urban employment: bigger than manufacturing.

F. Novel data allow us to focus on vertical relations.

1. Confidential offering memoranda data (OM) that lay out the tenant stack (tenant locations) of 90 buildings and rents by floor.

2. Commercial rent dataset produced by CompStak Inc. (CS): more buildings, but not entire buildings.

3. Establishment-level Dun and Bradstreet data (D&B): no rents, but firm characteristics.

G. Key conclusions:

1. The vertical density gradient is non-monotonic: high density at ground floor (best access) and top (worst access but best amenities). Clearly, access is not only force.

2. High density for older firms and HQs: productivity drives density.

3. Evidence of localization economies, in an unusual setting and with an unusual approach.

4. These agglomeration economies attenuate with distance.

H. Literature (beyond urban spatial structure and real estate):

1. Tall buildings. In addition to Liu et al (2016):

    a. Helsley-Strange (2008): game-theoretic model of skyscraper contests.
    b. Barr (2010, 2012) on patterns of building heights.
    c. Koster et al (2014a) on the relationship of office rents to building heights (but little on what happens within buildings).
    d. Ahlfeldt and McMillen (2015) document a robust relationship between building height and land rent.
    e. Ahlfeldt and McMillen show that departures are consistent with Helsley-Strange (2008).

H. Literature (cont.):

2. <u>Agglomeration economies:</u>

   a. Surveys: Rosenthal-Strange (2003), Behrens-Robert-Nicoud (2015), Combes-Gobillon (2015).

   b. Attenuation: Rosenthal and Strange (2001, 2005, 2008), Arzaghi and Henderson (2008), and Baum-Snow (2011)).

J. What we do

1. Analyze a theoretical model of vertical density.

2. Use a range of data sources (OM; CompStak; D&B)…

3. …to estimate the vertical density gradient

4. …in a way that sheds light on the agglomeration economies.

II. A theory of vertical density.

A. Primitives.

1. Three types of agent: tenants (commercial establishments), consumers, workers.

2. Competitive labor, product, and space markets.

3. Vertical differentiation: floor denoted z.

4. Fixed demand for space by tenants, s.

B. Access-only:

1. Product markets: competition gives $p(z) = p^0 - \tau^c z$, where p^0 is the price at ground floor and τ^c is access costs.

2. Labor markets: competition gives $w(z) = w^0 + \tau^w z$, where w^0 is the price at ground floor and τ^w is access costs.

3. Tenant production: $\alpha f(n)$, here $\alpha > 0$ is a productivity shifter.

4. Tenant profit:

$$\pi(z) = \alpha f(n)p(z) - w(z)n - r(z). \qquad \text{(II.1)}$$

B. Access-only (cont.):

5. Employment:

a. Tenant profit maximization

$$\alpha p(z) f'(n) - w(z) = 0 \qquad \text{(II.2)}$$

b. Second-order condition

$$\alpha p(z) f''(n) = \Delta < 0. \qquad \text{(II.3)}$$

B. Access-only (cont.):

6. The vertical density gradient depends on:

$$dn/dz = - [\alpha p'(z) f'(n) - w'(z)] / [\alpha p(z) f''(n)]. \qquad \text{(II.4)}$$

7. This has the sign of $[\alpha p'(z) f'(n) - w'(z)]$.

8. The access-only assumptions made above suffice to give $p'(z) < 0$ and $w'(z) < 0$, which in turn gives a <u>negatively sloped density gradient</u>, $dn/dz < 0$.

B. Access-only (cont.):

9. Bid-rent is also negatively sloped in this setting:

$$r(z) = \alpha p(z) f(n) - w(z) n, \qquad \text{(II.5)}$$

10. So access by itself generates a negatively sloped density gradient (as claimed) but also generates a negatively sloped vertical rent gradient (which is rejected empirically by Liu et al, 2016).

C. Access and amenities: simple model.

1. Amenities and consumers. Higher floor – higher price: $p(z) = p^0 - \tau^c z + \phi^c z$.

2. Amenities and workers. Higher floor-lower wage: $w(z) = w^0 + \tau^w z - + \phi^w z$.

3. Different than the amenities associated with residential buildings.

4. Here, the rent gradient is positively sloped and so is the density gradient.

D. Complementarities

1. How might one specify a model to capture the empirical characteristics of *both* the rent and density gradients?

2. Suppose that instead of being a linear function of floor, amenities for workers and customers include a complementarity between the floor location and the space devoted to each worker, $\sigma = n/s$.

3. Let the amenities be given by $h(z,\sigma)$ for workers and by $g(z,\sigma)$ for consumers, with both functions increasing in both arguments.

D. Complementarities (cont.)

4. These give modified price and wage equations: $p(z) = p^0 - \tau^c z + \phi^c h(z,\sigma)$, while for wage, $w(z) = w^0 + \tau^w z - \phi^w g(z,\sigma)$.

5. Employment is now:

$$p(z)f'(n) - w(z) + f(n)\phi^c \partial h/\partial\sigma \, \partial\sigma/\partial n + n\phi^w \partial g/\partial\sigma \, \partial\sigma/\partial n = 0. \quad \text{(II.8)}$$

The first two terms are as in (II.2). The last two capture complementarities.

D. Complementarities (cont.)

6. Rent gradient slope:

$$dn/dz = (-1/\Delta)\,[(-\tau^c + \phi^c\,\partial h/\partial z\,)f'(n) - (-\tau^w + \phi^w\,\partial g/\partial z)$$
$$+ f(n)\phi^c\,\partial^2 h/\partial\sigma\partial z + n\phi^w\,\partial^2 h/\partial\sigma\partial z], \qquad \text{(II.9)}$$

where

$$\Delta = p(z)f''(n) + f'(n)\,\phi^c\,\partial h/\partial\sigma\,\partial\sigma/\partial n + \phi^w\,\partial g/\partial\sigma\,\partial\sigma/\partial n$$
$$+ f(n)\phi^c[\partial^2 h/\partial\sigma^2\,(\partial\sigma/\partial n) + \partial h/\partial n\,\partial^2\sigma/\partial n^2]$$
$$+ n\phi^w\,[\partial^2 g/\partial\sigma^2\,(\partial\sigma/\partial n) + \partial g/\partial n\,\partial^2\sigma/\partial n^2] < 0 \qquad \text{(II.10)}$$

7. dn/dz is indeterminate, with the sign depending on the term in square brackets.

E. Some final comments.

1. Density rises with productivity.

2. Heterogeneous tenants: sorting will impact equilibrium density, with a possible tendency towards negative density gradients.

3. Variable space demand: tends towards positive density gradients.

4. With these in mind, we now turn to estimating and interpreting the vertical density gradient.

III. Data

A. Three sources.

1. Offering memoranda (OM): 93 tall buildings, 2003-2014, tenant stack and suite level rent.
2. CompStak (CS): more buildings, but not entire buildings.
3. Dun and Bradstreet (D&B): no rent, but characteristics including sales and employment at a site or for the firm, establishment type, corporate status, and risk.

B. OM data.

1. 90 offering memoranda for tall buildings in 18 U.S. metro areas that were up for sale at various times from 2003 to 2014.

2. Tenant stack and rents.

3. Hand coded!

4. Example: Prudential One in Chicago.

C. CompStak data.

1. Rent and tenant information.

2. More buildings covered, but not entire buildings.

3. More than 100,000 office suites over twelve cities.

4. We work with buildings over 20 stories in 5 city markets with good coverage (New York, Chicago, Los Angeles, Washington DC, and San Francisco).

D. D&B data.

1. Detailed information on employment and sales at an establishment's site (i.e. suite),

2. Also, establishment type (i.e. single site, branch, headquarters), corporate status (corporation, partnership, sole proprietorship), risk attributes, sales and employment of the overall firm for multi-site companies.

3. Match with OM and CS.

Table 1a: Data Sources

	Offering Memo (OM)	CompStak[a] (CS)
Number of Buildings	90	335
Number of Tenant-Suite Obs	2,567	906
Number of MSAs	18	5
Time Period for Data	2004 - 2014	1983, 1990, 1999 - 2015

[a] Compstak sample is restricted to buildings 20 floors or more in height.

Table 1b: Industry Composition and Employment Density

Panel A: Offering Memo Data

	Industry Composition (Percent)				Density (Employment/1,000 sq feet)			
	All Floors	Ground Floor & Concourse	Floor >= 2 and < 40	Floor >= 40	All Floors	Ground Floor & Concourse	Floor >= 2 and < 40	Floor >= 40
Retail (SIC 52-59)	6.86	41.64	2.85	2.07	11.27	12.76	8.59	11.51
FIRE (SIC 60-67)	28.24	18.59	29.26	30.57	8.56	16.08	7.77	10.50
Bus Serv (SIC 73)	7.48	4.46	7.79	8.29	7.55	12.25	7.17	7.89
Law Offices (SIC	21.15	4.83	21.33	41.97	14.49	46.88	12.36	21.12
Eng, Acc, Man (SIC	12.27	2.60	13.54	11.92	10.04	26.80	10.06	4.71
All Other Industries	24.00	27.88	25.23	5.18	9.28	11.27	9.06	5.70

Panel B: CompStak Data[a]

	Industry Composition (Percent)				Density (Employment/1,000 sq feet)			
Retail (SIC 52-59)	0.55	0.00	0.60	0.00	3.41	0.00	3.41	0.00
FIRE (SIC 60-67)	25.38	15.38	24.70	37.29	4.52	6.00	4.47	4.88
Bus Serv (SIC 73)	10.99	15.38	11.58	1.69	4.84	5.47	4.85	3.21
Law Offices (SIC	25.60	23.08	24.82	37.29	3.39	2.78	3.44	2.92
Eng, Acc, Man (SIC	15.37	23.08	16.71	10.17	5.94	9.71	5.93	4.16
All Other Industries	21.10	23.08	21.60	13.56	4.00	7.95	3.98	2.93

[a] Compstak sample is restricted to buildings 20 floors or more in height.

Table 1c: Building and Suite Location (by floor)[a]

	Average Floor	Median Floor	% Over Floor 30	% Over Floor 60	Minimum Floor	Maximum Floor
Building Height						
Offering Memo (90)	32.9	28	46.7	4.4	16	109
CompStak (322)	35.0	32	55.6	3.1	21	108
Suite Location						
Offering Memo Data (2,826)	17.9	15	17.2	1.3	-1	97
CompStak Data (910)	19.2	18	17.1	0.5	1	93

E. Summary statistics.

1. OM: 2,567 tenant-suite observations are spread across 90 buildings in 18 cities.

2. CS: 906 tenant-suite observations are spread across 335 buildings in 5 cities.

F. More summary statistics for OM.

1. Which industries? FIRE 28.2% and law 21.2%. Retail 6.9%.

2. Where are the industries?

   a. Ground: retail is 41.6%.

   b. Floors 2-39, retail is 2.9%, FIRE is 29.2% and law 21.3%.

   c. Above 40, retail is 2.1%, FIRE 30.6% and law 42%.

G. Still more OM summary statistics.

1. Variation by industry: 7.55 workers/1000sf (bus. services) to 14.49 (law).

2. Some industries show decreasing densities (engineering/accounting/management), while others show rising densities (law, FIRE).

H. Comparable in CS, with lower densities.

IV. Vertical density

A. Vertical density gradients: approaches.

1. Log density regressed on log floor…
2. …and other controls.
3. OM data.
4. Building FE.

Table 2: Density Gradients using Offering Memo Data
Dependent Variable= Log (Number of workers per 1000 square feet)

	All Industries				Law Offices		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Concourse	-	1.0992	0.9578	1.1515	-	2.4407	2.3340
	-	(3.20)	(3.17)	(4.64)	-	(4.20)	(4.05)
Ground Floor	-	0.3218	0.1683	0.4114	-	2.4829	2.4303
	-	(1.80)	(1.13)	(2.17)	-	(16.43)	(20.22)
Floor number	-0.0028	0.0032	-	-	0.0030	0.0130	-
	(-0.66)	(0.60)	-	-	(0.46)	(1.89)	-
Floor 2 to 3[a]	-	-	-0.5023	-0.2847	-	-	-0.2756
	-	-	(-2.92)	(-1.71)	-	-	(-0.84)
Floor 4 to 9[a]	-	-	-0.1265	-0.0303	-	-	-0.0364
	-	-	(-0.88)	(-0.24)	-	-	(-0.18)
Floor 20 to 39[a]	-	-	-0.1440	-0.1365	-	-	0.3658
	-	-	(-1.13)	(-1.07)	-	-	(2.50)
Floor 40 to 59[a]	-	-	0.2774	0.3594	-	-	0.5566
	-	-	(1.42)	(2.38)	-	-	(1.36)
Floor 60 and above[a]	-	-	0.1744	0.4870	-	-	1.2720
	-	-	(1.24)	(4.31)	-	-	(4.08)
Observations	2,567	2,567	2,567	2,567	543	543	543
Building Fixed Effects	90	90	90	90	68	68	68
SIC2 Fixed Effects	-	-	-	60	-	-	-
Within R-Squared	0.000652	0.0167	0.0252	0.145	0.000655	0.0885	0.104
Total R-squared	0.000449	0.0199	0.0304	0.160	0.0150	0.0742	0.0773

[a] Omitted floor category is floors 10 through 19.

B. Vertical density gradients: results.

1. Moving up one floor => density falls 0.28% (insignificant).

2. This is only weakly consistent with Ascher (2011).

3. A substantial ground floor effect on density (32 percent greater), and an even larger concourse effect (109 percent greater).

4. The bivariate negative density-floor relationship is thus driven by the high density at and below ground level.

B. Vertical density gradients: results (cont.):

5. Ground floor and top floors associated with higher density.

6. Little effect in middle floors > U-shaped density gradient.

7. Density on the ground floor is higher by 68% for all industries (column 3) and 237% than for floors 10-19.

8. Starting at Grand Central Station, to get the all industry change in density, one would need to move horizonally roughly 2 blocks (.1 miles).

9. The density gradient is highly nonlinear, so this is a lower bound.

B. Vertical density gradients: results (cont.):

10. Law firms merit special attention (20% of sample; 44% above floor 60).

11. Law is probably an amenity-oriented activity.

12. Results for law show a pronounced U-shape in the flexible models, with the amenity-orientation strong enough to produce a positive density gradient.

13. In sum, vertical density gradients are not as simple as an access-only model would suggest.

C. Other determinants of density.

1. Rent: ambiguous in theory.

2. Insignificant in estimated models.

3. More density at HQs.

4. Older firms have higher density.

5. Vertical pattern persists.

6. In sum: the density gradient is U-shaped, with deviations associated with high density for productive tenants.

Table 3: Density Gradients Controlling for Rent and Establishment Attributes Using OM Data
Dependent Variable= Log (Number of workers per 1000 square feet)

	All Industries			Law Offices		
	(1)	(2)	(3)	(4)	(5)	(6)
Concourse	1.1088	1.2080	1.2154	2.1198	2.0475	1.9675
	(4.56)	(4.91)	(4.82)	(3.05)	(2.58)	(2.46)
Ground Floor	0.4994	0.6170	0.6833	2.3144	2.3724	2.2407
	(2.74)	(3.65)	(4.00)	(16.32)	(9.71)	(11.67)
Floor 2 to 3[a]	-0.2930	-0.2677	-0.2422	-0.2584	-0.4092	-0.3260
	(-1.74)	(-1.75)	(-1.57)	(-0.77)	(-0.85)	(-0.80)
Floor 4 to 9[a]	-0.0435	-0.0018	0.0205	-0.0747	-0.0609	-0.0491
	(-0.35)	(-0.01)	(0.18)	(-0.35)	(-0.30)	(-0.24)
Floor 20 to 39[a]	-0.1163	-0.0320	0.0065	0.4366	0.4189	0.4457
	(-0.94)	(-0.28)	(0.06)	(2.85)	(2.85)	(3.22)
Floor 40 to 59[a]	0.3839	0.4139	0.4382	0.6071	0.5545	0.4680
	(2.52)	(2.51)	(2.52)	(1.46)	(1.71)	(1.56)
Floor 60 and above[a]	0.5091	0.5841	0.3432	1.3774	1.4585	0.9022
	(4.53)	(5.34)	(2.68)	(4.09)	(5.88)	(3.05)
Ann real rent/sq foot	-0.0033	-0.0025	-0.0018	-0.0103	-0.0101	-0.0114
	(-1.98)	(-1.40)	(-1.04)	(-1.42)	(-1.29)	(-1.57)
Headquarters	-	1.1336	0.8387	-	0.9231	0.5809
	-	(7.68)	(5.54)	-	(2.56)	(1.96)
Branch	-	0.6187	0.0442	-	0.5470	-0.1301
	-	(5.57)	(0.20)	-	(2.92)	(-0.39)
Yr orig < 1950	-	-	1.5630	-	-	1.4299
	-	-	(6.02)	-	-	(2.00)
Yr orig 1950 to 1979	-	-	1.5098	-	-	0.9178
	-	-	(8.61)	-	-	(1.29)
Yr orig 1980 to 1999	-	-	1.1823	-	-	0.7872
	-	-	(7.33)	-	-	(1.27)
Yr orig 2000 to 2009	-	-	1.0045	-	-	0.4099
	-	-	(5.96)	-	-	(0.62)
Observations	2,567	2,567	2,567	543	543	543
Building Fixed Effects	90	90	90	68	68	68
SIC2 Fixed Effects	60	60	60	-	-	-
Within R-Squared	0.148	0.217	0.264	0.111	0.169	0.208
Total R-squared	0.160	0.255	0.309	0.0232	0.103	0.121

[a] Omitted floor category is floors 10 through 19.

V. Within-building agglomeration and density.

A. Overview

1. If agglomeration economies exist, then tenants impacted by productivity spillovers will choose higher density.

2. We depart from prior work by: considering vertical spatial organization, the allocation of space as an agglomeration variable, and (mostly) considering the office sector.

Table 4: Within Building Agglomeration and Density – Offering Memo Data
Dependent Variable= Log (Number of workers per 1000 square feet)

	All Industries			Law Offices		
	Without Building Fixed Effects	With Building Fixed Effects	Control for Within Bldg Agglom	Without Building Fixed Effects	With Building Fixed Effects	Control for Within Bldg Agglom
	(1)	(2)	(3)	(4)	(5)	(6)
Building Height	0.0000	-	-	-0.0051	-	-
	(0.01)	-	-	(-1.47)	-	-
Concourse	1.2117	1.2154	0.9872	2.5216	1.9675	1.9012
	(5.14)	(4.82)	(3.68)	(5.78)	(2.46)	(2.11)
Ground Floor	0.5966	0.6833	0.7893	2.0926	2.2407	3.2187
	(4.14)	(4.00)	(4.65)	(7.57)	(11.67)	(3.75)
Floor 2 to 3[a]	-0.2920	-0.2422	-0.2489	-0.0743	-0.3260	0.2167
	(-2.44)	(-1.57)	(-1.51)	(-0.11)	(-0.80)	(0.48)
Floor 4 to 9[a]	0.0542	0.0205	0.0407	-0.0964	-0.0491	0.0219
	(0.54)	(0.18)	(0.35)	(-0.58)	(-0.24)	(0.11)
Floor 20 to 39[a]	-0.0210	0.0065	-0.0610	0.1518	0.4457	0.4913
	(-0.36)	(0.06)	(-0.55)	(0.95)	(3.22)	(3.68)
Floor 40 to 59[a]	0.3695	0.4382	0.2188	0.6241	0.4680	0.6120
	(1.95)	(2.52)	(1.48)	(2.10)	(1.56)	(1.88)
Floor 60 and above[a]	0.2044	0.3432	0.0699	1.1734	0.9022	1.6174
	(1.73)	(2.68)	(0.36)	(4.11)	(3.05)	(4.43)
Ann real rent/sq foot	-0.0004	-0.0018	-0.0024	0.0161	-0.0114	-0.0060
	(-0.42)	(-1.04)	(-1.56)	(4.27)	(-1.57)	(-0.83)
Headquarters	1.0210	0.8387	0.8168	0.8362	0.5809	0.7657
	(12.49)	(5.54)	(5.05)	(2.80)	(1.96)	(2.79)
Branch	0.1150	0.0442	-0.0611	0.1457	-0.1301	-0.1508
	(0.71)	(0.20)	(-0.27)	(0.81)	(-0.39)	(-0.36)
Yr orig < 1950	1.5176	1.5630	1.6819	1.4229	1.4299	1.7146
	(13.41)	(6.02)	(6.18)	(2.25)	(2.00)	(2.64)
Yr orig 1950 to 1979	1.6683	1.5098	1.5595	1.2594	0.9178	0.9504
	(11.25)	(8.61)	(8.71)	(2.45)	(1.29)	(1.43)
Yr orig 1980 to 1999	1.2632	1.1823	1.2050	1.1907	0.7872	0.8842
	(12.11)	(7.33)	(7.69)	(1.63)	(1.27)	(1.56)
Yr orig 2000 to 2009	1.0549	1.0045	1.0192	1.1748	0.4099	0.4467
	(12.92)	(5.96)	(6.09)	(2.10)	(0.62)	(0.74)

Continued on next page

Table 4 continued: Within Building Agglomeration and Density – Offering Memo Data
Dependent Variable= Log (Number of workers per 1000 square feet)

	All Industries			Law Offices		
	Without Building Fixed Effects	With Building Fixed Effects	Control for Within Bldg Agglom	Without Building Fixed Effects	With Building Fixed Effects	Control for Within Bldg Agglom
	(1)	(2)	(3)	(4)	(5)	(6)
FLA_own_0[b]	-	-	0.0324	-	-	0.0325
	-	-	(5.60)	-	-	(2.36)
FLA_own_1[b]	-	-	0.0041	-	-	0.0039
	-	-	(1.74)	-	-	(0.88)
FLA_own_2[b]	-	-	0.0010	-	-	0.0060
	-	-	(0.46)	-	-	(1.64)
FLA_own_3[b]	-	-	0.0007	-	-	0.0042
	-	-	(0.26)	-	-	(0.88)
FLA_other_0[b]	-	-	-0.0173	-	-	-0.0308
	-	-	(-2.23)	-	-	(-3.16)
FLA_other_1[b]	-	-	0.0029	-	-	0.0094
	-	-	(1.13)	-	-	(1.92)
FLA_other_2[b]	-	-	-0.0029	-	-	0.0038
	-	-	(-1.56)	-	-	(0.86)
FLA_other_3[b]	-	-	-0.0026	-	-	0.0078
	-	-	(-1.33)	-	-	(1.64)
Observations	2,567	2,567	2,567	543	543	543
City Fixed Effects	18	-	-	18	-	-
Building Fixed Effects	-	90	90	-	68	68
SIC2 Fixed Effects	60	60	60	-	-	-
Within R-Squared	0.324	0.264	0.336	0.221	0.208	0.360
Total R-squared	0.326	0.309	0.363	0.261	0.121	0.225

[a] Omitted floor category is floors 10 through 19.
[b] FLA variables measure the square footage of space occupied on the own floor (_0) and also 1, 2, and 3 floors away for own 2-digit SIC industry ("own") and establishments outside of the own industry ("other").

B. Agglomeration models: results.

1. Column (1) has city fixed effects.

2. Otherwise, building fixed effects.

3. U-shaped density gradient as above in Column (2).

4. Other controls also as above.

5. Especially sharp results for law.

B. Agglomeration models: results (cont.)

1. FLA variables: floor area to proxy for nearby activity, one of own-industry (urbanization) and one for other-industry (localization).

2. Urbanization results insignificant.

3. Localization results significant, with a clear pattern of attenuation.

4. Sorting and selection bedevil the estimation of agglomeration economies.

5. The issues seem less serious here.

VI. Vertical density and agglomeration in CompStak data

A. CS vs. OM

1. Coverage of more buildings vs. complete tenant stacks.

2. Smaller number of buildings in OM allows building FE models. Instead, we use controls such as building height to proxy for neighborhood characteristics otherwise captured by FE.

3. Hand matching for OM gives accuracy.

B. Agglomeration variables.

1. Without the complete tenant stack, we cannot use the novel FLA variables discussed above.

2. We instead use more traditional nearby employment regressors (empt. within 1/10 mile).

Table 5: Nearby Agglomeration and Density – CompStak Data
Dependent Variable= Log (Number of workers per 1000 square feet)

	All Industries			Law Offices			
	Without Employment	All Emp Within 0.1 Miles	All Emp Within 0.25 Miles	Without Employment	All Emp Within 0.1 Miles	All Emp Within 0.25 Miles	Law and Non-Law Employment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Building Height (in floors)	-0.0024	-0.0025	-0.0026	-0.0032	-0.0020	-0.0024	-0.0023
	(-0.67)	(-0.69)	(-0.69)	(-0.19)	(-0.14)	(-0.16)	(-0.15)
Ground Floor	0.4371	0.4374	0.4306	0.2614	0.1094	0.1144	0.0554
	(1.64)	(1.69)	(1.66)	(3.94)	(2.69)	(2.76)	(0.61)
Floor 2 to 3[a]	0.1371	0.1537	0.1446	0.5182	0.5345	0.4953	0.4782
	(0.71)	(0.76)	(0.70)	(2.86)	(2.67)	(2.53)	(2.25)
Floor 4 to 10[a]	-0.0101	-0.0175	-0.0277	0.3490	0.3277	0.3075	0.3139
	(-0.07)	(-0.12)	(-0.19)	(7.34)	(12.53)	(19.70)	(11.10)
Floor 20 to 39[a]	-0.0712	-0.0617	-0.0675	0.2468	0.2261	0.2141	0.2093
	(-0.51)	(-0.44)	(-0.49)	(1.27)	(1.23)	(1.12)	(1.11)
Floor 40 to 59[a]	-0.1949	-0.1919	-0.1976	0.4223	0.4462	0.4498	0.4681
	(-1.66)	(-1.73)	(-1.64)	(0.72)	(0.76)	(0.76)	(0.76)
Floor 60 and above[a]	0.5303	0.5297	0.5526	-	-	-	-
	(0.63)	(0.63)	(0.66)	-	-	-	-
Ann real rent/sq foot	0.0027	0.0027	0.0027	0.0064	0.0062	0.0060	0.0063
	(4.63)	(4.99)	(5.07)	(6.29)	(6.11)	(5.07)	(4.73)
Headquarters	0.1681	0.1678	0.1643	0.0112	-0.0163	-0.0027	-0.0233
	(2.25)	(2.32)	(2.33)	(0.07)	(-0.12)	(-0.02)	(-0.14)
Branch	0.1952	0.1666	0.1237	0.9127	1.0701	0.9388	0.9285
	(1.49)	(1.67)	(1.31)	(4.35)	(3.32)	(2.95)	(3.57)
Yr orig < 1950	-0.4956	-0.4386	-0.4678	0.7577	0.6019	0.6197	0.5773
	(-1.16)	(-1.08)	(-1.14)	(6.18)	(5.25)	(5.06)	(3.07)
Yr orig 1950 to 1979	-0.5855	-0.5493	-0.5779	0.5372	0.4887	0.5133	0.5134
	(-1.85)	(-1.85)	(-1.91)	(2.90)	(2.54)	(2.49)	(1.94)
Yr orig 1980 to 1999	-0.5712	-0.5476	-0.5827	0.6584	0.6242	0.6340	0.6208
	(-1.55)	(-1.60)	(-1.69)	(2.86)	(2.94)	(2.89)	(2.59)
Yr orig 2000 to 2009	-0.5686	-0.5413	-0.5754	-0.0161	-0.0325	-0.0180	0.0011
	(-0.98)	(-0.96)	(-1.02)	(-0.04)	(-0.08)	(-0.05)	(0.00)

Continued on next page

Table 5 continued: Nearby Agglomeration and Density – CompStak Data
Dependent Variable= Log (Number of workers per 1000 square feet)

	All Industries			Law Offices			
	Without Employment	Employment to 0.1 Miles	Employment to 0.25 Miles	Without Employment	Employment to 0.1 Miles	Employment to 0.25 Miles	Law and Non-Law Employment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
All Emp within 0.1 miles	-	-0.0025	-0.0033	-	0.0065	0.0055	-
	-	(-1.75)	(-3.33)	-	(3.05)	(2.44)	-
All Emp 0.1 to 0.25 miles	-	-	0.0006	-	-	0.0011	-
	-	-	(1.84)	-	-	(1.72)	-
Law Emp within 0.1 miles	-	-	-	-	-	-	0.0071
	-	-	-	-	-	-	(2.69)
Law Emp 0.1 to 0.25 miles	-	-	-	-	-	-	-0.0056
	-	-	-	-	-	-	(-2.15)
Non-Law Emp within 0.1 miles	-	-	-	-	-	-	0.0019
	-	-	-	-	-	-	(0.69)
Non-Law Emp 0.1 to 0.25 miles	-	-	-	-	-	-	0.0024
	-	-	-	-	-	-	(2.88)
Observations	906	904	904	520	520	520	520
City Fixed Effects	5	5	5	4	4	4	4
SIC2 Fixed Effects	39	39	39	-	-	-	-
Total R-squared	0.184	0.186	0.187	0.179	0.183	0.179	0.183

[a] Omitted floor category is floors 10 through 19.

C. CS results.

1. Ground floor density 43-44% higher.
2. Top floors have higher density, but imprecisely estimated.
3. Maybe because of the lack of building FE?
4. Negative urbanization effects.
5. Some evidence of localization in law.
6. Broadly similar to earlier OM results, but noisier.

VII. Conclusion.

A. Results.

1. The pattern of vertical density is more complex than has been thought.

2. High at ground and near top, lower in between.

3. High when productivity is high.

4. Evidence of attenuating agglomeration economies.

B. Ongoing research deals further with agglomeration.

1. The next paper in this project will probably deal with the spatial clustering of activities within buildings and at the floor level.

2. This requires improvements on standard geographic approaches to clustering, such as the Duranton-Overman (2005) statistic.

3. The present paper also suggests a refinement to standard urban economic analysis of density.