Appendix A

DOWNTOWN VIBRANCY SCORES			
Atlanta	103.3	Minneapolis	152.8
Austin	112.3	Nashville	83.5
Baltimore	151.3	New Orleans	124.3
Birmingham	59.3	New York Midtown	448.6
Charlotte	94.1	Oakland	157.7
Chicago	300.1	Oklahoma City	47.7
Cincinnati	119.1	Orlando	94.9
Cleveland	86.0	Philadelphia	211.1
Columbus	88.1	Phoenix	87.0
Dallas	134.5	Pittsburgh	134.7
Denver	152.8	Portland	158.5
Des Moines	80.3	Raleigh	50.2
Detroit	105.4	Richmond	89.1
Fort Worth	59.7	Sacramento	111.5
Grand Rapids	85.5	Salt Lake City	70.0
Hartford	82.6	San Antonio	93.6
Houston	119.1	San Diego	117.8
Indianapolis	76.0	San Francisco	230.9
Kansas City	89.9	San Jose	81.4
Las Vegas	80.3	Seattle	184.9
Los Angeles	203.0	St. Louis	106.9
Memphis	69.2	St. Paul	100.5
Miami	117.1	Tampa	72.9
Milwaukee	137.1	Washington, D.C.	222.1

ADJACENT/ANCHOR DTS			
Atlanta Midtown	63.5	NYC Downtown	329.4
Austin Medical Center	47.4	NYC Brooklyn downtown	280.3
Birmingham-UAB	70.3	Philadelphia U City	130.0
Chicago U Illinois	116.2	Phoenix North DT	63.8
Cleveland Univ Circle	41.9	Pittsburgh Oakland	98.8
Detroit Midtown	86.7	San Diego UCSD&Med Ctr	34.9
LA Hollywood	137.3	San Francisco: Civic Ctr	186.0
LA Wilshire/Koreatown	151.5	Seattle University District	111.0
Nashville Vandy Univ&Med	78.0	Washington: Georgetown	90.4

Vibrancy and Property Performance of Major U.S. Employment Centers

SECONDARY CITIES	VIBRANCY SCORE
Alexandria, VA	77.6
Ann Arbor, MI	86.0
Bellevue, WA	81.1
Durham, NC	37.0
Ft. Lauderdale	93.9
Jersey City, NJ	173.9
Long Beach, CA	97.5
Pasadena, CA	114.4
Santa Ana, CA	96.2
Scottsdale, AZ	42.0
Tacoma, WA	68.0
Tempe, AZ	56.3

SOP	VIBRANCY SCORE
Bellevue I405-I520 OP	10.6
Houston Greenway Plaza	101.9
Irvine, CA SOP	75.6
Irving, TX SOP	21.1
Las Vegas Strip	79.3
Overland Park Sprint Camp	9.9
Redmond Microsoft Camp	33.7
Richardson Texas Instru	33.5
San Bernardino South OP	33.7
Santa Clara South OP	43.0
San Jose Cisco Campus	41.0
Tysons Corner, VA	9.3

Appendix B

MODELS OF PERFORMANCE

The author and doctoral research associate Yan Chen conducted regression analysis to analyze five dependent variables, five independent variables and two dummy variables.

Dependent Variables.

Four of the five dependent variables are straightforward. We examined office asking rents and vacancy rates in 2Q17 and changes in office rents and vacancies from 2Q11 to 2Q17. The fifth dependent variable is the absolute change in the inventory of income-generating properties from 2Q11 to 2Q17, not relative inventory change. Occupancy increased over this six-year period, and the absolute amount of inventory growth represents the new supply available to absorb this amount of demand.

Independent Variables.

The variable of primary interest is the overall vibrancy score for the 90 centers shown in **Appendix A**. The size measure is what we call critical mass, which is the total number of jobs and population within the one-mile geography as compiled by Levy and Gilchrist. Critical mass is important since it should actualize the benefits of size. We intentionally double count the people who both live and work in the center since they spend considerably more time there each day compared to people who only work or only live in the center.

Employment growth is the traditional demand indicator expected to correlate with property performance outcomes. Employment growth is the ratio of employment in 2016 to employment in 2010. We measured this six-year growth rate for the 45 metropolitan areas under study. Three of the 48 urban areas contain two central cities and therefore two CBDs: Dallas-Fort Worth, Minneapolis-St. Paul and San Francisco-Oakland.

We controlled for crime and housing costs. We used the citywide murder rate per 100K population, which includes suicides, as the crime measure since the behavior of local police has less influence on this statistic than on other types of reported crime. We compiled data on housing affordability at the metropolitan level. The measure is the percentage of households who spent more than 30% of their annual income to rent or to own housing in 2010. We measure neither control variable nor employment growth for the same census-tract geography as the employment centers to reduce the possibility that the dependent variables could exert influence on the independent variables.

Dummy Variables.

We created two sets of dummy variables, one for region and one for type of center. We have four regional dummy variables for West, Southwest, Northeast and Southeast with Midwest as the base case. We have three dummy variables indicating secondary downtowns, downtowns in secondary cities or suburban centers treating CBDs as the base case.

RESULTS OF THE ANALYSIS

The amount of variation explained (adjusted R-squared) in three of five regression models was high enough to warrant the attention of real estate professionals. In the models for absolute change in inventory, office rent in 2017 and change in office rent since 2011, adjusted R-squared was 67%, 55% and 30%, respectively. However, the two vacancy models each explained less than 3% of the variation. The factors that explain vacancy rates appear to be market specific.[25] Relevant local factors such as differences in the functionality of office space, floor plate size, age and condition, time lines for new construction, conversions to other uses, etc. are not among the factors included in this analysis.

Table 5 shows the three final models that we tested for collinearity (high correlations among independent variables) and heteroscedasticity (non-random error terms). The models were heteroskedastic but not collinear according to the variance inflation test. We used robust standard errors to address heteroscedasticity. In addition, the five percent level became the threshold for significance instead of the ten percent level to establish

DEPENDENT VARIABLE			
	Rent 17/11	Abs.Ch.11-17	Rent 2Q17
Employment Growth	0.072***	142,088.8	1.432
	(0.023)	(0.023)	(0.995)
Vibrancy Score	0.136***	3,235,168***	6.121***
	(0.045)	(672,136.3)	(1.773)
Critical Mass	-0.061**	658,514.7	1.251
	(0.030)	(579,400)	(1.166)
Crime Rate	-0.014	-516,210.8**	-1.044
	(0.022)	(230,916.7)	(0.789)
House Affordability	-0.023	-149,689.8	1.380
	(0.029)	(473,433.4)	(1.038)
NE Region	0.0003	-2,400,234***	-0.197
	(0.072)	(822,495.5)	(2.599)
SE Region	0.065	878,414.8	6.703***
	(0.045)	(598,362.6)	(2.143)
SW Region	0.039	949,753.2	5.898**
	(0.052)	(713,648.5)	(2.376)
W Region	0.185**	-1,338,003	5.637**
	(0.072)	(1,243,691)	(2.743)
Secondary DT	0.082	-507,483.1	4.325**
	(0.044)	(556,727.5)	(1.890)
Suburban Center	0.079	579,411.5	4.229
	(0.075)	(844,489.7)	(2.630)
Constant	1.139***	4,485,958***	23.039***
	(0.040)	(568,615.6)	(1.498)
Observations	90	90	90
R2	0.395	0.717	0.606
Adjusted R2	0.301	0.673	0.545
Resid. Std. Error df = 77	0.176	2,335,860	6.936
F Statistic (df = 12;77)	4.195***	16.259***	9.885***

*Note: **p<0.05 ***p<0.01*

a higher standard. We standardized the five continuous independent variables in order to make their coefficient values comparable.

The model for change in rent from 2Q11 to 2Q17 has two significant variables beyond the 1% level: employment growth and the vibrancy score. Critical mass and the shift parameter for the West region are significant beyond the 5% level. However, critical mass has a negative association instead of the expected positive one. Location in the west region associates with significantly greater rent increases compared to the Midwest base case.

The standardized vibrancy score has the largest coefficient (0.136) compared to the other four interval variables and almost twice the coefficient value for employment growth (0.072). Thus, vibrancy is the most

important factor in the rent change model since one standardized unit increase in vibrancy would result in the largest increase in office rents.

The model for absolute inventory change has three significant variables: vibrancy (1% level), crime rate (5% level) and location in the northeast region (1% level). More vibrancy and less crime thus associate with higher inventory growth. The shift parameter for northeast is negative compared to the base case indicating less inventory growth in that region. Again, the vibrancy score has by far the largest standardized coefficient making vibrancy the most important factor in the model explaining absolute inventory growth.

In the third model explaining variation in 2Q17 rent levels, the vibrancy score is the only significant non-dummy variable and has the largest standardized coefficient compared to the other four interval variables. Four dummy variables are significant at either the 5% level or the 1% level. All have positive shift parameters. Rents are higher in the southeast, southwest and west compared to the Midwest. Rents are also higher in adjacent or anchored secondary downtowns compared to CBDs.

Comparing results across the three models, we find that critical mass is not significant in two of them. Critical mass has a high positive correlation with vibrancy (+0.83). This correlation suggests that vibrancy and critical mass are mutually reinforcing but that vibrancy is the more dominant factor.

Crime rate has negative coefficients in the three models and a significant one in the inventory change model. Therefore, crime has the expected negative influence on property performance.

Employment growth is positively associated with rent level and with rent increases from 2011 to 2017. One plausible explanation is that many centers adding employment have greater physical or regulatory constraints on supply and therefore will experience upward pressure on rents. However, there is a more likely explanation in the context of vibrant centers. These larger and more vibrant employment centers have "thicker" labor markets.[26] Thick labor markets attract additional employers as well as more employees, generating a positive feedback cycle. In these employment centers, space demand often exceeds supply. Rents are higher and rent increases are greater as a result.

As noted, housing affordability percentages increase as households spend more than 30% of their income on housing in the metro area. Although not statistically significant, rents and inventories increased more in metropolitan areas with more affordable housing markets. On the other hand, rent levels were highest in employment centers located in metropolitan areas with less affordable housing markets.

Regional location is somewhat important. One region is significant in the first two models; three of the four regions have significant positive effects in the model for 2017 asking rents. Although type of center is not significant in the first two models, adjacent or anchored secondary downtowns have a positive influence on 2017 office rent levels.

ENDNOTES

25. Some would cite the natural office vacancy rate, which varies from market to market. See Shilling, J, Sirmans, C.F. and Corgel, J. (1992). Natural Office Vacancy Rates: Some Additional Estimates, *Journal of Urban Economics*, 31, 140-143.

26. For more discussion of thick labor markets, see Moretti E. (2013). *The New Geography of Jobs*. Boston: Mariner Books, pp. 125-131.