Apartment Volatility Determinants Across the United States Markets

by

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Submitted to the Program in Real Estate Development in Conjunction with the Center for Real Estate in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development

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ABSTRACT

Much research has been done to examine the volatilities of return on public and private real estate investments. However, little is known about market volatility in real estate in general and in apartment real estate in particular.

This paper uses 21-year quarterly data across 46 markets in the United States to analyze the market volatility behavior of apartment real estate markets. In addition to summarizing the general profile of apartment volatilities such as vacancy change and revenue change, this paper conducts a significant amount of cross-sectional time-series regression analysis to test the determinants of such volatilities. It is found that demand volatilities dominate the volatility of vacancy change of apartment markets. As for the revenue change volatility, it is almost equally determined by occupancy change and rent change volatilities.

Furthermore, the paper finds that big markets, fast economic growth, and a decreased concentration magnitude tend to reduce vacancy and revenue volatilities. Regulations on redevelopment tend to increase the volatilities of revenue change and rent change. The supply elasticities are proved to increase the volatility of vacancy change and revenue change, but to decrease the volatilities of demand and rent change.

This paper provides a better understanding of apartment market volatilities, and can be used to hedge risk by improving apartment diversification strategies for both private equity real estate firms and public real estate investment trusts (REITs).

Thesis Supervisor: Williams Wheaton
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1. INTRODUCTION

Apartments are an important component of the country's real estate market. The United States was a renters' country in the 1920s with 56% of the population living in rental housing. Since World War II, roughly 36% of the population has lived in rental housing (Jud, Benjamin, Sirmans 1996). Also, with other property types, apartment real estate consists of investment portfolios of direct and public investors with exposure to real estate market.

It has been documented that the real estate market is cyclical (Wheaton 1999), and, empirically, apartment real estate is observed to be strongly affected by the overall economy. Many studies have focused on comparing the return of real estate with that of other asset classes. A number of studies have estimated the return and return volatility pattern of the aggregated real estate market. Some studies go further to stratify return analyses by property type. Surprisingly little is known about the market volatility of apartment real estate.

This paper describes apartment real estate market volatilities by focusing on vacancy and revenue variance over the period from 1985 to 2010, covering 45 metro areas across the United States. This is undertaken through a two-step procedure. Using cross-sectional and time-series data, I first examined the characteristics of volatilities across markets and test whether demand volatility dominates the volatility of vacancy change and revenue change in apartment real estate. Then, by running a regression analysis, I tested factors, such as market size, employment growth rate and four other explanatory variables, and determine which of these variables affect those volatilities and to what degree.

The intent of this paper is to provide a precise and objective understanding of market volatilities and their effects on apartment real estate in the United States.

2. LITERATURE REVIEW

2.1 Real Estate Return and Return Volatility Research

Because both public real estate investment trusts (REITs) and private equity investors have a growing interest in real estate, much existing research about the real estate market is focused on the return and return volatility of real estate markets (Riddiough, Moriarty, Yeatman 2005, Goetzmann, and Valaitis 2006, Mueller, Boney, and Mueller 2008). Some research compares the return and volatility of public real estate with other general equity investments (Robertson 2007). Geltner, and Goetzman (2000) documented 20 years of commercial real estate performance in the United States using data from the National Council of Real Estate Investment Fiduciaries (NCREIF) Property Index. By using a Repeated - Measures Regression-Based Version of the NCREIF Index, they found that the real estate returns from 1977 to 1997 were volatile and the magnitude of volatilities of different property types were different. Return in office space is more volatile than other property types, including apartment, retail, and industrial.

Using the combination of NCRIEF Property Index and two other data sources, Ling and Naranjo (1999) prove that the market for exchange-traded real estate companies, including REITs, is integrated with the market for exchange-traded (non-real-estate) stocks. Work done by Case, Goetzman, and Rouwenhost (2000) finds strong evidence that the correlation among international real estate markets is high, despite the fact that they are segmented.

Meanwhile, as seen in the literature review above, most research estimating return and return volatility of commercial real estate uses data from NCREIF. The advancement of NCREIT is that it offers sufficient data covering various property types over a long period of time. However, there are some drawbacks to using NCREIF data. The NCREIF suffers an appraisal-smoothing and apparent seasonality problem, which leads to some bias. To modify this problem, Fisher, Geltner, Gatzlaff and Haurin (2003) developed a method estimating returns and their volatilities by using transaction indices. This method raises some concern about the lack of sufficient transaction data. An improved alternative to NCREIF, publicly traded real estate securities data is used to estimate commercial real estate return because stock markets can incorporate information more quickly than appraisers. The correlation of real estate returns with other equity assets is found in the work by Liu and Mei (1992).

When calculating return, two components, including both cash flow return and price appreciations, are incorporated to estimate the total return. Therefore, return volatility does not capture market volatility.

2.2 Apartment Real Estate Behavior Study

A number of academic studies have been done on apartment real estate behaviors, including apartment real estate cycles, demand and supply, hedonic analysis of rents, vacancy rates and market equilibrium, and other broad issues.

In their study of residential housing construction in the United State since World War II, Grebler and Burns (1982) showed that residential construction leads GNP by peaking one year earlier but tends to move together with overall economy during troughs. Demand and supply elasticity research can be found in several researchers' work. Using Annual Housing Survey data for renters in 1977, Goodman and Kawai (1984) found that measured income elasticity varies from +0.2 to +0.3. This suggests that the rental housing market is sensitive to income and overall economics. Based on work done by Follain (1999), the long-run supply housing is completely volatile with respect to price. Also, Grieson (1973) reports price elasticity varies from 1.8 to 2.2, showing that rental housing is very volatile. Hedonic approach has been widely used to analyze rental income and values. The hedonic approach believes that rent is determined by a series of physical attributes of properties and other non-physical characteristics like property management and security factors. Current hedonic research can be found at Follain and Gunterman and Norrbin (1987), Jud and Winkler (1991), and many others.

Because vacant apartment units are often observed, it has been believed that a natural vacancy rate exists, suggesting that under the natural vacancy rate, not the zero vacancy rate, the rental market is clear, reaching market equilibrium. Gabriel and Nothaft (1988) found that the natural vacancy rate on average across cities in their sample is 8%. They also found that natural vacancy rates are higher in rapid growth cities. That suggests that the pattern of vacancy varies by employment growth rate of cities.

2.3 Market Volatility Analyses on Other Property Types

Despite a sizable body of studies done in exploring the return and return volatility and apartment market behaviors, much less has been done in estimating market volatilities in the general real estate market and in specific property types. That is highly likely due to insufficient cross-sectional and time- series data. However, there are a few remarkable exceptions. Wheaton (1987) studied the office market cyclic behaviors. Wheaton (1999) further discovered that different property types of real estate markets have very different cyclic properties. Using rental data from REIS reports for a period of ten years from 1981 to 1990 for twenty-one metro areas, Pollakowsaki, Wacher, and Lynford (1992) found that office market behaviors vary by market size, and larger markets' behaviors are better interpreted by classical models. Using data source from PricewaterhouseCoopers and F.W.Dodge/McGraw-Hill and other sources, Gallagher and Mansour (2000) examined hotel market characteristics in both national and metro levels, with various measures of supply and demand volatility, and historical revenue per available room (REVPAR) performance. Unfortunately, similar work regarding market volatility on apartments has not been found.

3. DATA

The source of the most real estate data in this paper is the CBRE TWR, based in Boston. CBRE TWR gathers data through its affiliates in the United States. Key data items include stock, employment, average rent, vacancy, population, income, and submarket stock, all of which are quarterly-based extending from the fourth quarter of 1985 to the first quarter in 2010 for 54 metropolitan areas in the United States.

The data set this paper is using is based on a filtered subset of the original CBRE data. Due to the lack of information of Wharton Regulatory Index in some markets, this paper draws a data set consisting of a 21-year period of the second quarter of year 1989 through the first quarter of year 2010 for 46 metropolitan areas. There are 64 observations for each metro area.

From these basic data, I construct vacancy rate, completion, absorption, and other variables described in the following sections.

3.1 Data Specification

Based on the work of Wheaton (1987), this paper develops the equations and models as follows,

$$\%V_{rt} = \frac{V_{rt}}{S_{rt}}, \qquad (1)$$

where $\%V_{rt}$ denotes the vacancy rate in area r at the time t, V_{rt} is the vacancy in area r at the time t, and S_{rt} is stock in area r at the time t. Vacancy rate is viewed as an indicator of the relationship of demand and supply.

The completion, used as a proxy to supply of apartment space, is specified as the difference of stocks between one year and the previous year:

$$C_{rt} = S_{rt} - S_{rt-1}, \qquad (2)$$

where C_{rt} is the completion in metropolitan area r at the time t, S_{rt} is the stock in r at the time t and S_{rt-1} is the stock in r at the time t-1.

The absorption, used as a proxy to demand of apartment space, is specified as follows,

$$A_{rt} = C_{rt} + V_{rt-1} - V_{rt}\ , \qquad (3)$$

where A_{rt} is the absorption in metropolitan area r at the time t, C_{rt} is the stock in r at the time t V_{rt} is the vacancy in r at the time t and V_{rt-1} is the vacancy in r at the time t-1.

Dividing the Equation (3) by stock, I obtain

$$\frac{\Delta V_{rt}}{S_{rt}} = \frac{C_{rt}}{S_{rt}} - \frac{A_{rt}}{S_{rt}}\ , \qquad (4)$$

where ΔV_{rt} is the vacancy change.

The rent change is specified as follows,

$$\%\Delta R_{rt} = \frac{R_{rt} - R_{rt-1}}{R_{rt-1}}, \qquad (5)$$

where $\%\Delta R_{rt}$ is the percentage of rent change in the area r at the time t, R_{rt} is the rent in r at the time t, and R_{rt-1} is the rent in r at the time t. While the effective rent data is given in nominal terms, this paper converts to real US dollar terms by deflating them with the nation-wide US CPI index over the same period of time from Bureau of Labor Statistics, U.S. Department of Labor.

$$\Delta\%EMP_{rt} = \frac{EMP_{rt}}{EMP_{rt-1}} - 1, \qquad (6)$$

where $\Delta\%EMP_{rt}$ is the employment growth rate in the area r at the time t, EMP_{rt} is the employment in r at the time t, and EMP_{rt-1} is the employment in r at the time t-1.

Important lags during market prediction behavior likely exist in some relationships between variables expressed in the specifications above. However, having considered the effects of lags, this paper deliberates conducting specifications to incorporate this effect. For example, in

Equation (2), the difference of stock in the current year and previous year is designated to the completion in the current year, not the completion in the previous year.

3.2 Variable Descriptions

Table 1 exhibits the definitions of dependent and explanatory variables.

3.2.1 Dependent Variables

There are four dependent variables.
The first dependent variable is the *volatility of vacancy change*, which is defined in the Equation (9) in Chapter 4, capturing the variance of vacancy change.

The second dependent variable is the *volatility of revenue change,* which is defined in the Equation (14) in Chapter 4, depicting the volatility characteristics of revenue change.

The next dependent variable is the *demand share*, defined in the Equation (17) in Chapter 4. This variable is intended to capture how much *volatility of vacancy change* is due to demand volatility adjusted for covariance.

The last dependent variable is the *rent share*, specified in the Equation (22) in Chapter 4. This variable is designated to test how much *volatility of revenue change* is subject to rent volatility adjusted for covariance.

Table 1: Definitions of Variables

Definitions of Variables

Variable Name	Definition
Dependent variables	
Volatility of Revenue change	variance of revenue change
Volatility of Vacancy Change	variance of vacancy change
%D	the share of demand volatility adjusted for covariance
%R	the share of revenue change volatility adjusted for covariance
Independent Variables	
Employment	the average of employment growth rate
Employment Volatility	the volatility of employment growth change
Market	
Size	proxy to average of stock
WRI	physical or regulatory development constraints(Metro Areas with Pop over 50,000)
Concentration Index	describe the concentration degree of each metro area
Supply Elasticities	describe the supply elasticity characteristics

Source: Author

3.2.2 Explanatory Variables

There are six hypothesized explanatory variables.

The first explanatory variable is *employment growth rate*. It is the average of $\Delta\%EMP_{rt}$ for each market, the quarterly employment growth rate at the Equation (6), which is explained in detail in the following section.

The second explanatory variable is *volatility of employment growth rate,* which is the variance of $\Delta\%EMP_{rt}$, the quarterly employment growth rate at the Equation (6).

The third explanatory variable is *market size*, which is proxy to the average of S_{rt} in the Equation (1), the quarterly stock in the area r at time t.

Another data source is the *Supply Elasticities* developed by Saiz (2010). Based on natural, such as land scarcity, and policy constraints, the estimates of the *Supply Elasticities* combined geographic, regulatory constraints, and initial population levels in 2000. Appendix 2 presents the estimates for metropolitan areas with populations over 500,000 in 2000. The lower values in the *Supply Elasticities* can be thought of as being more inelastic. The metro areas with greater values in *Supply Elasticities*, are conversely more elastic. The population-weighted average of *Supply Elasticities* is 1.75 in metro areas and 2.5 unweighted. Miami, Los Angeles, San Francisco, San Diego, Oakland, Salt Lake City, Ventura, New York, and San Jose are the top ten cities on the list of most inelastic cities. Those cities are constrained by either the physical environment or policies. Austin, Kansas City, and Austin are larger metro areas with highly elastic supply. Those cities are mostly in the Midwest and have more developable land and have relatively loose policy control on real estate development.

The next variable is *Wharton Regulation Index (WRI),* obtained from the 2005 Wharton Regulation Survey. Analyzing the survey result, Gyourko, Saiz, and Summers (2008) create the

WRI to measure local policy controls on real estate development. Lower values in the *WRI* denote loose policies on real estate development. Metropolitan areas with higher values of the *WRI* can be deemed as having relatively stringent zoning regulations or project approval processes that limit new real estate development projects or redevelopment activities. The probability sample weights created by Gyourko, Saiz, and Summers (2008), Saiz (2010) processed the municipal-based data to construct average regulation indices by metro areas.

Appendix 3 exhibits the average *WRI* values for all metro areas in the United States with populations greater than 500,000. As seen in the table, most coastal cities have higher values of the *WRI* and the cities in the South and Midwest have lower values of the *WRI*. For example, amongst all 95 metro areas, the Boston area has the highest value of 1.7. The Boston Redevelopment Authority is well known for its stringent requirements on real estate redeployment.

The last explanatory variable is the *Concentration Index*, which is calculated as follows,

Concentration index = $\sum_{i=1}^{m}\left(\frac{S_i}{\sum(S_i)}\right)^2$,

where S_i stands for submarket size in the submarket area *i*, which is the proxy to stock of submarkets of each metro area, and *m* stands for the amount of the submarket in each metro area. The higher values in the *Concentration Index* can be thought of as being concentrated, while the lower values mean that the metro area is more dispersed. Therefore, the value 1 means that the metro area is concentrated in one market. The value 0 means that the metro area is completely dispersed. The index has a minimum value when stocks are equally dispersed across submarkets. If stocks are equally dispersed and the number of submarkets (*m*) gets bigger, the Index converges into 0. The *Concentration Index* is exhibited in Appendix 4. In the *Concentration Index*, the arithmetic mean of concentration level is 0.17. Dallas is the most concentrated, or the least dispersed, because all the submarkets are almost equally sized. In addition, the number of submarkets in the Dallas metro area is 30, the most amongst 46 metro areas, for which data is available. The most concentrated metro area is Newark with the value in the Concentration Index at 0.44. Newark has only three submarkets, one of which accounts for 60% of the metro area's total stock.

4 METHODOLOGY

In this paper, I use 21-year data for the period 1989 through 2010 to examine the market volatility of the apartment real estate market in 46 metro areas in the United States. I employ a two-step procedure to analyze the market volatility of apartment real estate market.

The first step is to analyze market volatility across market areas, estimating volatilities of vacancy changes and revenue changes. Then, I run decomposition analyses of vacancy change volatility and revenue change volatility, separately. The intent is to test if demand volatility is dominant in determining vacancy volatility, and if occupancy volatility dominates revenue change volatility.

The second step is to run regression analyses to specify vacancy change volatility and revenue change volatility in which each of these two factors is a function of a series of explanatory variables, including the *concentration index, WRI, supply elasticities, market size, employment growth rate, and volatility of employment growth rate.* By running regression analyses, I further specify the demand share and rent share as a function of the same six explanatory variables, separately.

It is necessary to note that, in order to examine seasonality, this paper also constructs the trailing year-to-year calculation of volatility. However, no significant difference has been found. The methodology described here is applied to the data described in Chapter 3. The results will be presented in two separate chapters, Chapter 5 for vacancy volatility analyses and Chapter 6 for revenue volatility analyses.

4.1 Volatility Analysis of Vacancy Change and Revenue Change

In this step, I first estimate the volatility characteristics of vacancy change, demand, supply, revenue change, occupancy change, and rent change across metro areas. Here, the volatility of absorption denotes the demand volatility, while that of completion refers to the supply volatility. Note that this paper tests volatilities of vacancy change, revenue change, and rent change, and not volatilities of vacancy, revenue, and rent. The reason why this paper uses those change metrics instead of level metrics is that it focuses on the trend of those changes, not the alteration of those level metrics. This approach will eliminate the effect of magnitudes of different markets and make fair comparisons among markets. By ranking all the 46 metro markets by vacancy volatility and revenue volatility separately, I discuss the results to examine which markets are more volatile than others.

Second, I construct decomposition analyses of vacancy change and revenue change. As for vacancy change volatility, I decompose it into two components, the supply share and the demand share. The supply share is the supply volatility adjusted for covariance and the demand share is the demand volatility adjusted for covariance. By doing this, I can observe in what degree the vacancy volatility is subject to demand volatility. Similarly, I decompose revenue change volatility into two components, the rent share and the occupancy share. The rent share is the rent change volatility adjusted for covariance and the occupancy share is the occupancy change volatility adjusted for covariance. Then, I estimate if occupancy change volatility dominates the revenue change volatility. In order to estimate the link between these variables, I will construct further analysis to separate covariance.

The models constructed in this paper are specified as follows.

Expected rents and the expected rents change are the functions of vacancy rates:

$$R_{rt} = \alpha_1 + \beta_1 * \%V_{rt} \text{ ,and} \qquad (7)$$

$$\frac{\Delta R_{rt}}{R_{rt}} = \alpha_2 + \beta_2 * \%V_{rt}, \tag{8}$$

where ΔR_{rt} is the rent change in the r at the time t, R_{rt} is the rent in r at the time t and $\%V_{rt}$ is the vacancy rate in r at the time t. The Equation (7) is constructing in absolute term while the Equation (8) is in percentage term.

From the Equation (4), I obtain,

$$\sigma^2(\frac{\Delta V_{rt}}{S_{rt}}) = \sigma^2(\frac{C_{rt}}{S_{rt}}) + \sigma^2(\frac{A_{rt}}{S_{rt}}) - 2 * \sigma^2(\frac{C_{rt}}{S_{rt}}, \frac{A_{rt}}{S_{rt}}), \tag{9}$$

where $\sigma^2(\frac{\Delta V_{rt}}{S_{rt}})$ is the variance of the change in vacancy rate, $\sigma^2(\frac{C_{rt}}{S_{rt}})$ is the variance of C_{rt} over stock, $\sigma^2(\frac{A_{rt}}{S_{rt}})$ is the variance of A_{rt} over stock, and $\sigma^2(\frac{C_{rt}}{S_{rt}}, \frac{A_{rt}}{S_{rt}})$ is the covariance of $\frac{C_{rt}}{S_{rt}}$ and $\frac{A_{rt}}{S_{rt}}$.

Revenue is specified:

$$REV_{rt} = \frac{OC_{rt}}{S_{rt}} * R_{rt} = (1 - \%V_{rt}) * R_{rt} \tag{10}$$

where REV_{rt} is the revenue in r at the time t, $\%V_{rt}$ is the vacancy rate in r at the time t, R_{rt} is the rent in r at the time t, which is specified in Equation (1).

From the equation above, I obtain:

$$Log(REV_{rt}) = Log(\frac{OC_{rt}}{S_{rt}}) + Log(R_{rt}), \text{ and} \tag{11}$$

$$\sigma^2 Log(REV_{rt}) = \sigma^2 Log(\frac{OC_{rt}}{S_{rt}}) + \sigma^2 Log(R_{rt}) + \sigma^2 \left[Log(\frac{OC_{rt}}{S_{rt}}), Log(R_{rt}) \right], \quad (12)$$

where $\sigma^2 Log(REV_{rt})$ is the variance of $Log(REV_{rt})$, $\sigma^2 Log(\frac{OC_{rt}}{S_{rt}})$ is the variance of $Log(\frac{OC_{rt}}{S_{rt}})$, $\sigma^2 Log(R_{rt})$ is the variance of $Log(R_{rt})$, and $\sigma^2 \left[Log(\frac{OC_{rt}}{S_{rt}}), Log(R_{rt}) \right]$ is the covariance of $Log(\frac{OC_{rt}}{S_{rt}})$ and $Log(R_{rt})$.

Equation (10) evolves to,

$$\%\Delta REV_{rt} = \%\Delta(\frac{OC_{rt}}{S_{rt}}) + \%\Delta R_{rt}, \quad (13)$$

where $\%\Delta REV_{rt}$ is the growth rate of revenue change in area r at the time t, $\%\Delta(\frac{OC_{rt}}{S_{rt}})$ is the percentage change of occupancy rate, and $\%\Delta R_{rt}$ is the percentage change of rent.

From the Equation (12), I have,

$$\sigma^2(\%\Delta REV_{rt}) = \sigma^2 \left[\%\Delta(\frac{OC_{rt}}{S_{rt}}) \right] + \sigma^2(\%\Delta R_{rt}) + \sigma^2 \left[\%\Delta(\frac{OC_{rt}}{S_{rt}}), \%\Delta R_{rt} \right], \quad (14)$$

where $\sigma^2(\%\Delta REV_{rt})$ is the variance of $\%\Delta REV_{rt}$, $\sigma^2 \left[\%\Delta(\frac{OC_{rt}}{S_{rt}}) \right]$ is the variance of $\%\Delta(\frac{OC_{rt}}{S_{rt}})$, and $\sigma^2(\%\Delta R_{rt})$ is the variance of $\%\Delta R_{rt}$, $\sigma^2 \left[\%\Delta(\frac{OC_{rt}}{S_{rt}}), \%\Delta R_{rt} \right]$ *is the covariance of* $\%\Delta(\frac{OC_{rt}}{S_{rt}})$ *and* $\%\Delta R_{rt}$.

In order to construct decompositions analysis, the following models are developed.

$$D = \sigma^2(\frac{A_{rt}}{S_{rt}}) - \sigma^2(\frac{C_{rt}}{S_{rt}}, \frac{A_{rt}}{S_{rt}}), \text{ and} \tag{15}$$

$$S = \sigma^2(\frac{C_{rt}}{S_{rt}}) - \sigma^2(\frac{C_{rt}}{S_{rt}}, \frac{A_{rt}}{S_{rt}}), \tag{16}$$

where D denotes the demand volatility adjusted for covariance and S denotes the supply volatility adjusted for covariance.

From Equation (15) and (16), I have

$$\%D = \frac{D}{\sigma^2\left(\frac{\Delta V_{rt}}{S_{rt}}\right)} = \frac{D}{D+S}, \text{ and} \tag{17}$$

$$\%S = \frac{S}{\sigma^2\left(\frac{\Delta V_{rt}}{S_{rt}}\right)} = \frac{S}{D+S}, \tag{18}$$

where the $\%D$, referring to the demand share, is specified as the D over the variance of vacancy change $\sigma^2\left(\frac{\Delta V_{rt}}{S_{rt}}\right)$, while $\%S$, referring to the supply share, is specified as the S over the vacancy change $\sigma^2\left(\frac{\Delta V_{rt}}{S_{rt}}\right)$.

Obviously, demand share plus supply share is equated to 1.

$$\%D + \%S = 1 \tag{19}$$

Applying the same approach to revenue change volatility analyses, I obtain,

$$R = \sigma^2\left(\%\Delta R_{rt}\right) + \sigma^2\left[\%\Delta(\frac{OC_{rt}}{S_{rt}}),\%\Delta R_{rt}\right], and \tag{20}$$

$$\frac{OC}{S} = \sigma^2\left(\%\Delta(\frac{OC_{rt}}{S_{rt}})\right) + \sigma^2\left[\%\Delta(\frac{OC_{rt}}{S_{rt}}),\%\Delta R_{rt}\right], \tag{21}$$

where *R* denotes the rent change volatility adjusted for covariance and $\frac{OC}{S}$ denotes the occupancy rate change volatility adjusted for covariance.

From Equations (20) and (21), I have

$$\%R = \frac{R}{\sigma^2(\%\Delta REV_{rt})} = \frac{R}{R + \frac{OC}{S}}, \text{ and} \tag{22}$$

$$\%\frac{OC}{S} = \frac{\frac{OC}{S}}{\sigma^2(\%\Delta REV_{rt})} = \frac{R}{R + \frac{OC}{S}} \tag{23}$$

The *%R*, referring to the rent share, is specified as the *R* over the variance of revenue change $\sigma^2(\%\Delta REV_{rt})$, while $\%\frac{OC}{S}$, referring to the occupancy share, is specified as the $\frac{OC}{S}$ over the variance of revenue change $\sigma^2(\%\Delta REV_{rt})$.

Obviously, the rent share plus the occupancy share is equated to 1.

$$\%R + \%\frac{OC}{S} = 1 \tag{24}$$

4.2 Regression Analyses of Volatilities of Vacancy Change and Revenue Change

In the second stage, I specify a vacancy rate volatility model in which the vacancy rate volatility is the function of six explanatory variable, including the *concentration index, WRI, supply* *elasticities, market size, employment growth rate, and volatility of employment growth rate.* The vacancy rate volatility regression is defined in equations below. There are three models for each regression analysis. In Model 1, the regression analysis only includes four independent variables – *supply elasticities, market size, employment growth rate, and volatility of employment growth rate*. Model 2 adds WRI. In model 3, all six hypothesis-related test variables are included.

The vacancy change volatility specification is defined as follows,

$$\sigma^2(\frac{\Delta V_{rt}}{S_{rt}}) = \alpha + \beta_1 * CI + \beta_2 * WRI + \beta_3 * SE + \beta_4 * M + \beta_5 * E + \beta_6 * VE + e, \qquad (25)$$

where $\sigma^2(\frac{\Delta V_{rt}}{S_{rt}})$ is the vacancy change volatility, and as in all three subsequent specifications, CI denotes *concentration index*, WRI denotes *WRI*, SE denotes *supply elasticities*, M denotes *market size*, E denotes *employment growth rate*, and VE denotes *volatility of employment growth rate*, all of which are endogenous to change of $\sigma^2(\frac{\Delta V_{rt}}{S_{rt}})$. The α is the intercept and the *e* is the error term.

Then, I perform another regression, regressing the demand share ($\%D$), which is defined in Equation (17). The demand share specification is defined as follows,

$$\%D = \alpha + \beta_1 * CI + \beta_2 * WRI + \beta_3 * SE + \beta_4 * M + \beta_5 * E + \beta_6 * VE + e, \qquad (26)$$

As for the regression analysis of revenue change volatility, the same approach is employed. The revenue change volatility specification is defined as follows,

$$\sigma^2(\%\Delta REV_{rt}) = \alpha + \beta_1 * CI + \beta_2 * WRI + \beta_3 * SE + \beta_4 * M + \beta_5 * E + \beta_6 * VE + e, \qquad (27)$$

where $\sigma^2(\%\Delta REV_{rt})$ is the volatility of revenue change.

Then, I regress the rent share ($\%R$), which is defined in Equation (22). The rent share specification is defined as follows.

$$\%R = \alpha + \beta_1 * CI + \beta_2 * WRI + \beta_3 * SE + \beta_4 * M + \beta_5 * E + \beta_6 * VE + e, \qquad (28)$$

5 VOLATILITY OF VACANCY CHANGE

The procedure described in Chapter 4 is applied to the database depicted in Chapter 3. The results are presented in the following figures and tables.

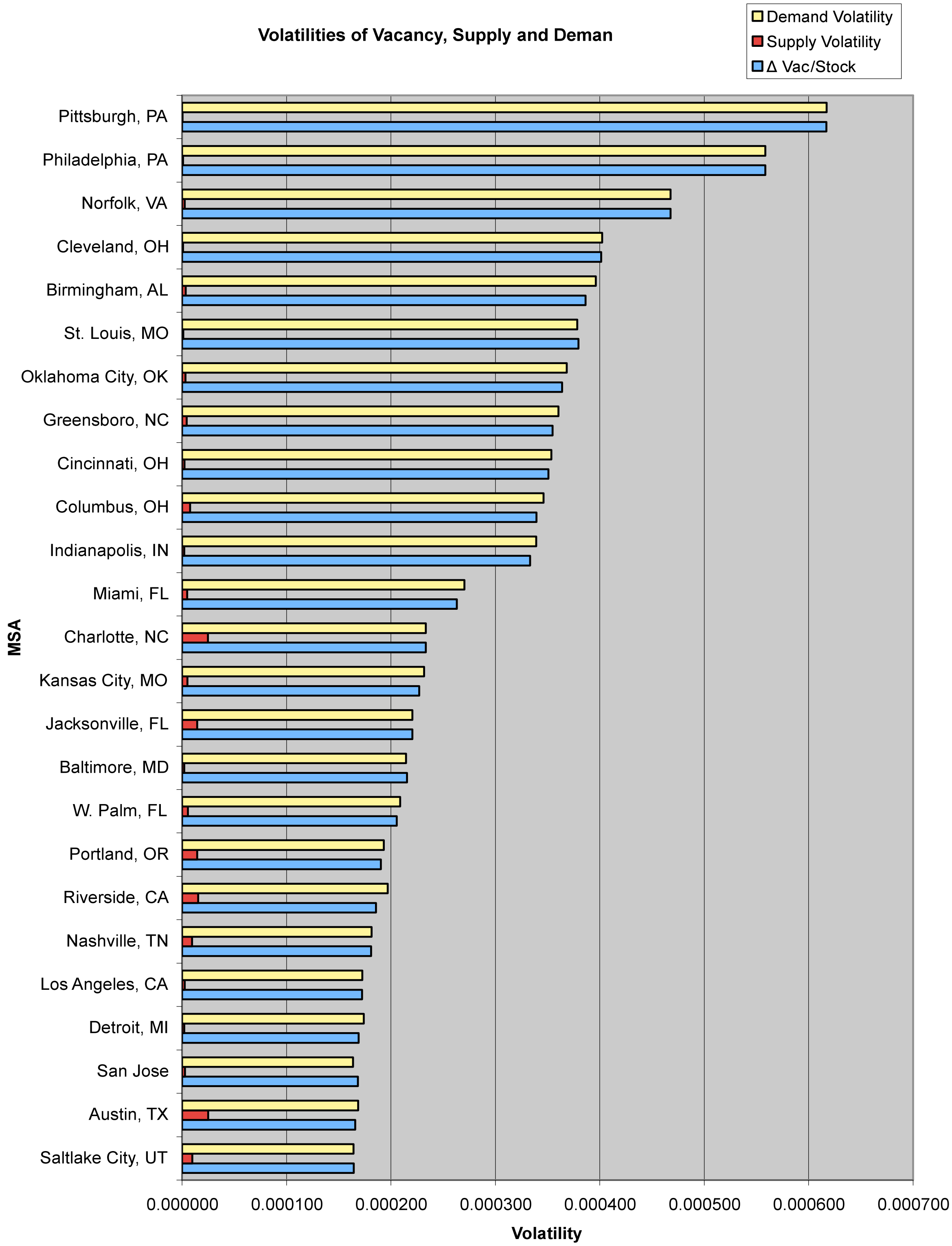
5.1 Vacancy Change, Supply and Demand

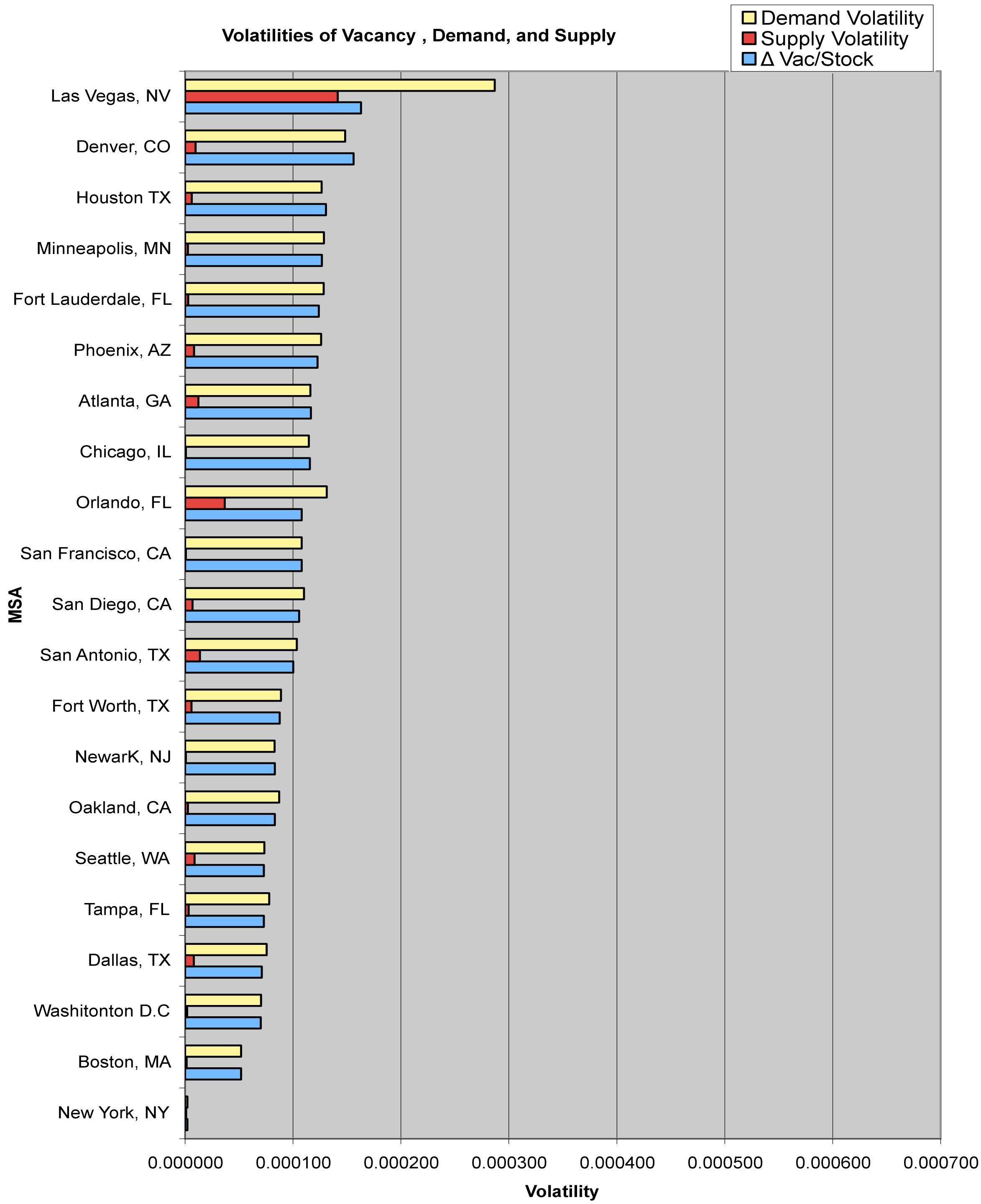
Figure 1 exhibits descriptive statistics characterizing volatilities of vacancy rate change, demand, and supply across markets from 1989 to 2010 across the 46 metro areas.

The average vacancy change volatility is 0.000204, with a range from 0.000002 to 0.000617. The average demand volatility is 0.000617 varying from 0.000002 to 0.000617. The average demand volatility is 0.000010, with a range from 0.000001 to 0.000141. It is clear that volatility varies by metro areas.

The top ten markets, as ranked by vacancy change volatility, include three mid-Atlantic cities Pittsburg, Pilladelphia, and Norfolk, with most in the Midwest. The markets with the lowest degree of vacancy volatility include some of the large apartment markets such as New York, Washinton D.C., and Boston. It is interesting to note that three metro areas in Texas - Dallas, Fort Worth, and San Antonio - are among the least volatile areas. This might be related to their unique supply elasticicities. This will be discussed in detail later. The remaining seven are either located on the east coast or west coast, where the economy is more vibrant and diverse. New York has the least vacancy volatility, demand volatility, and supply volatility, all of which are close to zero.

Figure 1: Volatility of Rent Change, Supply and Demand





Notes: Supply volatility is the variance of quarterly completion change as % of stock adjusted for covariance. Demand volatility is the variance of quarterly absorption change as % of stock, adjusted for covariance.
Source: Author

It is also interesting to note that the volatility of supply in all cities is very small, except for Las Vegas and Orlando. Las Vegas is one of the the nation's most desirable tourist destinations, as well as an international convention and luxury recreation destination. The economic factors are highly influenced by the general economic sitution. When the economy is booming, there are more vistors in Las Vegas. In contrast, when the economy is slow, consumers tend to limit spending on travel. When the economy vacillates, it becomes difficult to predict, so the volatility of supply becomes greater. The situation is similar for Orlando, Florida, also a tourism-based city.

5.2 Decomposition of Vacancy Change

5.2.1 Decomposition of Vacancy Change Volatility into Demand Share and Supply Share

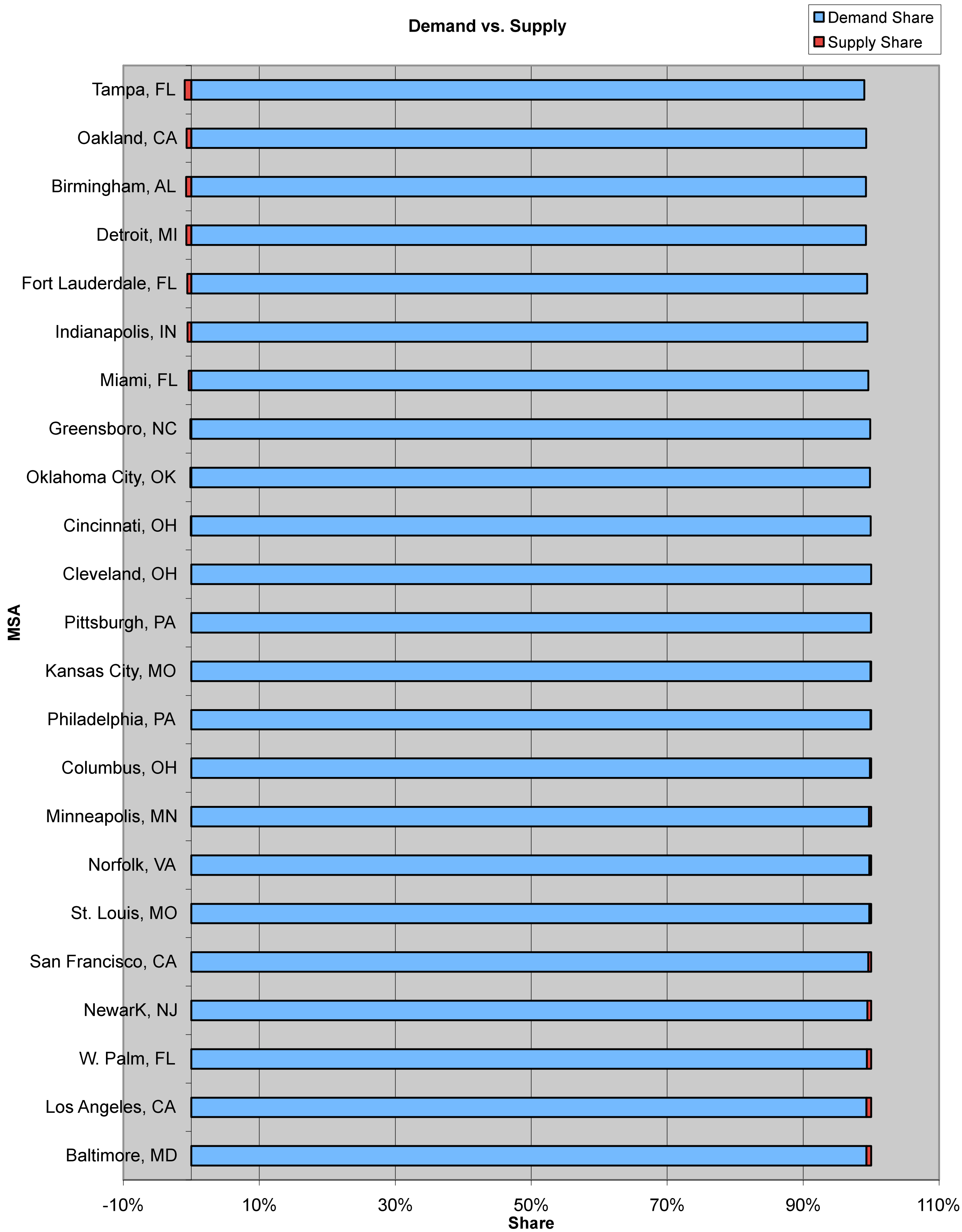
Figure 2 shows that the shares of two components of vacancy change volatility.

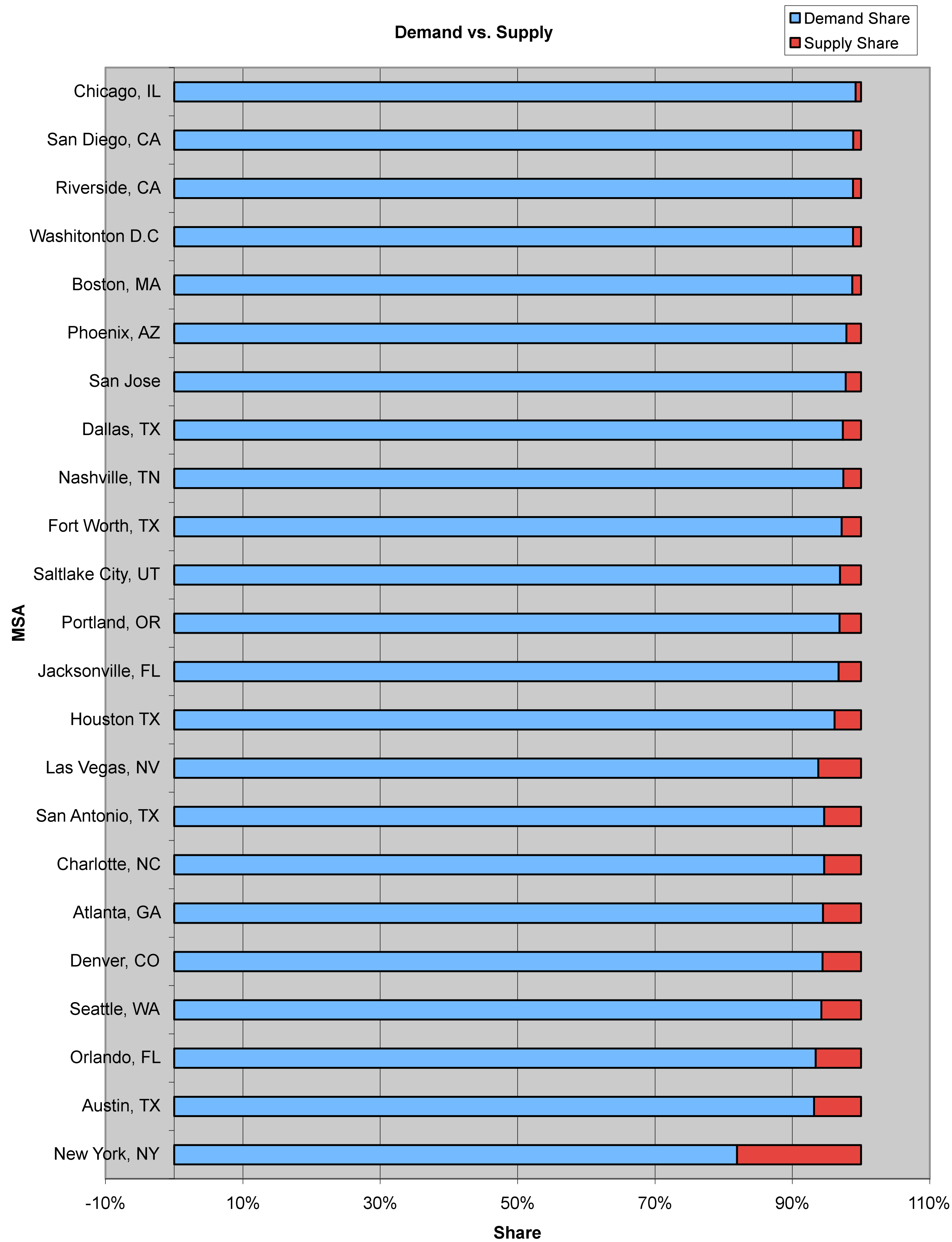
The average share of the demand share is 98%, ranging from 82% to 101%, while the average share of supply is 2% varying from -1% to 18%. It is apparent that demand volatility is the dominant factor of vacancy change volatility. New York is the city where the demand share is most dominant, and Tampa is the one where the demand is least dominant.

This may be explained by three factors.

First, the lag between start and completion of the apartment market is much less substantial than other property types like offices and hotels. The development lag of apartment buildings is widely known to be very short – typically one year (Wheaton 1999). Unlike office or hotel properties, which may take two to three years to design, construct, and stablize, apartment buildings may only take one year to one year and a half years to construct, due to their relatively small sizes and simplicities. This helps developers better evaluate and respond to markets, resulting in a smoothed supply volatility.

Figure 2: Demand Share vs. Supply Share





Demand vs. Supply
Demand Share
Supply Share
MSA
Chicago, IL
San Diego, CA
Riverside, CA
Washitonton D.C
Boston, MA
Phoenix, AZ
San Jose
Dallas, TX
Nashville, TN
Fort Worth, TX
Saltlake City, UT
Portland, OR
Jacksonville, FL
Houston TX
Las Vegas, NV
San Antonio, TX
Charlotte, NC
Atlanta, GA
Denver, CO
Seattle, WA
Orlando, FL
Austin, TX
New York, NY
-10%
10%
30%
50%
70%
90%
110%
Share

Second, the short-term leases of apartment markets result in rapid reponses to the market situation. Unlike office markets, which constrain long term leases which range from three years to thirty years, the typical lease of apartments is one year. These short-term leases will reflect the relationship of supply and demand through vacancy rates and adjusted rents. Rent is usually renewed annually. Thus, developers and investors can adjust their developments or investments almost simultaneously. Therefore, the supply volatility is futhure reduced.

In addition, apartments have a heterogeneous mix of tenants of varying lengths. Usually, one tenant occupies only one unit. The blending of a large number of tenants eliminates the oscillation of occupancy. By constrast, one tenant may occupy an office building from 10% to 100%. If this tenant defauts or moves out, the vacancy rate might be 100%. It is often observed that apartment markets have a relativley flat vacancy rate year to year.

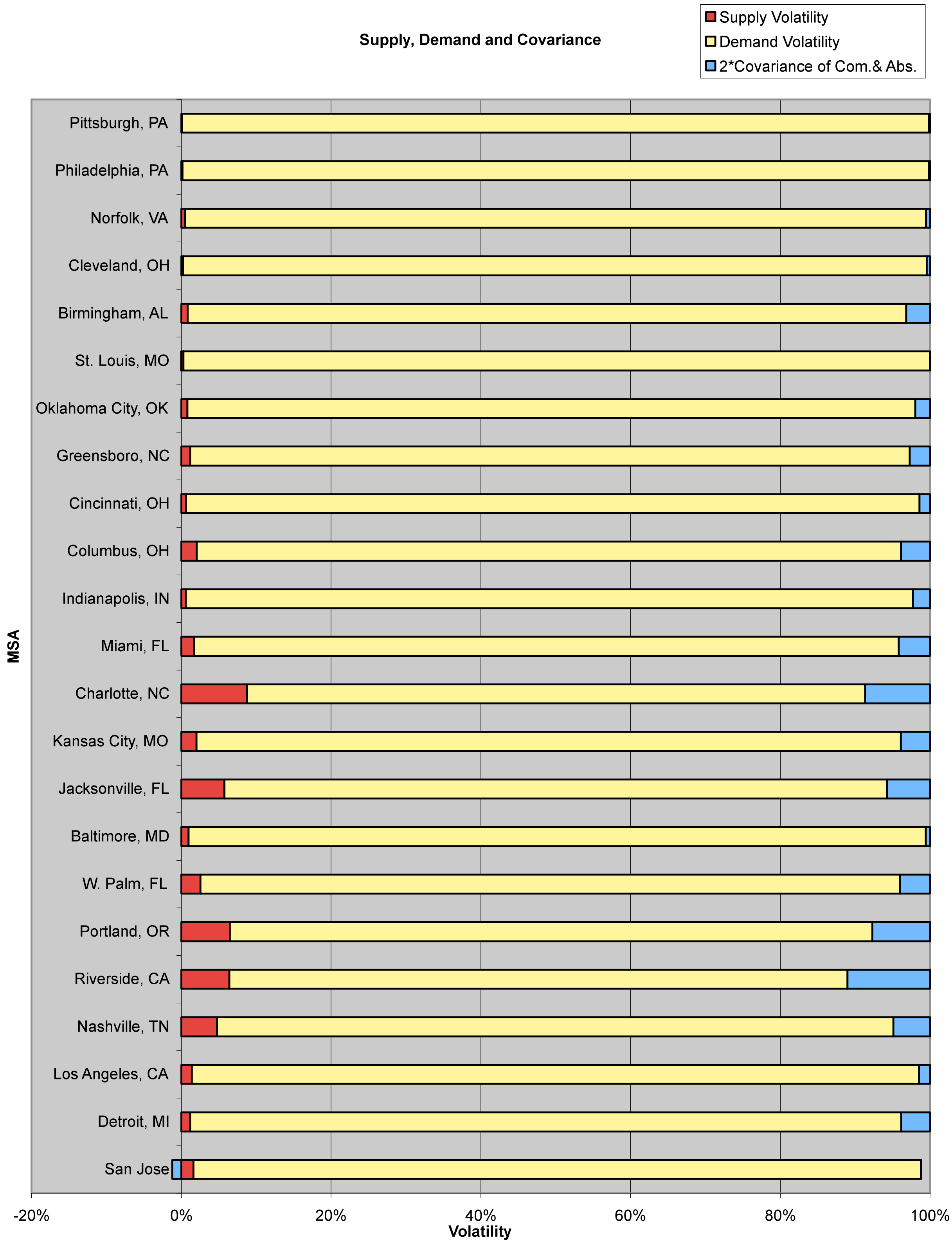
5.2.2 Decomposition of Vacancy Change Volatility into Demand, Supply and Covariance

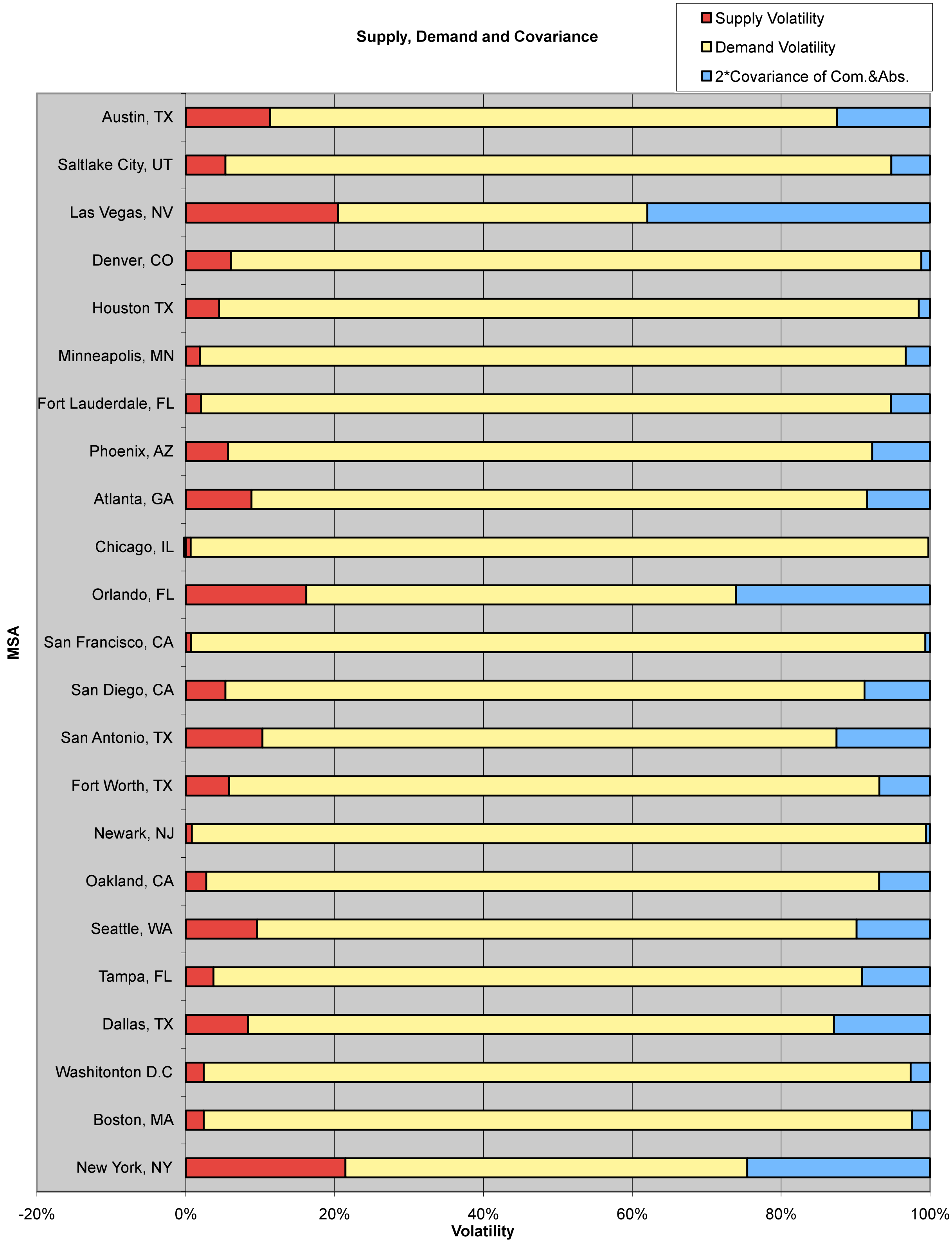
In this section, the vacancy change volatility is decomposed into three components: demand volatility, supply volatility, and two times of covariance of demand and supply. Figure 3, where cities are ranked by vacancy change volatility, graphically shows the results. The same is true in Figure 1, Phildelphia has the most voalitity and New York has the least.

The average covariance is 0.000007, ranging from -0.000001 to 0.000131. Las Vegas, Orlando, and New York are the three cities where the covariances are the highest, and San Jose has the least covariance. The other cities are all flat.

Recall from the Equation (9) that the covariance of demand and supply will reduce the vacancy volatility. If the covariance is high, then the covariance will offset each other and the vacancy change volatility can be relatively low. For example,New York is where the vacancy change is least volatile and also the one of the three cities where the covariance is greater than most others.

Figure 3: Supply, Demand and 2*Covariance





Notes: the covariance share is two times of covariance of supply and demand.
Source: Author

5.3 Determinants of Overall Vacancy Change Volatility

5.3.1 Vacancy Change Volatility Regression Analysis

Table 2 presents the estimates of Equation (25), the vacancy change volatility equation.

In Model 1 of Table 2, I examine the effects of four explanatory variables, as specified in the previous chapter. The results in Model 1 of Table 2 strongly suggest that *supply elasticity* is positively associated with *vacancy change volatility*, and *market size*, and *employment growth rate*, while *volatility of employment growth rate* is negatively associated with *vacancy change volatility*. The results show only the *market size* to be significant.

In Model 2 of Table 2, I allow the effect of *WRI*. The results suggest that all five explanatory variables, including *supply elasticities,* are negatively associated with *vacancy change volatility*. Note that T stats tend to drop because of increased correlation among those explanatory variables. Only *market size* and *volatility of employment growth rate* are significant.

Finally, in Model 3 of Table 2, I add the *concentration index*. The results imply that the *concentration index* and *supply elasticity* are positively associated with *vacancy change volatility*, and *market size*, *employment growth rate* and *volatility of employment growth rate* are negatively associated with *vacancy change volatility*. The results show *concentration, index market size*, and *employment growth rate* to be significant.

The results show that more concentrated cities are more volatile, while more dispersed cities tent to be less volatile. For instance, Tampa is both least concentrated and volatile. The results also imply that cities with greater regulation control and less elasticity tend to be less volatile. This explains why those coastal cities with physical constraints and stringent regulation controls, such as Boston and San Francisco, are less volatile than those Southern and Midwest cities, which have more developable land and have loose regulation.

Table 2
Estimation of volatility of vacancy change (Dependent variable: variance of vacancy change)

Model	**Model 1**				**Model 2**				**Model 3**			
Variable	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	0.00031819376	0.00006194936	5.14	0.000007	0.00036898267	0.00007374717	5.00	0.000012	0.00021589967	0.00011463147	1.88	0.067116
Concentration Index									0.00044267628	0.00025790157	1.72	0.094013
WRI					-0.00004949231	0.00003961562	-1.25	0.218812	-0.00002342915	0.00004155892	-0.56	0.576147
Supply Elasticity	0.00001985938	0.00002258518	0.88	0.384358	-0.00000077497	0.00002785685	-0.03	0.977944	0.00002642197	0.00003148108	0.84	0.406418
Market Size	-0.00000000019	0.00000000006	-3.09	0.003563	-0.00000000019	0.00000000006	-3.06	0.003985	-0.00000000016	0.00000000006	-2.65	0.011537
Employment Growth Rate	-0.01413930703	0.00915172921	-1.54	0.130034	-0.01462622515	0.00909812894	-1.61	0.115787	-0.01545648531	0.00889771280	-1.74	0.090257
Volatility of Employment Growth Rate	-0.99423260800	0.67768468327	-1.47	0.149978	-1.13600344779	0.68259595474	-1.66	0.103880	-0.74355479399	0.70469467942	-1.06	0.297852
Adjusted R Square	**0.26**				**0.27**				**0.31**			
Observations	**46**				**46**				**46**			

The results also suggest that big markets are less volatile. This might explain why large cities such as New York and Washington D.C. are among the least volatile cities. Big cities tend to offer a good blending of jobs and lack dominant players on the supply side as well. As expected, cities with faster growth and greater volatility of employment growth are more volatile. This explains why cities where the economy is less vibrant, such as Pittsburgh and Birmingham, are among the most volatile markets.

In sum, the vacancy change volatility equation in Table 2 demonstrates that the magnitude of concentration, regulation, and supply constrain beget vacancy volatility, while big markets, fast economy growth, and great volatility of economy growth reduce vacancy volatility. This is consistent with vacancy change volatility results in figure 1.

5.3.2 Demand Share Regression Analysis

I now move to assessing how important these six variables are associated with *the demand share*, the dominant instrument in determining vacancy change volatility.

Table 3 summarizes the estimates of Equation (26), the demand share equation.

The results in all three models of Table 3 strongly suggest that all six explanatory variables are negatively associated with *the demand share*. The results in all three models also show only *market size* and *employment growth* to be significant.

Unlike the vacancy change volatility equation, the *supply elasticities* index is negatively associated with *the demand share*. The results suggest that when *supply elasticities* are greater, demand volatilities will decrease. This might be explained that on markets with greater *supply elasticities*, demands are easier and faster to be satisfied, reducing the demand volatilities.

Table 3
Estimation of Demand Share (Dependent variable: Share of Demand Volatility Adjusted for Covariance)

Model	**Model 1**				**Model 2**				**Model 3**			
Variable	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	1.028920457	0.010613774	96.94	0.0000	1.034930746	0.012763345	81.09	0.0000	1.043876425	0.020492325	50.94	0.0000
Concentration Index									-0.025868580	0.046104293	-0.56	0.5779
WRI					-0.005856850	0.006856233	-0.85	0.3981	-0.007379898	0.007429363	-0.99	0.3267
Supply Elasticity	-0.003762348	0.003869515	-0.97	0.3366	-0.006204188	0.004821156	-1.29	0.2055	-0.007793489	0.005627778	-1.38	0.1740
Market Size	-0.000000083	0.000000011	-7.91	0.0000	-0.000000083	0.000000011	-7.84	0.0000	-0.000000084	0.000000011	-7.69	0.0000
Employment Growth Rate	-6.231454211	1.567964251	-3.97	0.0003	-6.289075419	1.574603539	-3.99	0.0003	-6.240557682	1.590617536	-3.92	0.0003
Volatility of Employment Growth Rate	-50.712847076	116.107604690	-0.44	0.6646	-67.489809804	118.136158962	-0.57	0.5710	-90.423248632	125.976162581	-0.72	0.4772
Adjusted R Square	**0.61**				**0.60**				**0.60**			
Observations	**46**				**46**				**46**			

In sum, the demand share equation implies that heavy concentration, stringent regulation, great supply elasticity, big market, fast economy growth, and great volatility of economy growth will reduce the overall demand volatility.

6 VOLATILITY OF REVENUE CHANGE

6.1 Volatilities of Revenue Change, Rent Change, and Occupancy Change

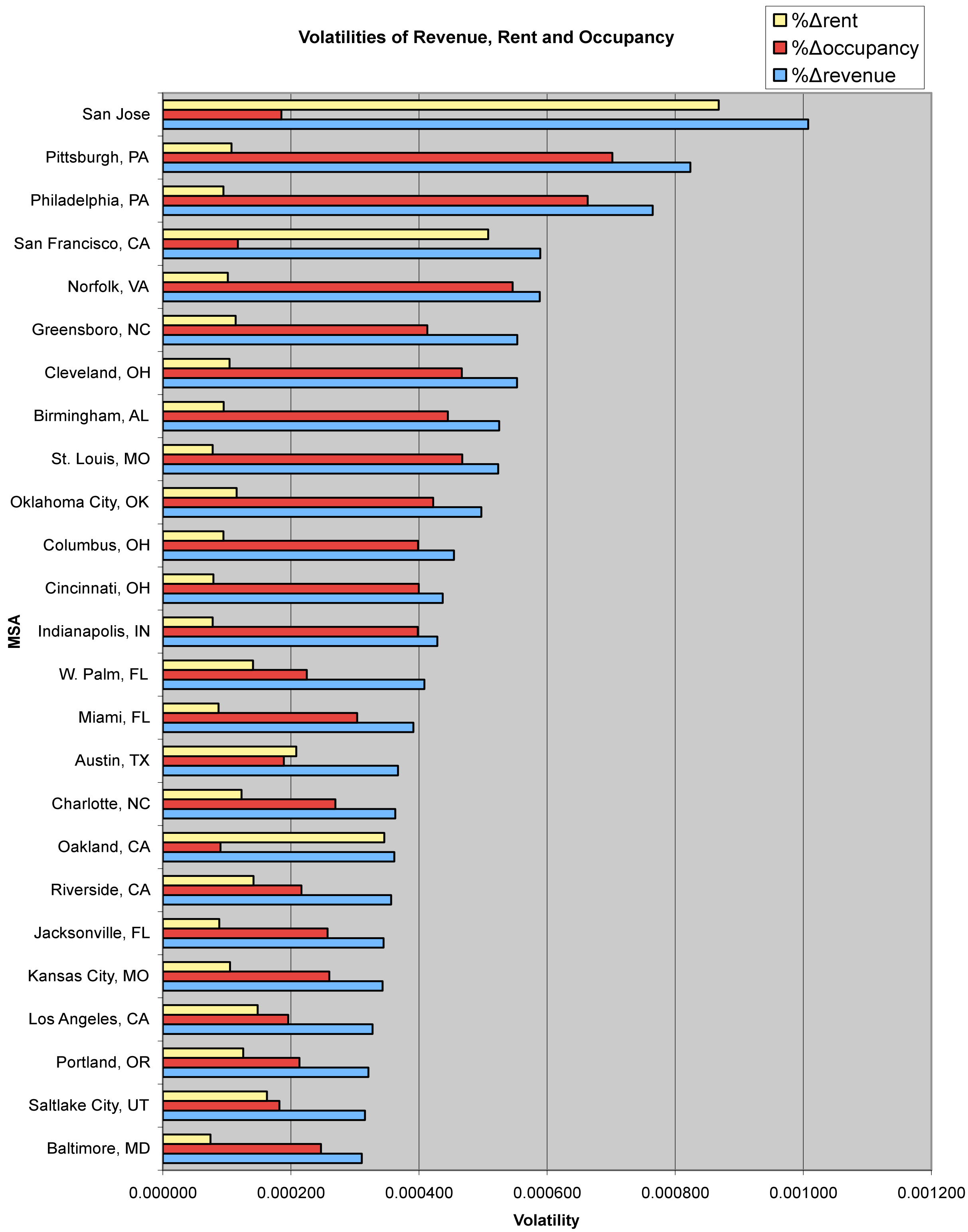
Figure 4 shows descriptive statistics characterizing volatilities of revenue change, rent change, and vacancy change of each apartment market across the United States. The average revenue change volatility is 0.000358, with a range from 0.000095 to 0.001008. The average rent change volatility is 0.000143 varying from 0.000055 to 0.000868. The average occupancy is 0.000235, with a range from 0.000002 to 0.000702.

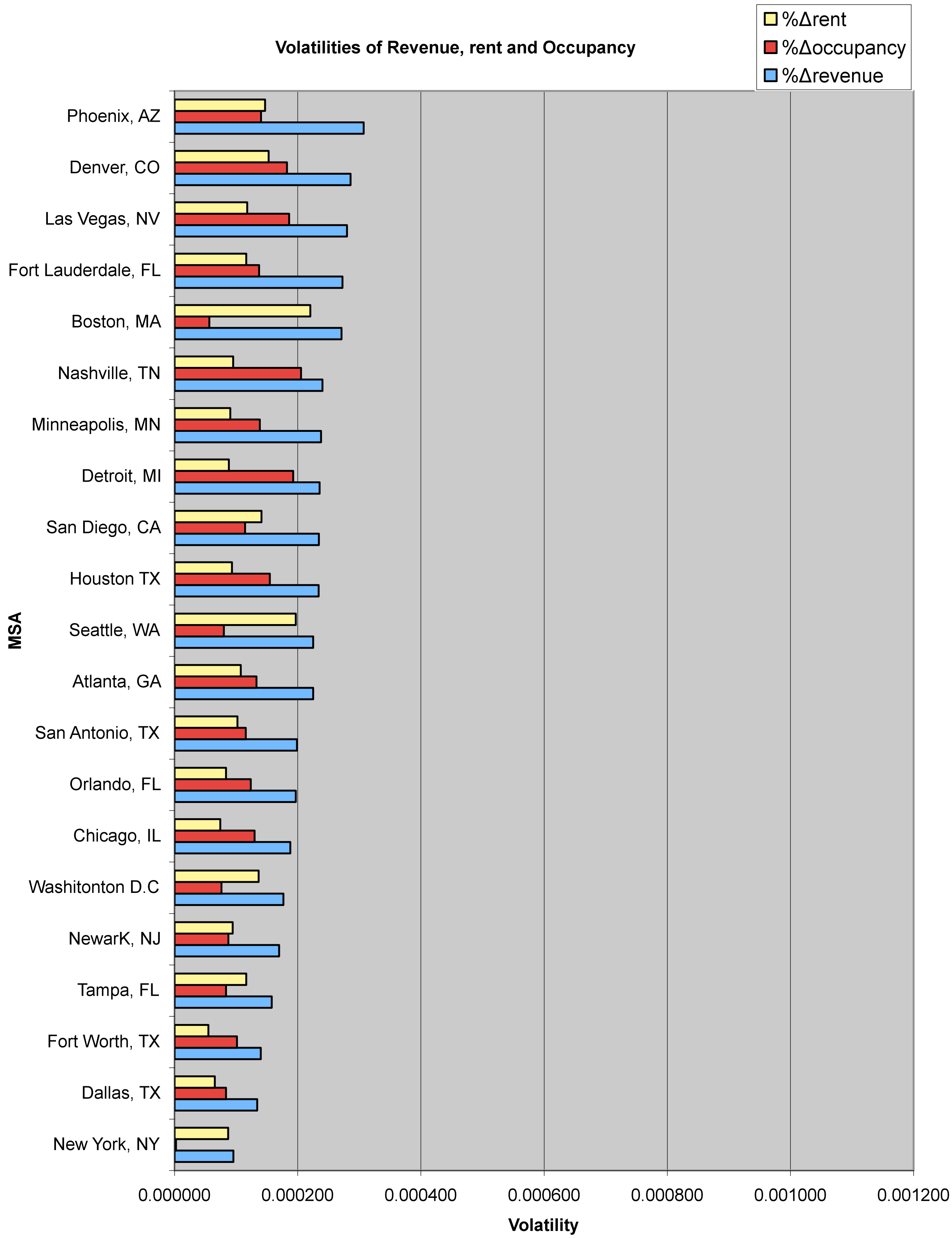
The top ten markets, ranked by volatilities of revenue change, include San Jose, Pittsburg, Philadelphia, and Norfolk. Except for two cities - San Jose and San Francisco-, all other eight cities also have great vacancy rate volatilities. Except for Atlanta, Orlando, and Chicago, the remaining seven cities of the bottom ten cities are the same bottom cities, as ranked by vacancy change volatility. For example, New York is the least volatile city in terms of both revenue change and vacancy change.

As for the volatility of occupancy change, New York and Newark enjoy the least volatility while Pittsburg has the highest, which is the same result of vacancy change. The result is obvious because vacancy rate is equated to one minus occupancy rate.

As a check whether the volatility of revenue change is consistent with rent change, this paper examines the volatility of rent change. Not surprisingly, New York has the least volatility while San Jose has the highest. The rent change volatilities of three California cities -San Jose, San Francisco, and Oakland - are extremely higher than the other metro areas. This may be due to the booming economy in California, especially in the San Francisco Bay area, in the past two decades.

Figure 4: Volatility of Revenue Change, Rent Change, and Occupancy Change





%Δrent
%Δoccupancy
%Δrevenue
Volatilities of Revenue, rent and Occupancy
MSA
Phoenix, AZ
Denver, CO
Las Vegas, NV
Fort Lauderdale, FL
Boston, MA
Nashville, TN
Minneapolis, MN
Detroit, MI
San Diego, CA
Houston TX
Seattle, WA
Atlanta, GA
San Antonio, TX
Orlando, FL
Chicago, IL
Washitonton D.C
NewarK, NJ
Tampa, FL
Fort Worth, TX
Dallas, TX
New York, NY
0.000000
0.000200
0.000400
0.000600
0.000800
0.001000
0.001200
Volatility

6.2 Decomposition of Revenue Change Volatility

6.2.1 Decomposition of Revenue Change Volatility into Rent Share and Occupancy Share

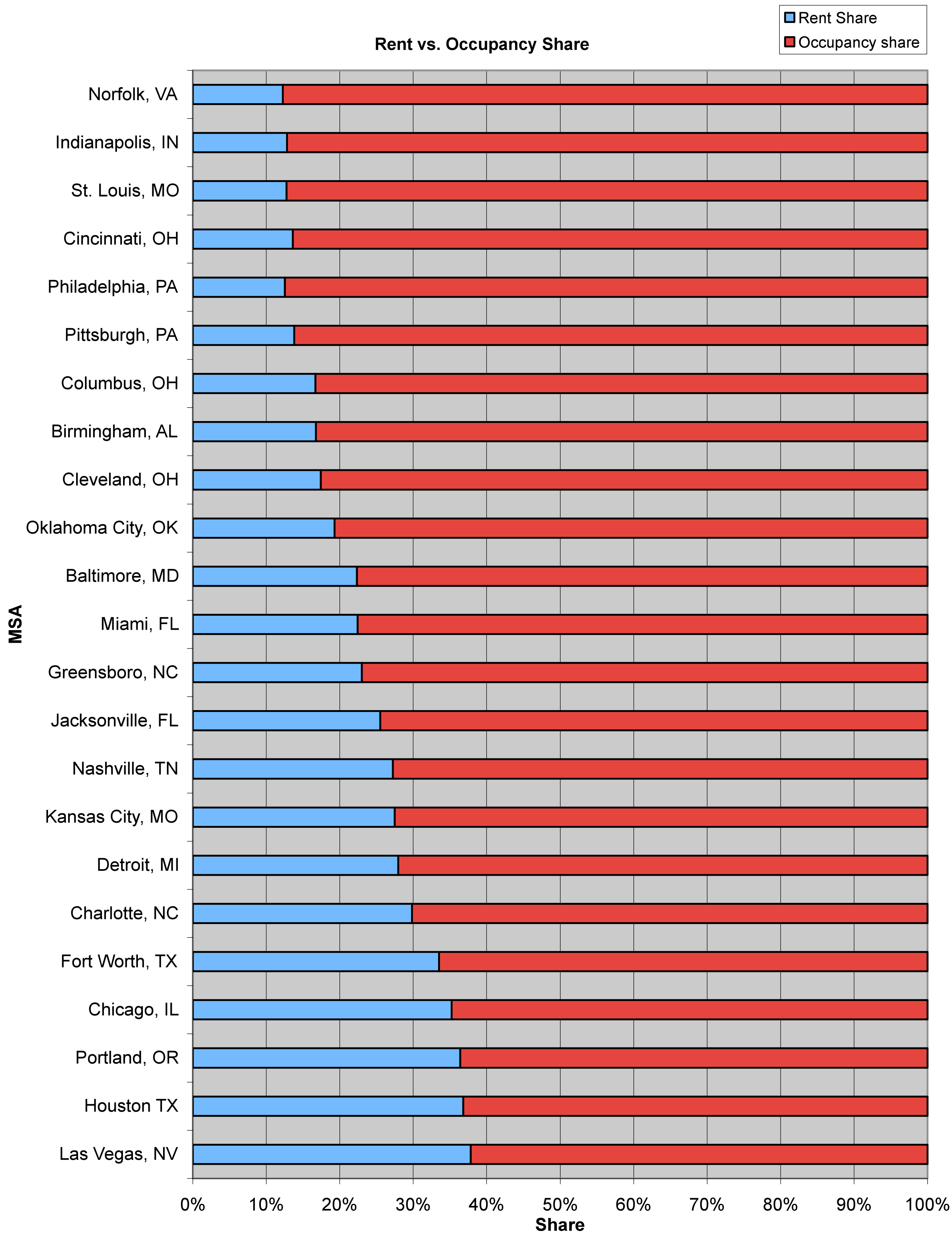
Figure 5 shows the results of decomposition of revenue change volatility, which is decomposed into the rent share and the occupancy share. The results suggest that occupancy share is roughly balanced with the rent share to determine the revenue volatility. The average share of the rent share is 40%, ranging from 12% to 94%, while the average of occupancy share is 60% varying from 6 % to 88%. Unlike the vacancy change volatility in which the demand volatility is a dominant factor, there is no dominant factor in determining revenue change volatility.

6.2.2 Decomposition of Revenue Change Volatility into Rent Change Variance, Occupancy Change Variance and Covariance

In this section, the revenue change volatility is decomposed into three components: rent change volatility, occupancy change volatility and two times of covariance of rent change, and occupancy change. Figure 6, where cities are ranked by revenue change volatility, exhibits the result graphically.

The average covariance is -0.000010, ranging from -0.000037 to 0.000022. Oakland enjoys the least covariance, and West Palm has the greatest. Unlike the covariance in the vacancy change equation, a higher covariance in the revenue change volatility equation adds to overall volatility. Recall from the Equation (14) that covariance of rent change and occupancy change will increase the revenue change volatility. If the covariance is high, then the covariance will reinforce each other and the revenue change volatility can be relatively high.

Figure 5: Occupancy Share vs. Rent Share



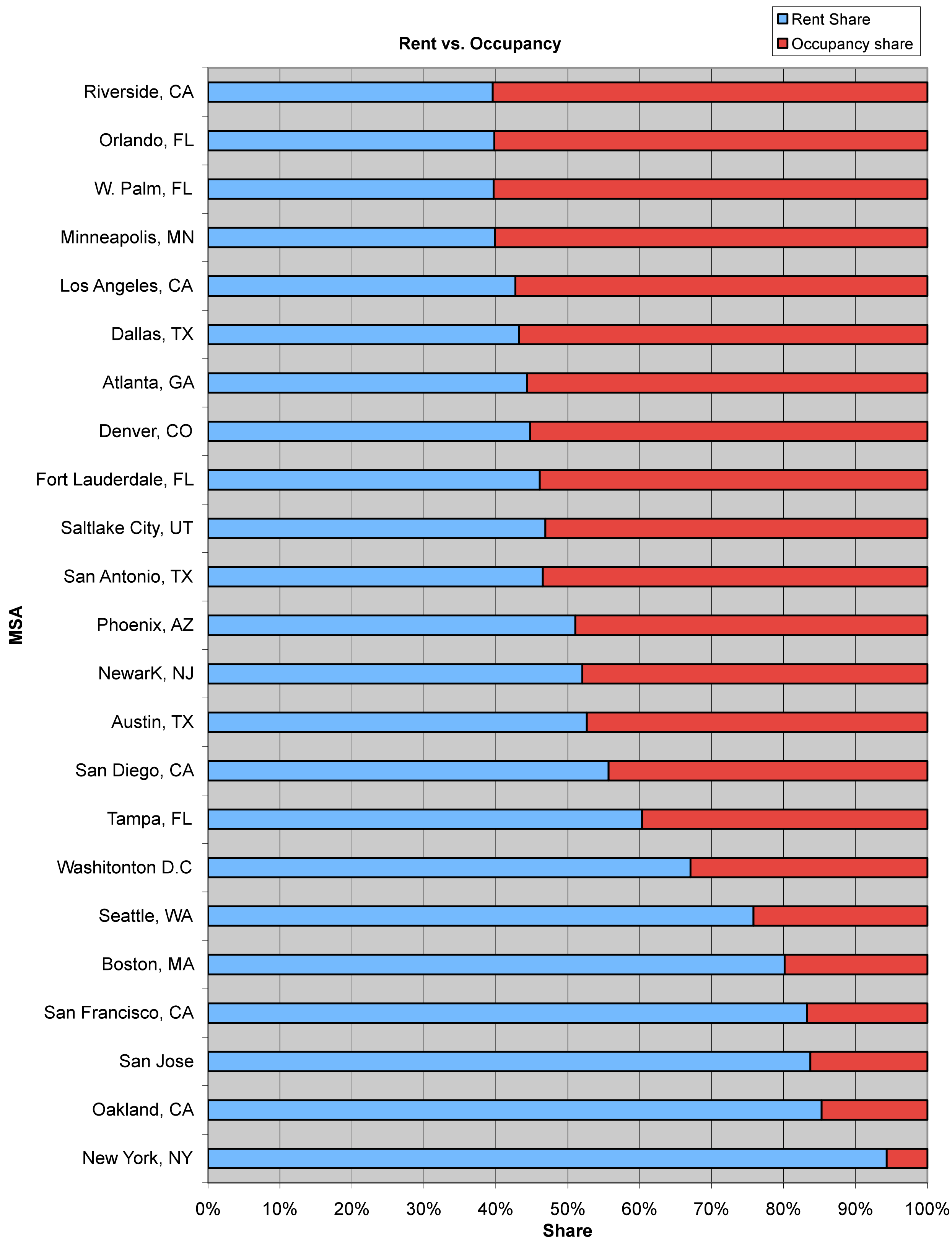
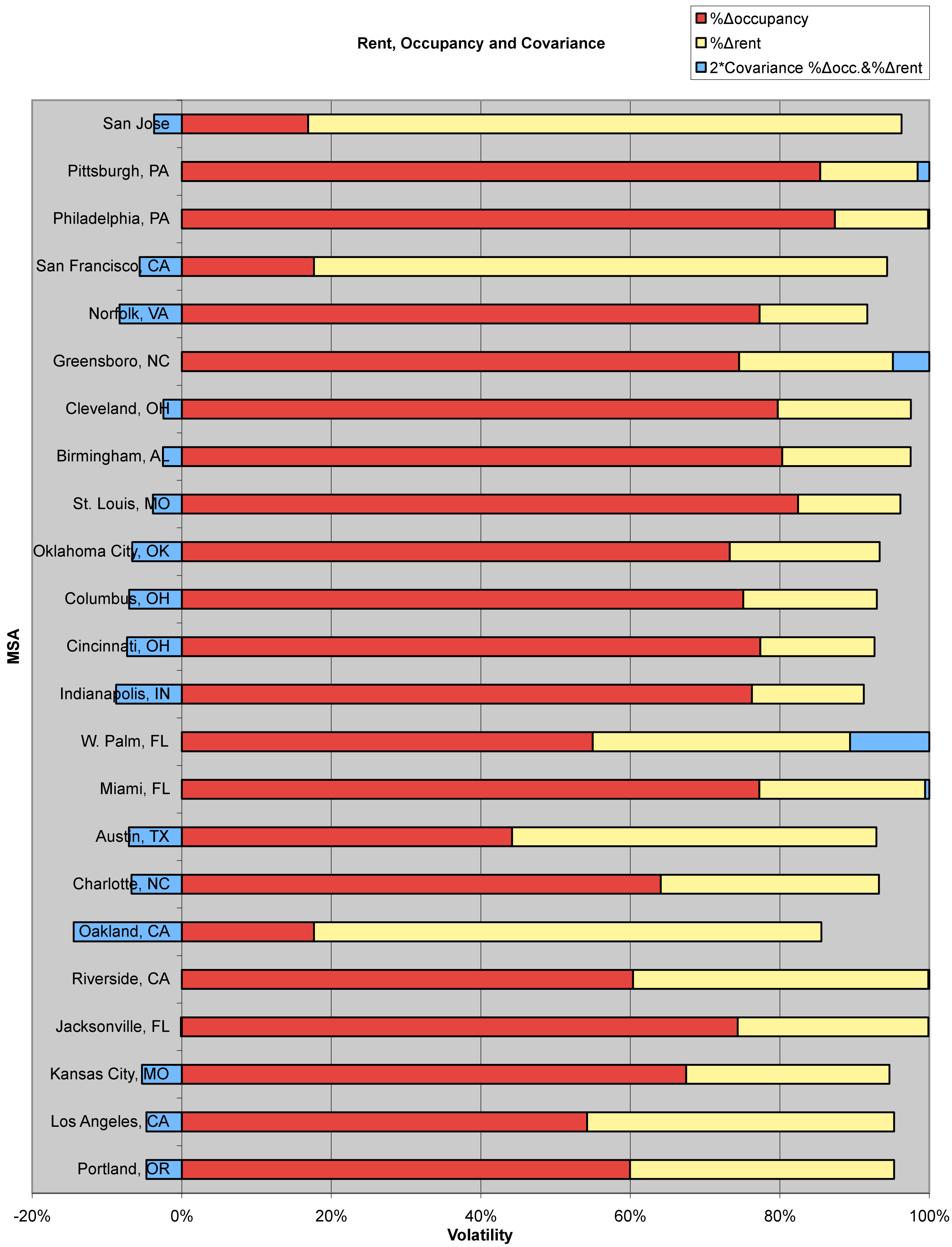
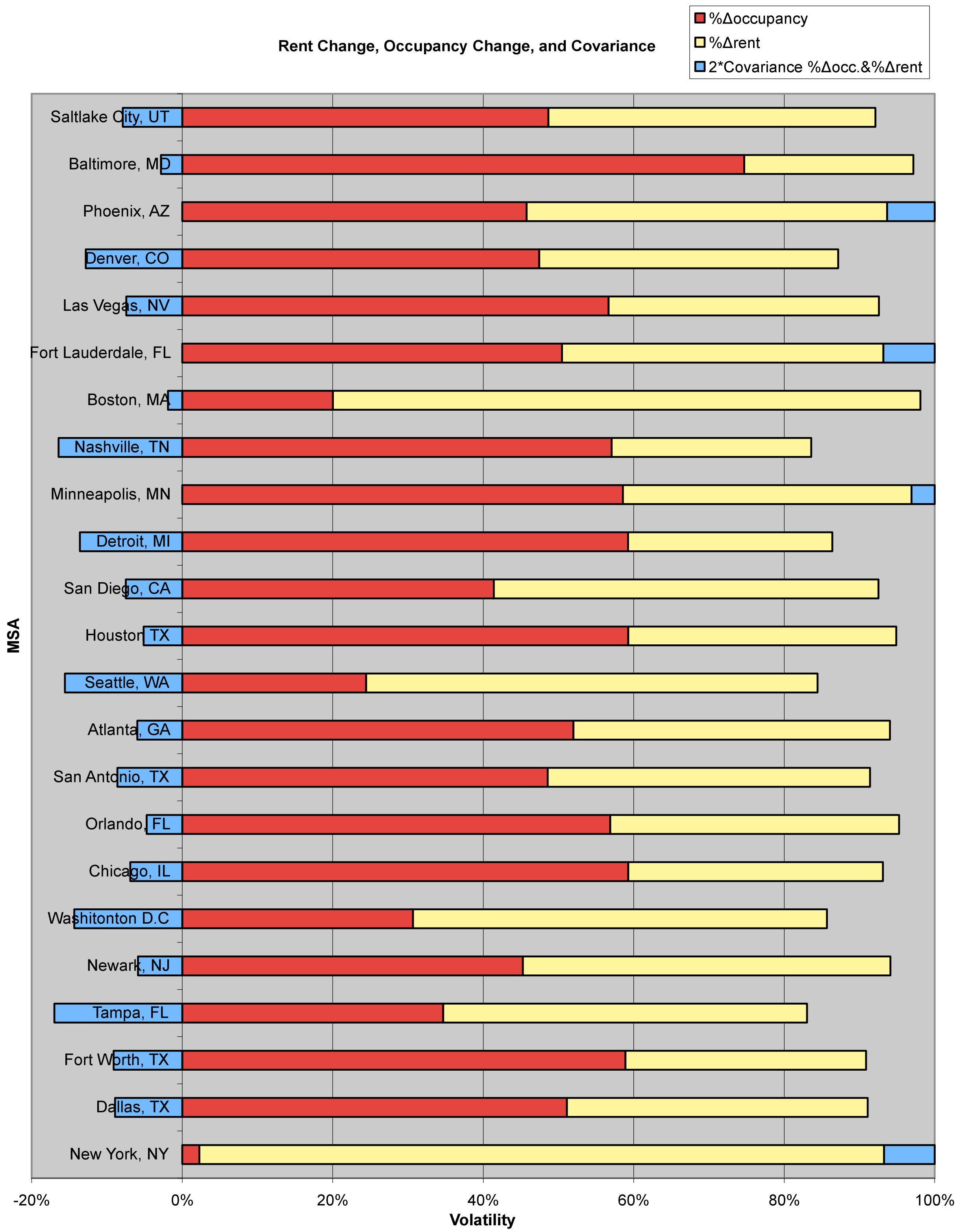

Rent vs. Occupancy
Rent Share
Occupancy share
MSA
Riverside, CA
Orlando, FL
W. Palm, FL
Minneapolis, MN
Los Angeles, CA
Dallas, TX
Atlanta, GA
Denver, CO
Fort Lauderdale, FL
Saltlake City, UT
San Antonio, TX
Phoenix, AZ
NewarK, NJ
Austin, TX
San Diego, CA
Tampa, FL
Washitonton D.C
Seattle, WA
Boston, MA
San Francisco, CA
San Jose
Oakland, CA
New York, NY
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share

Figure 6: Decompostion: Rent, Occupancy and Covariance





Notes: The covariance share is two times of covariance of occupancy change and rent change.
Source: Author

6.3 Determinants of Overall Revenue Change

6.3.1 Revenue Change Volatility Regression Analysis

Table 4 exhibits the estimates of Equation (27), the revenue change volatility equation.

In Model 1 of Table 4, four explanatory variables, as specified in chapter 3, are included. The results in Model 1 of Table 4 strongly suggest that *supply elasticity* and *volatility of employment growth rate* is positively associated with *revenue change volatility*, and *market size*, *employment growth rate* are negatively associated with *vacancy change volatility*. The results show *market size* and *employment growth rate* to be significant.

In Model 2 of Table 4, I allow the effect of *WRI*. The results suggest that in addition to *market size* and *employment growth rate*, *WRI* is negatively associated with *revenue change volatility*. Note that the T stats tend to drop because of increased correlation among those explanatory variables.

In Model 3 of Table 4, I add the *concentration index*. Except for *market size* and *employment growth rate*, all other four variables are positively associated with *revenue change volatility*. The results suggest that the c*oncentration index* and *supply elastisities* to be not significant.

The results show that more concentrated cities have more volatile revenue change, while more dispersed cities tend to be less volatile. The results also imply that cities with greater regulation controls tend to be less volatile. This explains why those coastal cities with physical constraints and stringent regulation controls, such as Boston and San Francisco, are less volatile than those Southern and Midwest cities, which have more developable land and have looser regulations. Opposed to that, in the vacancy change volatility equation, however, great *supply elasticities* increase revenue change volatilities.

Like that in the vacancy change volatility equation, big market and fast economy growth reduce revenue change volatility. This explains why big cities such as New York and Washington D.C. are among the least volatile cities in terms of revenue change.

To sum, the revenue change volatility equation in Table 4 demonstrates that the magnitude of concentration, regulation, supply constraints, and volatility of economy growth increase revenue change volatility, while big market and fast economy growth reduce revenue vacancy volatility. This is consistent with revenue change volatility results in Figure 2.

6.3.2 Rent Share Regression Analysis

In this section, I start exploring how significantly those six variables are associated with *the rent share*, the rent change volatility adjusted for covariance, as specified in Equation (22).

Table 5 summarizes the estimates of Equation (28), the rent share specification.

There are four explanatory variables in Model 1 of Table 5. The results in Model 1 of Table 5 suggest that *supply elasticity* and *employment growth rate* are negatively associated with the *rent share*. Also, the results show that *market size* and *volatility of employment growth rate* are positively associated with the *rent share*. The results show *employment growth rate* to be not significant.

In Model 2 of Table 4, I add *WRI*. The results suggest that in addition to *market size* and *volatility of employment growth rate*, *WRI* is positively associated with the *rent share*. The results show that *supply elasticities* and *employment growth rate* to be not significant. It is not surprising that the T stats of *supply elasticities* drop sharply so that it becomes to be not significant.

Similar to the procedure in demand share regression analyses, I add the *concentration index* in Model 3 of Table 4. Except for the *concentration index* and *supply elasticities*, all other four variables are positively associated with the *rent share*. The results suggest that the *concentration index*, *WRI*, *supply elastisities*, and *employment growth rate* to be not significant.

Table 4
Estimation of volatility of revenue change (Dependent variable: variance of revenue change)

Model	**Model 1**				**Model 2**				**Model 3**			
Variable	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	0.00044928041	0.00008493331	5.29	0.000004	0.00047115942	0.00010287073	4.58	0.00004	0.00025659479	0.00015984241	1.61	0.11650
Concentration Index									0.00062046520	0.00035961861	1.73	0.09238
WRI					-0.00002132046	0.00005526026	-0.39	0.70168	0.00001521026	0.00005794986	0.26	0.79434
Supply Elasticity	0.00002112442	0.00003096455	0.68	0.498940	0.00001223549	0.00003885783	0.31	0.75449	0.00005035534	0.00004389729	1.15	0.25832
Market Size	-0.00000000028	0.00000000008	-3.30	0.002016	-0.00000000028	0.00000000009	-3.24	0.00238	-0.00000000024	0.00000000009	-2.84	0.00718
Employment Growth Rate	-0.04472033509	0.01254712907	-3.56	0.000944	-0.04493009128	0.01269107944	-3.54	0.00103	-0.04609380291	0.01240699355	-3.72	0.00064
Volatility of Employment Growth Rate	1.38709604192	0.92911372250	1.49	0.143113	1.32602353217	0.95216055416	1.39	0.17142	1.87608854259	0.98262806800	1.91	0.06361
Adjusted R Square	**0.26**				**0.25**				**0.28**			
Observations	**46**				**46**				**46**			

Table 5
Estimation of volatility of the Rent Share (Dependent Variable: the Rent Share)

Model	**Model 1**				**Model 2**				**Model 3**			
Variable	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	0.31687146	0.09574876	3.31	0.0020	0.20315608	0.11151384	1.82	0.0760	0.33585448	0.17767663	1.89	0.0662
Concentration Index									-0.38372931	0.39974260	-0.96	0.3430
WRI					0.11081232	0.05990318	1.85	0.0717	0.08821974	0.06441554	1.37	0.1787
Supply Elasticity	-0.05971133	0.03490759	-1.71	0.0947	-0.01351142	0.04212263	-0.32	0.7501	-0.03708681	0.04879508	-0.76	0.4518
Market Size	0.00000029	0.00000009	3.03	0.0043	0.00000028	0.00000009	3.03	0.0043	0.00000026	0.00000009	2.72	0.0096
Employment Growth Rate	-0.34915473	14.14488693	-0.02	0.9804	0.74104548	13.75737257	0.05	0.9573	1.46074783	13.79128823	0.11	0.9162
Volatility of Employment Growth Rate	1992.73634639	1047.42754071	1.90	0.0641	2310.15850530	1032.16023130	2.24	0.0308	1969.96848872	1092.26355682	1.80	0.0790
Adjusted R Square	**0.32**				**0.36**				**0.36**			
Observations	**46**				**46**				**46**			

In sum, the rent share equation implies that heavy concentration and great supply elasticity will reduce the rent change volatility, however, restricted regulation, big market, fast economy growth, and great volatility of economy growth will increase the rent change volatility.

7 CONCLUSION

This paper reports the results on estimations of market volatility under the two-stage analysis. In the first stage, the results suggest the volatilities of vacancy change and revenue change vary by markets with a wide range. Further, it is found that the vacancy change volatility is dominated by demand volatility and the effect of supply volatility can be almost ignored. However, the revenue change volatility is well impartially determined by rent change volatility and occupancy change volatility.

In the second stage, it is found that big markets and fast growth economies tend to reduce vacancy change volatility, revenue change volatility, and demand volatility, but increase rent change volatility. By contrast, the concentration magnitude always increases the volatility of vacancy change and revenue change. The more concentrated cities are more volatile than otherwise. The stringent regulations on redevelopment tend to increase the volatilities of revenue change and rent change, but to decrease volatility of demand and vacancy change. Similarly, the supply elasticities are proved to increase volatility of vacancy change and revenue change, but decrease the volatilities of demand and rent change. However, these effects from regulation and supply elasticities are not significant. In addition, homeownership may play a role in this process. With data series of homeownership covering the same period of time, future work may need to further examine what happens when homeownership rate changes from time to time.

Because of this paper's focus on market volatility, it provides distinctive measures as opposed to research focusing on return volatility of the apartment real estate market from 1989 to 2010. The implications of these results are twofold. First, the vacancy volatility of apartment real estate is determined by demand volatility. In order to better predict and respond to the market, market agents may pay more attention to demand-side factors. Second, as long-believed, big market and fast growth reduce the volatilities of vacancy change and revenue change. This knowledge can be used to hedge risk by allocating assets in various size cities with various economic growth rates.

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APPENDIX

Appendix 1: National CPI

Consumer Price Index - All Urban Consumers
Original Data Value

Series Id: CUUR0000SA0
Not Seasonally Adjusted
Area: U.S. city average
Item: All items
Base Period: 1982-84=100
Years: 1985 to 2010

Series ID	Year	Period	Value
CUUR0000SA0	1985	M01	105.5
CUUR0000SA0	1985	M02	106.0
CUUR0000SA0	1985	M03	106.4
CUUR0000SA0	1985	M04	106.9
CUUR0000SA0	1985	M05	107.3
CUUR0000SA0	1985	M06	107.6
CUUR0000SA0	1985	M07	107.8
CUUR0000SA0	1985	M08	108.0
CUUR0000SA0	1985	M09	108.3
CUUR0000SA0	1985	M10	108.7
CUUR0000SA0	1985	M11	109.0
CUUR0000SA0	1985	M12	109.3
CUUR0000SA0	1985	M13	107.6
CUUR0000SA0	1985	S01	106.6
CUUR0000SA0	1985	S02	108.5
CUUR0000SA0	1986	M01	109.6
CUUR0000SA0	1986	M02	109.3
CUUR0000SA0	1986	M03	108.8
CUUR0000SA0	1986	M04	108.6
CUUR0000SA0	1986	M05	108.9
CUUR0000SA0	1986	M06	109.5
CUUR0000SA0	1986	M07	109.5
CUUR0000SA0	1986	M08	109.7
CUUR0000SA0	1986	M09	110.2
CUUR0000SA0	1986	M10	110.3
CUUR0000SA0	1986	M11	110.4
CUUR0000SA0	1986	M12	110.5
CUUR0000SA0	1986	M13	109.6
CUUR0000SA0	1986	S01	109.1
CUUR0000SA0	1986	S02	110.1
CUUR0000SA0	1987	M01	111.2
CUUR0000SA0	1987	M02	111.6
CUUR0000SA0	1987	M03	112.1
CUUR0000SA0	1987	M04	112.7
CUUR0000SA0	1987	M05	113.1
CUUR0000SA0	1987	M06	113.5
CUUR0000SA0	1987	M07	113.8
CUUR0000SA0	1987	M08	114.4
CUUR0000SA0	1987	M09	115.0

Series ID	Year	Period	Value
CUUR0000SA0	1999	M10	168.2
CUUR0000SA0	1999	M11	168.3
CUUR0000SA0	1999	M12	168.3
CUUR0000SA0	1999	M13	166.6
CUUR0000SA0	1999	S01	165.4
CUUR0000SA0	1999	S02	167.8
CUUR0000SA0	2000	M01	168.8
CUUR0000SA0	2000	M02	169.8
CUUR0000SA0	2000	M03	171.2
CUUR0000SA0	2000	M04	171.3
CUUR0000SA0	2000	M05	171.5
CUUR0000SA0	2000	M06	172.4
CUUR0000SA0	2000	M07	172.8
CUUR0000SA0	2000	M08	172.8
CUUR0000SA0	2000	M09	173.7
CUUR0000SA0	2000	M10	174.0
CUUR0000SA0	2000	M11	174.1
CUUR0000SA0	2000	M12	174.0
CUUR0000SA0	2000	M13	172.2
CUUR0000SA0	2000	S01	170.8
CUUR0000SA0	2000	S02	173.6
CUUR0000SA0	2001	M01	175.1
CUUR0000SA0	2001	M02	175.8
CUUR0000SA0	2001	M03	176.2
CUUR0000SA0	2001	M04	176.9
CUUR0000SA0	2001	M05	177.7
CUUR0000SA0	2001	M06	178.0
CUUR0000SA0	2001	M07	177.5
CUUR0000SA0	2001	M08	177.5
CUUR0000SA0	2001	M09	178.3
CUUR0000SA0	2001	M10	177.7
CUUR0000SA0	2001	M11	177.4
CUUR0000SA0	2001	M12	176.7
CUUR0000SA0	2001	M13	177.1
CUUR0000SA0	2001	S01	176.6
CUUR0000SA0	2001	S02	177.5
CUUR0000SA0	2002	M01	177.1
CUUR0000SA0	2002	M02	177.8
CUUR0000SA0	2002	M03	178.8

CUUR0000SA0	**1987**	**M10**	115.3	**CUUR0000SA0**	**2002**	**M04**	179.8
CUUR0000SA0	**1987**	**M11**	115.4	**CUUR0000SA0**	**2002**	**M05**	179.8
CUUR0000SA0	**1987**	**M12**	115.4	**CUUR0000SA0**	**2002**	**M06**	179.9
CUUR0000SA0	**1987**	**M13**	113.6	**CUUR0000SA0**	**2002**	**M07**	180.1
CUUR0000SA0	**1987**	**S01**	112.4	**CUUR0000SA0**	**2002**	**M08**	180.7
CUUR0000SA0	**1987**	**S02**	114.9	**CUUR0000SA0**	**2002**	**M09**	181.0
CUUR0000SA0	**1988**	**M01**	115.7	**CUUR0000SA0**	**2002**	**M10**	181.3
CUUR0000SA0	**1988**	**M02**	116.0	**CUUR0000SA0**	**2002**	**M11**	181.3
CUUR0000SA0	**1988**	**M03**	116.5	**CUUR0000SA0**	**2002**	**M12**	180.9
CUUR0000SA0	**1988**	**M04**	117.1	**CUUR0000SA0**	**2002**	**M13**	179.9
CUUR0000SA0	**1988**	**M05**	117.5	**CUUR0000SA0**	**2002**	**S01**	178.9
CUUR0000SA0	**1988**	**M06**	118.0	**CUUR0000SA0**	**2002**	**S02**	180.9
CUUR0000SA0	**1988**	**M07**	118.5	**CUUR0000SA0**	**2003**	**M01**	181.7
CUUR0000SA0	**1988**	**M08**	119.0	**CUUR0000SA0**	**2003**	**M02**	183.1
CUUR0000SA0	**1988**	**M09**	119.8	**CUUR0000SA0**	**2003**	**M03**	184.2
CUUR0000SA0	**1988**	**M10**	120.2	**CUUR0000SA0**	**2003**	**M04**	183.8
CUUR0000SA0	**1988**	**M11**	120.3	**CUUR0000SA0**	**2003**	**M05**	183.5
CUUR0000SA0	**1988**	**M12**	120.5	**CUUR0000SA0**	**2003**	**M06**	183.7
CUUR0000SA0	**1988**	**M13**	118.3	**CUUR0000SA0**	**2003**	**M07**	183.9
CUUR0000SA0	**1988**	**S01**	116.8	**CUUR0000SA0**	**2003**	**M08**	184.6
CUUR0000SA0	**1988**	**S02**	119.7	**CUUR0000SA0**	**2003**	**M09**	185.2
CUUR0000SA0	**1989**	**M01**	121.1	**CUUR0000SA0**	**2003**	**M10**	185.0
CUUR0000SA0	**1989**	**M02**	121.6	**CUUR0000SA0**	**2003**	**M11**	184.5
CUUR0000SA0	**1989**	**M03**	122.3	**CUUR0000SA0**	**2003**	**M12**	184.3
CUUR0000SA0	**1989**	**M04**	123.1	**CUUR0000SA0**	**2003**	**M13**	184.0
CUUR0000SA0	**1989**	**M05**	123.8	**CUUR0000SA0**	**2003**	**S01**	183.3
CUUR0000SA0	**1989**	**M06**	124.1	**CUUR0000SA0**	**2003**	**S02**	184.6
CUUR0000SA0	**1989**	**M07**	124.4	**CUUR0000SA0**	**2004**	**M01**	185.2
CUUR0000SA0	**1989**	**M08**	124.6	**CUUR0000SA0**	**2004**	**M02**	186.2
CUUR0000SA0	**1989**	**M09**	125.0	**CUUR0000SA0**	**2004**	**M03**	187.4
CUUR0000SA0	**1989**	**M10**	125.6	**CUUR0000SA0**	**2004**	**M04**	188.0
CUUR0000SA0	**1989**	**M11**	125.9	**CUUR0000SA0**	**2004**	**M05**	189.1
CUUR0000SA0	**1989**	**M12**	126.1	**CUUR0000SA0**	**2004**	**M06**	189.7
CUUR0000SA0	**1989**	**M13**	124.0	**CUUR0000SA0**	**2004**	**M07**	189.4
CUUR0000SA0	**1989**	**S01**	122.7	**CUUR0000SA0**	**2004**	**M08**	189.5
CUUR0000SA0	**1989**	**S02**	125.3	**CUUR0000SA0**	**2004**	**M09**	189.9
CUUR0000SA0	**1990**	**M01**	127.4	**CUUR0000SA0**	**2004**	**M10**	190.9
CUUR0000SA0	**1990**	**M02**	128.0	**CUUR0000SA0**	**2004**	**M11**	191.0
CUUR0000SA0	**1990**	**M03**	128.7	**CUUR0000SA0**	**2004**	**M12**	190.3
CUUR0000SA0	**1990**	**M04**	128.9	**CUUR0000SA0**	**2004**	**M13**	188.9
CUUR0000SA0	**1990**	**M05**	129.2	**CUUR0000SA0**	**2004**	**S01**	187.6
CUUR0000SA0	**1990**	**M06**	129.9	**CUUR0000SA0**	**2004**	**S02**	190.2
CUUR0000SA0	**1990**	**M07**	130.4	**CUUR0000SA0**	**2005**	**M01**	190.7
CUUR0000SA0	**1990**	**M08**	131.6	**CUUR0000SA0**	**2005**	**M02**	191.8
CUUR0000SA0	**1990**	**M09**	132.7	**CUUR0000SA0**	**2005**	**M03**	193.3
CUUR0000SA0	**1990**	**M10**	133.5	**CUUR0000SA0**	**2005**	**M04**	194.6
CUUR0000SA0	**1990**	**M11**	133.8	**CUUR0000SA0**	**2005**	**M05**	194.4
CUUR0000SA0	**1990**	**M12**	133.8	**CUUR0000SA0**	**2005**	**M06**	194.5
CUUR0000SA0	**1990**	**M13**	130.7	**CUUR0000SA0**	**2005**	**M07**	195.4
CUUR0000SA0	**1990**	**S01**	128.7	**CUUR0000SA0**	**2005**	**M08**	196.4
CUUR0000SA0	**1990**	**S02**	132.6	**CUUR0000SA0**	**2005**	**M09**	198.8
CUUR0000SA0	**1991**	**M01**	134.6	**CUUR0000SA0**	**2005**	**M10**	199.2
CUUR0000SA0	**1991**	**M02**	134.8	**CUUR0000SA0**	**2005**	**M11**	197.6
CUUR0000SA0	**1991**	**M03**	135.0	**CUUR0000SA0**	**2005**	**M12**	196.8

CUUR0000SA0	**1991**	**M04**	135.2	**CUUR0000SA0**	**2005**	**M13**	195.3
CUUR0000SA0	**1991**	**M05**	135.6	**CUUR0000SA0**	**2005**	**S01**	193.2
CUUR0000SA0	**1991**	**M06**	136.0	**CUUR0000SA0**	**2005**	**S02**	197.4
CUUR0000SA0	**1991**	**M07**	136.2	**CUUR0000SA0**	**2006**	**M01**	198.3
CUUR0000SA0	**1991**	**M08**	136.6	**CUUR0000SA0**	**2006**	**M02**	198.7
CUUR0000SA0	**1991**	**M09**	137.2	**CUUR0000SA0**	**2006**	**M03**	199.8
CUUR0000SA0	**1991**	**M10**	137.4	**CUUR0000SA0**	**2006**	**M04**	201.5
CUUR0000SA0	**1991**	**M11**	137.8	**CUUR0000SA0**	**2006**	**M05**	202.5
CUUR0000SA0	**1991**	**M12**	137.9	**CUUR0000SA0**	**2006**	**M06**	202.9
CUUR0000SA0	**1991**	**M13**	136.2	**CUUR0000SA0**	**2006**	**M07**	203.5
CUUR0000SA0	**1991**	**S01**	135.2	**CUUR0000SA0**	**2006**	**M08**	203.9
CUUR0000SA0	**1991**	**S02**	137.2	**CUUR0000SA0**	**2006**	**M09**	202.9
CUUR0000SA0	**1992**	**M01**	138.1	**CUUR0000SA0**	**2006**	**M10**	201.8
CUUR0000SA0	**1992**	**M02**	138.6	**CUUR0000SA0**	**2006**	**M11**	201.5
CUUR0000SA0	**1992**	**M03**	139.3	**CUUR0000SA0**	**2006**	**M12**	201.8
CUUR0000SA0	**1992**	**M04**	139.5	**CUUR0000SA0**	**2006**	**M13**	201.6
CUUR0000SA0	**1992**	**M05**	139.7	**CUUR0000SA0**	**2006**	**S01**	200.6
CUUR0000SA0	**1992**	**M06**	140.2	**CUUR0000SA0**	**2006**	**S02**	202.6
CUUR0000SA0	**1992**	**M07**	140.5	**CUUR0000SA0**	**2007**	**M01**	202.416
CUUR0000SA0	**1992**	**M08**	140.9	**CUUR0000SA0**	**2007**	**M02**	203.499
CUUR0000SA0	**1992**	**M09**	141.3	**CUUR0000SA0**	**2007**	**M03**	205.352
CUUR0000SA0	**1992**	**M10**	141.8	**CUUR0000SA0**	**2007**	**M04**	206.686
CUUR0000SA0	**1992**	**M11**	142.0	**CUUR0000SA0**	**2007**	**M05**	207.949
CUUR0000SA0	**1992**	**M12**	141.9	**CUUR0000SA0**	**2007**	**M06**	208.352
CUUR0000SA0	**1992**	**M13**	140.3	**CUUR0000SA0**	**2007**	**M07**	208.299
CUUR0000SA0	**1992**	**S01**	139.2	**CUUR0000SA0**	**2007**	**M08**	207.917
CUUR0000SA0	**1992**	**S02**	141.4	**CUUR0000SA0**	**2007**	**M09**	208.490
CUUR0000SA0	**1993**	**M01**	142.6	**CUUR0000SA0**	**2007**	**M10**	208.936
CUUR0000SA0	**1993**	**M02**	143.1	**CUUR0000SA0**	**2007**	**M11**	210.177
CUUR0000SA0	**1993**	**M03**	143.6	**CUUR0000SA0**	**2007**	**M12**	210.036
CUUR0000SA0	**1993**	**M04**	144.0	**CUUR0000SA0**	**2007**	**M13**	207.342
CUUR0000SA0	**1993**	**M05**	144.2	**CUUR0000SA0**	**2007**	**S01**	205.709
CUUR0000SA0	**1993**	**M06**	144.4	**CUUR0000SA0**	**2007**	**S02**	208.976
CUUR0000SA0	**1993**	**M07**	144.4	**CUUR0000SA0**	**2008**	**M01**	211.080
CUUR0000SA0	**1993**	**M08**	144.8	**CUUR0000SA0**	**2008**	**M02**	211.693
CUUR0000SA0	**1993**	**M09**	145.1	**CUUR0000SA0**	**2008**	**M03**	213.528
CUUR0000SA0	**1993**	**M10**	145.7	**CUUR0000SA0**	**2008**	**M04**	214.823
CUUR0000SA0	**1993**	**M11**	145.8	**CUUR0000SA0**	**2008**	**M05**	216.632
CUUR0000SA0	**1993**	**M12**	145.8	**CUUR0000SA0**	**2008**	**M06**	218.815
CUUR0000SA0	**1993**	**M13**	144.5	**CUUR0000SA0**	**2008**	**M07**	219.964
CUUR0000SA0	**1993**	**S01**	143.7	**CUUR0000SA0**	**2008**	**M08**	219.086
CUUR0000SA0	**1993**	**S02**	145.3	**CUUR0000SA0**	**2008**	**M09**	218.783
CUUR0000SA0	**1994**	**M01**	146.2	**CUUR0000SA0**	**2008**	**M10**	216.573
CUUR0000SA0	**1994**	**M02**	146.7	**CUUR0000SA0**	**2008**	**M11**	212.425
CUUR0000SA0	**1994**	**M03**	147.2	**CUUR0000SA0**	**2008**	**M12**	210.228
CUUR0000SA0	**1994**	**M04**	147.4	**CUUR0000SA0**	**2008**	**M13**	215.303
CUUR0000SA0	**1994**	**M05**	147.5	**CUUR0000SA0**	**2008**	**S01**	214.429
CUUR0000SA0	**1994**	**M06**	148.0	**CUUR0000SA0**	**2008**	**S02**	216.177
CUUR0000SA0	**1994**	**M07**	148.4	**CUUR0000SA0**	**2009**	**M01**	211.143
CUUR0000SA0	**1994**	**M08**	149.0	**CUUR0000SA0**	**2009**	**M02**	212.193
CUUR0000SA0	**1994**	**M09**	149.4	**CUUR0000SA0**	**2009**	**M03**	212.709
CUUR0000SA0	**1994**	**M10**	149.5	**CUUR0000SA0**	**2009**	**M04**	213.240
CUUR0000SA0	**1994**	**M11**	149.7	**CUUR0000SA0**	**2009**	**M05**	213.856
CUUR0000SA0	**1994**	**M12**	149.7	**CUUR0000SA0**	**2009**	**M06**	215.693

CUUR0000SA0	**1994**	**M13**	148.2
CUUR0000SA0	**1994**	**S01**	147.2
CUUR0000SA0	**1994**	**S02**	149.3
CUUR0000SA0	**1995**	**M01**	150.3
CUUR0000SA0	**1995**	**M02**	150.9
CUUR0000SA0	**1995**	**M03**	151.4
CUUR0000SA0	**1995**	**M04**	151.9
CUUR0000SA0	**1995**	**M05**	152.2
CUUR0000SA0	**1995**	**M06**	152.5
CUUR0000SA0	**1995**	**M07**	152.5
CUUR0000SA0	**1995**	**M08**	152.9
CUUR0000SA0	**1995**	**M09**	153.2
CUUR0000SA0	**1995**	**M10**	153.7
CUUR0000SA0	**1995**	**M11**	153.6
CUUR0000SA0	**1995**	**M12**	153.5
CUUR0000SA0	**1995**	**M13**	152.4
CUUR0000SA0	**1995**	**S01**	151.5
CUUR0000SA0	**1995**	**S02**	153.2
CUUR0000SA0	**1996**	**M01**	154.4
CUUR0000SA0	**1996**	**M02**	154.9
CUUR0000SA0	**1996**	**M03**	155.7
CUUR0000SA0	**1996**	**M04**	156.3
CUUR0000SA0	**1996**	**M05**	156.6
CUUR0000SA0	**1996**	**M06**	156.7
CUUR0000SA0	**1996**	**M07**	157.0
CUUR0000SA0	**1996**	**M08**	157.3
CUUR0000SA0	**1996**	**M09**	157.8
CUUR0000SA0	**1996**	**M10**	158.3
CUUR0000SA0	**1996**	**M11**	158.6
CUUR0000SA0	**1996**	**M12**	158.6
CUUR0000SA0	**1996**	**M13**	156.9
CUUR0000SA0	**1996**	**S01**	155.8
CUUR0000SA0	**1996**	**S02**	157.9
CUUR0000SA0	**1997**	**M01**	159.1
CUUR0000SA0	**1997**	**M02**	159.6
CUUR0000SA0	**1997**	**M03**	160.0
CUUR0000SA0	**1997**	**M04**	160.2
CUUR0000SA0	**1997**	**M05**	160.1
CUUR0000SA0	**1997**	**M06**	160.3
CUUR0000SA0	**1997**	**M07**	160.5
CUUR0000SA0	**1997**	**M08**	160.8
CUUR0000SA0	**1997**	**M09**	161.2
CUUR0000SA0	**1997**	**M10**	161.6
CUUR0000SA0	**1997**	**M11**	161.5
CUUR0000SA0	**1997**	**M12**	161.3
CUUR0000SA0	**1997**	**M13**	160.5
CUUR0000SA0	**1997**	**S01**	159.9
CUUR0000SA0	**1997**	**S02**	161.2
CUUR0000SA0	**1998**	**M01**	161.6
CUUR0000SA0	**1998**	**M02**	161.9
CUUR0000SA0	**1998**	**M03**	162.2
CUUR0000SA0	**1998**	**M04**	162.5
CUUR0000SA0	**1998**	**M05**	162.8
CUUR0000SA0	**1998**	**M06**	163.0

CUUR0000SA0	**2009**	**M07**	215.351
CUUR0000SA0	**2009**	**M08**	215.834
CUUR0000SA0	**2009**	**M09**	215.969
CUUR0000SA0	**2009**	**M10**	216.177
CUUR0000SA0	**2009**	**M11**	216.330
CUUR0000SA0	**2009**	**M12**	215.949
CUUR0000SA0	**2009**	**M13**	214.537
CUUR0000SA0	**2009**	**S01**	213.139
CUUR0000SA0	**2009**	**S02**	215.935
CUUR0000SA0	**2010**	**M01**	216.687
CUUR0000SA0	**2010**	**M02**	216.741
CUUR0000SA0	**2010**	**M03**	217.631
CUUR0000SA0	**2010**	**M04**	218.009

CUUR0000SA0	**1998**	**M07**	163.2
CUUR0000SA0	**1998**	**M08**	163.4
CUUR0000SA0	**1998**	**M09**	163.6
CUUR0000SA0	**1998**	**M10**	164.0
CUUR0000SA0	**1998**	**M11**	164.0
CUUR0000SA0	**1998**	**M12**	163.9
CUUR0000SA0	**1998**	**M13**	163.0
CUUR0000SA0	**1998**	**S01**	162.3
CUUR0000SA0	**1998**	**S02**	163.7
CUUR0000SA0	**1999**	**M01**	164.3
CUUR0000SA0	**1999**	**M02**	164.5
CUUR0000SA0	**1999**	**M03**	165.0
CUUR0000SA0	**1999**	**M04**	166.2
CUUR0000SA0	**1999**	**M05**	166.2
CUUR0000SA0	**1999**	**M06**	166.2
CUUR0000SA0	**1999**	**M07**	166.7
CUUR0000SA0	**1999**	**M08**	167.1
CUUR0000SA0	**1999**	**M09**	167.9

Source: the website of the Bureau of Labor Statistics, U.S. Department of Labor

Appendix 2: Supply Elasticity

Supply Elasticities (Metro Areas with Pop>500,000)

Rank	MSA/NECMA Name	Supply Elasticity
1	Miami, FL	0.60
2	Los Angeles-Long Beach, CA	0.63
3	Fort Lauderdale, FL	0.65
4	San Francisco, CA	0.66
5	San Diego, CA	0.67
6	Oakland, CA	0.70
7	Salt Lake City-Ogden, UT	0.75
8	Ventura, CA	0.75
9	New York, NY	0.76
10	San Jose, CA	0.76
11	New Orleans, LA	0.81
12	Chicago, IL	0.81
13	Norfolk-Virginia Beach-Newport News, VA-NC	0.82
14	West Palm Beach-Boca Raton, FL	0.83
15	Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH	0.86
16	Seattle-Bellevue-Everett, WA	0.88
17	Sarasota-Bradenton, FL	0.92
18	Riverside-San Bernardino, CA	0.94
19	New Haven-Bridgeport-Stamford-Danbury-Waterbury, CT	0.98
20	Tampa-St. Petersburg-Clearwater, FL	1.00
21	Cleveland-Lorain-Elyria, OH	1.02
22	Milwaukee-Waukesha, WI	1.03
23	Jacksonville, FL	1.06
24	Portland-Vancouver, OR-WA	1.07
25	Orlando, FL	1.12
26	Vallejo-Fairfield-Napa, CA	1.14
27	Newark, NJ	1.16
28	Charleston-North Charleston, SC	1.20
29	Pittsburgh, PA	1.20
30	Tacoma, WA	1.21
31	Baltimore, MD	1.23
32	Detroit, MI	1.24
33	Las Vegas, NV-AZ	1.39
34	Rochester, NY	1.40
35	Tucson, AZ	1.42
36	Knoxville, TN	1.42
37	Jersey City, NJ	1.44
38	Minneapolis-St. Paul, MN-WI	1.45
39	Hartford, CT	1.50
40	Springfield, MA	1.52
41	Denver, CO	1.53
42	Providence-Warwick-Pawtucket, RI	1.61
43	Washington, DC-MD-VA-WV	1.61
44	Phoenix-Mesa, AZ	1.61
45	Scranton-Wilkes-Barre-Hazleton, PA	1.62
46	Harrisburg-Lebanon-Carlisle, PA	1.63
47	Bakersfield, CA	1.64
48	Philadelphia, PA-NJ	1.65
49	Colorado Springs, CO	1.67
50	Albany-Schenectady-Troy, NY	1.70
51	Gary, IN	1.74
52	Baton Rouge, LA	1.74
53	Memphis, TN-AR-MS	1.76
54	Buffalo-Niagara Falls, NY	1.83
55	Fresno, CA	1.84
56	Allentown-Bethlehem-Easton, PA	1.86
57	Wilmington-Newark, DE-MD	1.99
58	Mobile, AL	2.04
59	Stockton-Lodi, CA	2.07
60	Raleigh-Durham-Chapel Hill, NC	2.11
61	Albuquerque, NM	2.11
62	Birmingham, AL	2.14
63	Dallas, TX	2.18
64	Syracuse, NY	2.21
65	Toledo, OH	2.21
66	Nashville, TN	2.24
67	Ann Arbor, MI	2.29
68	Houston, TX	2.30
69	Louisville, KY-IN	2.34
70	El Paso, TX	2.35
71	St. Louis, MO-IL	2.36
72	Grand Rapids-Muskegon-Holland, MI	2.39
73	Cincinnati, OH-KY-IN	2.46
74	Atlanta, GA	2.55
75	Akron, OH	2.59
76	Richmond-Petersburg, VA	2.60
77	Youngstown-Warren, OH	2.63
78	Columbia, SC	2.64
79	Columbus, OH	2.71
80	Greenville-Spartanburg-Anderson, SC	2.71
81	Little Rock-North Little Rock, AR	2.79
82	Fort Worth-Arlington, TX	2.80
83	San Antonio, TX	2.98
84	Austin-San Marcos, TX	3.00
85	Charlotte-Gastonia-Rock Hill, NC-SC	3.09
86	Greensboro-Winston-Salem-High Point, NC	3.10
87	Kansas City, MO-KS	3.19
88	Oklahoma City, OK	3.29
89	Tulsa, OK	3.35
90	Omaha, NE-IA	3.47
91	McAllen-Edinburg-Mission, TX	3.68
92	Dayton-Springfield, OH	3.71
93	Indianapolis, IN	4.00
94	Fort Wayne, IN	5.36
95	Wichita, KS	5.45

Source: Albert Saiz. 2010. Geographic Determinants of Housing Supply. *Quarterly Journal of Economics*

Appendix 3: Wharton Regulatory Index

Physical and Regulatory Development Constraints (Metro Areas with Pop>500,000)

Rank	MSA/NECMA Name	Undevelopable Area	WRI	Rank	MSA/NECMA Name	Undevelopable Area	WRI
1	Ventura, CA	79.64%	1.21	49	Minneapolis-St. Paul, MN-WI	19.23%	0.38
2	Miami, FL	76.63%	0.94	50	Buffalo-Niagara Falls, NY	19.05%	-0.23
3	Fort Lauderdale, FL	75.71%	0.72	51	Toledo, OH	18.96%	-0.57
4	New Orleans, LA	74.89%	-1.24	52	Syracuse, NY	17.85%	-0.59
5	San Francisco, CA	73.14%	0.72	53	Denver, CO	16.72%	0.84
6	Salt Lake City-Ogden, UT	71.99%	-0.03	54	Columbia, SC	15.23%	-0.76
7	Sarasota-Bradenton, FL	66.63%	0.92	55	Wilmington-Newark, DE-MD	14.67%	0.47
8	West Palm Beach-Boca Raton, FL	64.01%	0.31	56	Birmingham, AL	14.35%	-0.23
9	San Jose, CA	63.80%	0.21	57	Phoenix-Mesa, AZ	13.95%	0.61
10	San Diego, CA	63.41%	0.46	58	Washington, DC-MD-VA-WV	13.95%	0.31
11	Oakland, CA	61.67%	0.62	59	Providence-Warwick-Pawtucket, RI	13.87%	1.89
12	Charleston-North Charleston, SC	60.45%	-0.81	60	Little Rock-North Little Rock, AR	13.71%	-0.85
13	Norfolk-Virginia Beach-Newport News, VA-NC	59.77%	0.12	61	Fresno, CA	12.88%	0.91
14	Los Angeles-Long Beach, CA	52.47%	0.49	62	Greenville-Spartanburg-Anderson, SC	12.87%	-0.94
15	Vallejo-Fairfield-Napa, CA	49.16%	0.96	63	Nashville, TN	12.83%	-0.41
16	Jacksonville, FL	47.33%	-0.02	64	Louisville, KY-IN	12.69%	-0.47
17	New Haven-Bridgeport-Stamford, CT	45.01%	0.19	65	Memphis, TN-AR-MS	12.18%	1.18
18	Seattle-Bellevue-Everett, WA	43.63%	0.92	66	Stockton-Lodi, CA	12.05%	0.59
19	Milwaukee-Waukesha, WI	41.78%	0.46	67	Albuquerque, NM	11.63%	0.37
20	Tampa-St. Petersburg-Clearwater, FL	41.64%	-0.22	68	St. Louis, MO-IL	11.08%	-0.73
21	Cleveland-Lorain-Elyria, OH	40.50%	-0.16	69	Youngstown-Warren, OH	10.52%	-0.38
22	New York, NY	40.42%	0.65	70	Cincinnati, OH-KY-IN	10.30%	-0.58
23	Chicago, IL	40.01%	0.02	71	Philadelphia, PA-NJ	10.16%	1.13
24	Knoxville, TN	38.53%	-0.37	72	Ann Arbor, MI	9.71%	0.31
25	Riverside-San Bernardino, CA	37.90%	0.53	73	Grand Rapids-Muskegon-Holland, MI	9.28%	-0.15
26	Portland-Vancouver, OR-WA	37.54%	0.27	74	Dallas, TX	9.16%	-0.23
27	Tacoma, WA	36.69%	1.34	75	Richmond-Petersburg, VA	8.81%	-0.38
28	Orlando, FL	36.13%	0.32	76	Houston, TX	8.40%	-0.40
29	Boston-Worcester-Lawrence, MA-NH	33.90%	1.70	77	Raleigh-Durham-Chapel Hill, NC	8.11%	0.64
30	Jersey City, NJ	33.80%	0.29	78	Akron, OH	6.45%	0.07
31	Baton Rouge, LA	33.52%	-0.81	79	Tulsa, OK	6.29%	-0.78
32	Las Vegas, NV-AZ	32.07%	-0.69	80	Kansas City, MO-KS	5.82%	-0.79
33	Gary, IN	31.53%	-0.69	81	El Paso, TX	5.13%	0.73
34	Newark, NJ	30.50%	0.68	82	Fort Worth-Arlington, TX	4.91%	-0.27
35	Rochester, NY	30.46%	-0.06	83	Charlotte-Gastonia-Rock Hill, NC-SC	4.69%	-0.53
36	Pittsburgh, PA	30.02%	0.10	84	Atlanta, GA	4.08%	0.03
37	Mobile, AL	29.32%	-1.00	85	Austin-San Marcos, TX	3.76%	-0.28
38	Scranton-Wilkes-Barre-Hazleton, PA	28.78%	0.01	86	Omaha, NE-IA	3.34%	-0.56
39	Springfield, MA	27.08%	0.72	87	San Antonio, TX	3.17%	-0.21
40	Detroit, MI	24.52%	0.05	88	Greensboro-Winston-Salem-High Point, NC	3.12%	-0.29
41	Bakersfield, CA	24.21%	0.40	89	Fort Wayne, IN	2.56%	-1.22
42	Harrisburg-Lebanon-Carlisle, PA	24.02%	0.54	90	Columbus, OH	2.50%	0.26
43	Albany-Schenectady-Troy, NY	23.33%	-0.09	91	Oklahoma City, OK	2.46%	-0.37
44	Hartford, CT	23.29%	0.49	92	Wichita, KS	1.66%	-1.19
45	Tucson, AZ	23.07%	1.52	93	Indianapolis, IN	1.44%	-0.74
46	Colorado Springs, CO	22.27%	0.87	94	Dayton-Springfield, OH	1.04%	-0.50
47	Baltimore, MD	21.87%	1.60	95	McAllen-Edinburg-Mission, TX	0.93%	-0.45
48	Allentown-Bethlehem-Easton, PA	20.86%	0.02				

Note: WRI = Wharton Regulation Index

Source: Albert Saiz. 2010. Geographic Determinants of Housing Supply. *Quarterly Journal of Economics.*

Appendix 4: Concentration Index

Market	Index	Market	Index
Atlanta	0.0799	Nashville	0.1406
Austin	0.1187	New York	0.2037
Baltimore	0.1559	Norfolk	0.2013
Birmingham	0.3172	Newark	0.4445
Boston	0.1330	Oakland	0.2793
Chicago	0.2959	Oklahoma City	0.2007
Charlotte	0.1521	Orange County	0.1242
Cincinnati	0.1852	Orlando	0.1435
Cleveland	0.1487	Phoenix	0.0915
Columbus	0.1739	Pittsburgh	0.2326
Dallas	0.0422	Portland	0.3452
Denver	0.1143	Riverside	0.1811
Detroit	0.1308	Sacramento	0.1408
Edison	0.2186	Salt Lake City	0.2855
Fort Lauderdale	0.1745	San Antonio	0.1945
Fort Worth	0.1033	San Diego	0.1006
Greensboro	0.1746	Seattle	0.0895
Houston	0.1603	San Francisco	0.1881
Indianapolis	0.1466	San Jose	0.1686
Jacksonville	0.1847	St. Louis	0.2058
Kansas City	0.1210	Tampa	0.1177
Los Angeles	0.1187	Washington D.C.	0.1161
Las Vegas	0.1757	West Palm Beach	0.2955
Miami	0.2368	Philadelphia	0.0874
Minneapolis	0.2041		

Source: Author

Appendix 5: **Summary Statistics, Property Type Subindices, quarterly total returns, 1984.4 to 1998.4 (57 observations)**

	RMRoff	RMRret	RMRind	RMRapt	NPIoff	NPIret	NPIind	NPIapt
Mean %	1.09%	2.06%	1.89%	2.05%	1.14%	1.96%	1.88%	2.10%
Standard deviation %	2.89%	2.05%	2.20%	1.94%	2.49%	1.78%	1.77%	1.26%
Jarque-Bera	0.7380	2.4666	2.5204	6.8181	42.4300	6.7656	12.6391	26.3038
Correlations:								
RMRoff	100%	29%	72%	44%	83%	44%	79%	63%
RMRret	29	100	44	39	46	72	52	40
RMRind	72	44	100	32	73	38	78	51
RMRapt	44	39	32	100	53	30	55	61
NPIoff	83	46	73	53	100	57	92	73
NPIret	44	72	38	30	57	100	63	53
NPIind	79	52	78	55	92	63	100	76
NPIapt	63	40	51	61	73	53	76	100

Note. The official NPI is not published for the apartment subindex prior to 1984.4 due to insufficient numbers of properties (less than 20). However, we are able to estimate a RMR version of the apartment index starting in 1978.1 using the Bayesian estimator.

Source: David Geltner, William Goetzman. 2000. Two Decades of Commercial Property Returns: A Repeated- Measures Regression-Based Version of the NCREIF Index. *Journal of the American Real Estate and Urban Economics Association*