Neighborhood Attributes and House Price Risk[1]

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Neighborhood Attributes and House Price Risk

Abstract

Idiosyncratic risk in house prices is important to homeowners as it directly affects uncertainty in the value of the asset as well as in home value appreciation. This paper empirically examines whether this risk is systematically related to the level of neighborhood (delineated with zip codes) median household incomes, controlling for other local housing market attributes using about 26 million transactions of single-family homes sold between 1996:Q1 and 2012:Q3 in 7,658 zip codes across the US. For each neighborhood, we fit the parameters of the same hedonic house price model to transactions for each of three separate time periods: (1) when US house prices were essentially constant in real terms; (2) during the recent housing boom; and (3) during the recent housing bust, and then use the standard deviation of the residuals to measure the house price risk. We find U-shape relationships between house price risk and household income in all three periods: the risk is relatively high in both low- and high-income neighborhoods and substantially lower in moderate income neighborhoods. The pattern persists after controlling for statistical and economic attributes that influence the measurement of house price risk. We then estimate the risk and returns to owner-occupied housing where homebuyers finance the acquisition of their home using various degrees of leverage. In most circumstances, leverage increases returns to homeownership with significant increases in risk. Leveraged risk is higher for properties located in low-income neighborhoods relative to properties located in moderate income neighborhoods.

I. Introduction

Idiosyncratic risk in house prices increases the uncertainty in home value appreciation, and thus the uncertainty in household wealth, which might further impact the consumption and investment decisions of homeowners. To see the impact of idiosyncratic house price risk on uncertainty in home value appreciation, consider a market of homogeneous properties, in which the price of property i in period t, denoted by $P_{i,t}$, only differs from the average/equilibrium price in the same period, denoted by $P_{m,t}$, by an idiosyncratic risk $\varepsilon_{i,t}$ that is i.i.d. across properties within a given submarket and over time.

$$P_{i,t} = P_{m,t}\varepsilon_{i,t} \tag{1}$$

or

$$\log\left(P_{i,t}\right) = \log\left(P_{m,t}\right) + \log\left(\varepsilon_{i,t}\right) \tag{2}$$

Denote the variance of $\log\left(\varepsilon_{i,t}\right)$ by δ^2.

The idiosyncratic risk in price generates extra uncertainty in home value appreciation for individual homeowners, as the value appreciation for property i from period buy_i to period $sell_i$ differs from the average value appreciation in the market.

$$\log\left(\frac{P_{i,sell_i}}{P_{i,buy_i}}\right) \neq \log\left(\frac{P_{m,sell_i}}{P_{m,buy_i}}\right) \tag{3}$$

One can quantify the magnitude of this uncertainty with

$$\mathrm{var}\left(\log\left(\frac{P_{i,sell_i}}{P_{i,buy_i}}\right) - \log\left(\frac{P_{m,sell_i}}{P_{m,buy_i}}\right)\right). \tag{4}$$

It is easy to see that

$$\begin{aligned}
&\log\left(\frac{P_{i,sell_i}}{P_{i,buy_i}}\right) - \log\left(\frac{P_{m,sell_i}}{P_{m,buy_i}}\right) \\
&= \log\left(P_{i,sell_i}\right) - \log\left(P_{m,sell_i}\right) - \log\left(P_{i,buy_i}\right) + \log\left(P_{m,buy_i}\right) \\
&= \log\left(\varepsilon_{i,sell_i}\right) - \log\left(\varepsilon_{i,buy_i}\right).
\end{aligned} \tag{5}$$

Assuming the valuation errors are i.i.d., the magnitude of the uncertainty in the value appreciation is simply $2\delta^2$. This suggests that idiosyncratic risk in house prices directly determines uncertainty in value appreciation. This effect is particularly important for homeowners with less wealth, as home equity likely constitutes a larger portion of their household wealth.

Understanding the relationship between house price risk and household income is important for a variety of reasons. Uncertainty in the market value of the asset increases the risk associated with the expected return to owner-occupied housing. House price risk is an important parameter in models of tenure choice, in portfolio allocation models, and in models where households decide how to optimally hedge against future housing consumption costs. Most of these models assume that house price risk is constant across the distribution of household income. In addition, the Federal government has numerous programs that subsidize owner-occupied housing. Many of these programs are targeted towards low-income households. The question addressed in this paper is whether low-income households face the same level of house price risk as non-low-income households.

Despite the importance of the idiosyncratic risk, the current literature provides little theoretical prediction and no empirical evidence regarding its determinants. This paper empirically investigates two important questions regarding the distribution of the risk, which we call the "risk segmentation", in the housing market.[4] First, is the idiosyncratic risk in house prices related to neighborhood characteristics, particularly the level of household income, house prices, and the heterogeneity of the local housing stock? Second, do these relationships change over time? Particularly, do they vary across booming and busting periods of the housing market?

By analyzing these questions, this paper extends the research by Peng and Thibodeau (2013). While Peng and Thibodeau (2013) document the risk segmentation phenomenon, they measure the neighborhood house price risk with the *temporal* variation of the *average* house prices in the neighborhood. This paper, on the other hand, investigates the idiosyncratic risk in house prices, which pertains to the deviation of the actual transaction price from a predicted value obtained from a hedonic model of neighborhood house prices. These two different risk measurements, one being temporal and the other being cross-sectional, describe different aspects of house price

[4] Peng and Thibodeau (2013) find that temporal house price risk varies across neighborhoods and is related to neighborhood household income with low-income neighborhoods experiencing higher risk.

risk. Consequently, the results complement each other and help create a more complete picture regarding low-income households' exposure to housing risk.

The data for this analysis was obtained from Zillow.com and consists of 25,927,216 transactions of single-family homes sold over the 1996:Q1 through 2012:Q3 period. The properties are located in 7,658 zip codes across the United States. The analysis is conducted using the same hedonic house price specification for each zip code and for each of the three separate time periods: (1) when US house prices were essentially constant in real terms (between 1996:Q1 to 2000:Q4); (2) during the recent housing boom period (2001:Q1 to 2007:Q2); and (3) during the recent housing bust (2007:3 to 2012Q3). Hedonic house price equation residuals were computed for the same 7,658 zip codes in each of the three time periods.

II. Literature Review

Several papers have reported that house price risk is not constant, either spatially or temporally. Poterba, Weil and Shiller (1991) separate home sales data from 1970 to 1982 data from Atlanta, Chicago, Dallas and Oakland into four quartiles of the house price distribution and find that prices for high-value homes were more volatile over time than prices of lower-value homes. Mayer (1993) replicates that result and attributes the difference in volatility to variation in the user cost of owner-occupied housing and cyclical factors. Dolde and Tirtiroglue (1997) find evidence of time-varying volatility and positive relations between conditional variance and returns in towns in Connecticut and near San Francisco from 1971 to 1994. Dolde and Tirtiroglue (2002) analyze 36 volatility events in four regional housing markets from 1975 to 1993 and find associations between these volatility events and economic conditions. Capozza, Hendershott and Mack (2004) explore the dynamics of housing price mean reversion and responses to income, population and construction or supply costs for 62 metro areas from 1979 to 1995. They find heterogeneity in terms of the price trend responses to these economic variables based on the time period and the specific MSA. Miller and Peng (2006) use GARCH and panel VAR models to analyze time variation in the volatility of single-family home value appreciation rates in 277 MSAs between 1990:1 and 2002:2. They find evidence of time varying volatility in about 17% of the MSAs, and that the volatility relates to home appreciation rate and GMP growth rate. Bao and Long (2007) use a VAR - MGARCH model to analyze the weekly return and volatility in the Hong Kong residential property market. Miles (2008) tests fifty state housing markets for GARCH, and finds GARCH effects in over half the states with widely varying signs and magnitudes. Zhou and Haurin (2010) analyze the determinants of house price volatility at the national level using national American Housing Survey data over the 1974-2003 period. They find that house prices at both the high end and the low end of the price distribution are more volatile than prices in the middle of the distribution. Using two measures of house price volatility (the standard deviation in the annualized price change and a metric derived from a repeat sales house price equation), Ambrose, Buttimer and Thibodeau (2001) report that house price volatility in the Dallas market is U-shaped across the distribution of house prices – it is high for low-priced homes, low for moderately priced homes, and high for expensive homes.

Using data for 99 zip codes in the Denver metropolitan area, Peng and Thibodeau (2013) examine house price volatility (as measured by the standard deviation of quarterly house price gross appreciation rates) over the 2002:1 through 2007:4 period. They report volatility is systematically related to neighborhood socioeconomic characteristics. Neighborhood characteristics examined include median household income, poverty, turnover, density, and land leverage. They find strong empirical evidence that house price risk is higher in lower-income neighborhoods, controlling for housing turnover, density and land leverage.

There is a substantial academic literature that incorporates house price risk in models of consumer choice. Quantifying uncertainty in house price levels and in appreciation rates is important because house price risk influences households' tenure choice decisions, portfolio allocation decisions and hedging future housing consumption cost decisions.

Ortalo-Magné and Rady (2002) develop a theoretical household choice model where households select the tenure that maximizes their utility constrained by uncertain household income, house prices, and rents. House price risk is assumed constant across the distribution of household income. Davidoff (2006) empirically examines the influence that household income and local housing costs have on tenure choice. He concludes that the rate of homeownership is negatively related to the covariance between household income and house prices. Sinai and Souleles (2005) develop a model of tenure choice with endogenous house prices and show that homeownership is positively correlated with uncertainty in renting costs. They empirically demonstrate that households who live in high rent variance Metropolitan Statistical Areas (MSAs) are more likely to own compared to similar households who live in low rent variance MSAs. Turner (2003) reports that volatility in house prices reduces rates of homeownership. She also concludes that the impact is greater for low-income households and for first time homebuyers.

Englund, Hwang and Quigley (2002) examine the wealth implications of including returns to owner-occupied housing in portfolios consisting of common stock, public real estate equities and bonds. Their measure of returns to owner-occupied housing includes three components: (1) the rate of change in the market price of housing; (2) the imputed rent associated with owner-occupied housing; and (3) the idiosyncratic component of house price. They conclude that for longer holding periods, low-risk portfolios contain 15% to 50% owner-occupied housing. Han (2008) develops and estimates the parameters of a model that separates the effect of house price uncertainty on housing demand into two components: (1) a financial risk effect; and (2) a hedging effect. Financial risk measures the effect that house price volatility has on household wealth while the hedging effect measures the influence that house price uncertainty has on a household's desire to hedge future housing consumption. Han's empirical model relates housing demand to a variety of household socioeconomic characteristics (age of household head, level of education, professionally licensed employment, job tenure, family income, marital status, family size and presence of children). Han's empirical results indicate that households are motivated by both financial and hedging incentives when making housing consumption decisions.

III. Research design

The initial stage of our research has two steps. We first fit transaction prices in each zip code for each of three periods to a standard hedonic model, and use the hedonic residuals to measure idiosyncratic risk. In the second step, we analyze the relationship between idiosyncratic risk and the socioeconomic characteristics of the local housing market.

The hedonic house price specification used here is standard:

$$\ln(V_{i,t}) = \beta_0 + \beta_1*AREA + \beta_2*AGE + \beta_3*AGESQ + \beta_4*AGECUBE + \beta_5* OLDAGE$$

$$+ \beta_6*BED1 + \beta_7*BED2 + \beta_8*BED4 + \beta_9*BED5$$

$$+ \beta_{10}*BATHS\ 1.0 + \beta_{11}*BATHS\ 1.5 + \beta_{12}*BATHS\ 2.5$$

$$+ \beta_{13}*BATHS\ 3.0 + \beta_{14}*BATHS\ 3.5 + \beta_{15}*BATHS\ 4.0$$

$$+ \sum_{t=1}^{T} \delta_t * SOLD_t + \varepsilon_{i,t}, \qquad (6)$$

where

$V_{i,t}$ = the transaction price of the i^{th} house sold in quarter;

AREA = square feet of living area,

AGE = age of the dwelling in decades for properties built since 1940; sets year built to 1940 for properties built before 1940,

AGESQ = AGE squared,

AGECUBE = AGE cubed,

OLDAGE = dummy variable for properties built prior to 1940,

BEDSj = dummy variable for properties with j bedrooms; equals number of bedrooms for properties with 5 or more bedrooms,

BATHSj = dummy variable for the number of bathrooms; equals the number of bathrooms for properties with four or more bathrooms,

$SOLD_t$ = dummy variables for sale quarter: q1 = 1 if a property sold in 1996:1 and equals zero otherwise; q2 = 1 if a property sold in 1996:2 and equals zero otherwise; etc.

The same specification was used to estimate the parameters of the hedonic house price equation for each zip code and for each time period. Parameters were estimated separately for each of three time periods: (1) between 1996:Q1 and 2000:Q4; (2) between 2001:Q1 and 2007:Q2; and (3) between 2007:3 and 2012Q3). Hence, differences in the distribution of the residuals cannot be attributed to differences in model specification either across neighborhoods or over time.

We measure the idiosyncratic risk in each zip code and in each of the three periods with the standard deviation of the neighborhood hedonic residual. To control for the influence that location amenities have on house prices, it is important to estimate the parameters of the hedonic house price equation for small geographic areas, or neighborhoods, which are delineated using zip codes in this paper[5]. Under the reasonable assumption that houses in the same neighborhood are relatively homogeneous, regression residuals are more likely reflecting true noise in house pricing, instead of systematic deviations due to missing hedonic variables. Though the caveat of omitted variables always exists.

Determinants of House Price Risk

We relate the variation in local house prices, controlling for observed housing characteristics, to characteristics of the local housing market. We are primarily interested in whether variation in valuation accuracy varies across the distribution of household income. We attempt to isolate the relationship between house price risk and neighborhood household income by controlling for other economic and statistical attributes that may influence this relationship.

Following the literature, we hypothesize that the risk may be related to household incomes and/or house values in a non-linear way—high for low-income/low-house value neighborhoods; lower for moderate income/moderate house value neighborhoods and high again for upper income/house value neighborhoods. We test the hypotheses using cross sectional linear regressions of zip code level house price risk against an array of zip code level explanatory variables: (1) median household income and its square; (2) the median owner's estimate of value and its square; (3) variables measuring the heterogeneity of the local housing stock; (4) market liquidity; and (5) the number of observations used to estimate house price risk. To see if the relationships vary across time, we estimate parameters separately for each time period.

Ceteris paribus, owner-occupied homes located in low-income neighborhoods may be subject to greater risk for a variety of reasons. First, financial constraints are more binding for low-income households. Low-income households who chose to own may be forced into purchasing homes in

[5] Goodman and Thibodeau (2003) demonstrate that zip-code districts predicted house prices about as well as census tracts and elementary school zones in delineating local neighborhoods.

neighborhoods with less desirable risk/return tradeoffs relative to properties located in moderate income neighborhoods. Second, the degree of financial literacy may influence a home-buyers ability to value the asset. Low-income households may be at a financial literacy disadvantage relative to moderate- and upper-income households in this regard. Consequently, there may be more valuation uncertainty in the value of homes located in low-income neighborhoods.

In addition, the market value of an individual property may be more difficult to estimate accurately in high-priced neighborhoods relative to homes located in moderately priced neighborhoods. Consequently, the model that explains variation in house price risk includes the median owner-occupant's estimate of the value of the house in 2000.

Heterogeneity in the housing characteristics of the local housing stock may also influence the accuracy of value estimates. Goodman and Thibodeau (1995, 1997) report that the residuals in hedonic house price equations are systematically related to the age of the dwelling. The intuition is that the older a property, the less is known about its maintenance history and the more challenging it becomes to accurately estimate the market value of the property. Goodman and Thibodeau (1998) report a similar attribute of repeat sales house price equations. Thibodeau (2003) reports that, in addition to the age of a home, the probability that a predicted house price is within ten percent of a property's observed transaction price is also related to the size of a property; to the standard deviations of neighborhood property size and age; and to the liquidity of the neighborhood. Liquidity is measured using the rate of property transactions in the submarket.

Finally, the measure of risk may be influenced by the number of transactions used to estimate house price risk, with the standard deviation of the hedonic residual declining as the sample size increases.

The empirical model we use to explain variation in house price risk is:

$$\hat{\sigma}_i = \alpha + \beta_1 * Income_i + \beta_2 * Income_i^2 + \beta_3 * Value_i + \beta_4 * Value_i^2 + \beta_5 * Numobs_i + \\ + \beta_6 * Turnover_i + \beta_7 * Avgarea_i + \beta_8 * Avgage_i + \beta_9 * ProportionOld_i \\ + \beta_{10} * Stdarea_i + \beta_{11} * Stdage_i + \varepsilon_i \qquad (7)$$

where $\hat{\sigma}_i$ = the standard deviation of the residuals in neighborhood i;

$Income_i$	=	2000 Census median neighborhood income (÷ 10,000);
$Income_i^2$	=	$Income_i$ squared (to capture any non-linear relationship);
$Value_i$	=	2000 Census median (owner's estimate of) house value (÷ 100,000);
$Value_i^2$	=	$Value_i$ squared (to capture any non-linear relationship);
$Numobs_i$	=	Number of observations (÷ 1,000) used to estimate $\hat{\sigma}$;
$Turnover_i$	=	Number of transactions during the period divided by the number of owner-occupied homes in 2000;
$Avgarea_i$	=	Average square feet of living space for homes sold;
$Avgage_i$	=	Average age for properties built since 1940;
$ProportionOld_i$	=	Proportion of neighborhood homes built before 1940;
$Stdarea_i$	=	Standard deviation of average dwelling sizes;
$Stdage_i$	=	Standard deviation of average dwelling ages; and
ε_i	=	the residual.

Data on individual property transactions is available since 1996. Parameters in (7) are estimated twice for each of three time periods. During the first period (1996:1 and 2000:4) house prices were approximately constant in real terms nationally; housing prices increased significantly in real terms during the second period (2001:1 and 2007:3) and decreased substantially during the third time period (2007:4 and 2012:3). In addition, the parameters of (7) are estimated both with and without MSA fixed effects.

To control for the variation in the number of observations used to estimate risk across neighborhoods, we also compute estimates of house price risk by bootstrapping the hedonic residuals. We randomly draw 100 transactions from each of the zip codes, with replacement, and compute house price risk for each neighborhood using the sampled residuals.

We then examine the effect that leverage has on the relationship between house price risk and neighborhood median incomes. For each of the 100 randomly sampled transactions and for each of the three time periods we simulate a purchase at the beginning of the period and a sale at the end of the period where both the purchase and sale prices are subject to valuation errors. We compute the homeowner's equity at the beginning of the period assuming 80%, 90%, and 95%

financing. We assign the neighborhood average rate of appreciation to each purchase. Appreciation rates are obtained from the hedonic house price equations' estimated parameters. We assume the homebuyer who finances the acquisition of their property pays 1.7% of the purchase price in transaction costs. Cash buyers pay 0.85%. We assume the seller pays 6.5% in transaction costs. We also assume that homeowners default if their ending equity is negative with no additional cost. This last assumption understates the true cost of default and overestimates homeowners' returns to owner-occupied housing.

IV. The Data

Zillow.com has a database of over 80 million owner-occupied homes sold between 1996 and 2012:Q3. Many of these are single-family attached homes or condominiums. This analysis restricts the data to single-family detached properties. In addition, there is substantial variation in the availability of housing attributes across property assessment districts (a primary source of Zillow.com information). Consequently, neighborhoods were excluded from the analysis if data on dwelling size, dwelling age, number of bedrooms or bathrooms was unavailable. Finally, results reported in this paper are limited to the zip codes that had at least fifty owner-occupied homes in the 2000 census and at least one hundred transactions in each of the three time periods. The data for this analysis consists of 25,927,216 transactions of single-family homes sold over the 1996:Q1 through 2012:Q3 period. The properties are located in 7,658 zip codes across the United States. These zip codes are located in 210 of the largest Metropolitan Statistical Areas in the US.

Table 1 provides summary statistics for the number of observations used to estimate the hedonic parameters and for the residual standard deviations. The average number of transactions used to estimate hedonic parameters was 929.1 for the first time period (1996:1 to 2000:4); the standard deviation was 905.1 and the number of observations ranged from 100 transactions to 7,928 transactions. The average number of transactions used to estimate hedonic parameters increased to 1,712.5 during the housing market boom and decreased to 744.0 during the housing market bust. These transactions exclude foreclosures and short sales and represent market rate transactions. The across zip code average standard deviation in the hedonic residuals was 0.220 during the initial time period; 0.222 during the housing boom and 0.242 during the housing bust.

This paper examines whether the residual standard deviations are systematically related to neighborhood median household incomes, median house values, market liquidity, the heterogeneity of the local housing stock and the number of transactions used to estimate the hedonic parameters. Zip code level household incomes, median house values, and other housing market attributes (e.g. the number of owner-occupied housing units) are obtained from the 2000 Census' STF3 file. The mean 2000 Census median household income (divided by 100,000) for the 7,658 zip codes examined in this paper is 0.499 (or $49,900). Neighborhood median household incomes range from $27,400 to $196,300. The mean 2000 Census median homeowner's estimate of home value (divided by 100,000) in 2000 was 1.553 (or $155,300) with a range of from $27,400 to $1,000,000 (the top coded value category).

Turnover is computed as the total number of transactions during the period divided by the number of owner-occupied units in the zip code in 2000. Approximately 3.4% of the 2000 Census owner-occupied housing stock sold each year between 1996 and 2000. Average turnover nearly doubled between the first and second period, going from 0.172 to 0.336, reflecting the dramatic increase in housing transactions during the housing boom. Average turnover declined to 0.143 during the housing bust. The average size of properties (measured as the square feet of living area) increased over the three periods and the average age of homes sold declined during the 17 year period. The average size of homes sold was 1,730 square feet during the first period; 1,763 during the second period; and 1,810 during the third period. The average age of homes sold declined from 41.8 years old during the first period; to 39.3 in the second period and to 38.3 in the third period. The standard deviations in the average size and average dwelling age increased from the first to the second period, but decreased from the second to the third period.

V. The Results

Table 2 provides the results for the models that relate the residual standard deviations to neighborhood household income, median neighborhood house value, turnover, heterogeneity of the housing stock, and the number of transactions. With the exception of the square of median values in the first period and turnover in the third period, all of the estimated coefficients are statistically significant. The estimated coefficients indicate that, controlling for neighborhood house prices and other attributes of the local housing market, house price risk is non-linearly related to median neighborhood household incomes. The estimated coefficients for both the linear and quadratic income variables are highly significant. The results also indicate that an increase in the number of transactions used to estimate risk reduces risk, the expected statistical relationship.

The estimated coefficients for turnover have unexpected signs.

All the estimated coefficients for the housing stock heterogeneity variables are statistically significant at conventional levels with expected signs—the larger the neighborhood average property size, the greater the valuation risk; the older the neighborhood average property, the higher the valuation risk; and the greater the dispersion in both dwelling size and age, the greater the valuation risk.

Adjusted R-squares range from 0.28 in the first and second time periods to 0.32 in the third.

Interpreting individual estimated coefficients is challenging because income and value are specified as quadratics. Figures 1 and 2 provide a graphical representation of the relationship between neighborhood household income and house price risk. Figure 1 is derived from an equation that simply relates risk to a quadratic in median household income.[6] Figure 2 is derived from the estimated coefficients reported in Table 2 for various levels of income and other variables evaluated at their mean. Figure 1 clearly shows that the relationship between cross-sectional house price risk (or valuation uncertainty) and neighborhood household incomes is U-Shaped—high for low-income neighborhoods, declining substantially for moderate income neighborhoods, then increasing significantly for upper-income neighborhoods. The median neighborhood income for the 7,658 zip codes included in this analysis is about $50,000 so about half the observations are depicted in the left quarter of Figure1.

Figure 2 presents the relationship between house price risk and neighborhood house values controlling for the other attributes that influence valuation uncertainty. The relationship between

[6] These regression results are not reported in the paper but are available from the authors.

house price risk and neighborhood house values controlling for other attributes is also U-shaped, but controlling for other attributes appears to reduce valuation uncertainty for higher-income neighborhoods.

Table 3 reports estimated parameters for a house price risk model that includes MSA fixed effects. The zip codes used in this analysis include most of the largest metropolitan areas in the US. For the MSA fixed effects model, we eliminate any zip code that: (1) is not located in an MSA; or (2) is located in an MSA but has fewer than five zip codes. This leaves us with 6,682 neighborhoods located in 166 MSAs. About 92% of the MSA estimated coefficients are statistically significant. Consequently, the adjusted R-squares increase significantly in each of the three periods (to 0.45 in the first period; to 0.46 in the second period and to 0.50 in the third period). The relationship between house price risk and neighborhood income is still apparent. An increase in the number of transactions reduces the estimate of risk; turnover is significant in two of the three periods with the unexpected sign; and all the estimated coefficients for variables measuring the heterogeneity of the local housing stock are statistically significant with the expected signs.

Results presented in Tables 2 and 3 indicate that the estimate of risk is lower in neighborhoods with more transactions. Recall the sample sizes used to estimate risk range from 100 observations to 14,541 (in the second period). To separate this statistical influence from the relationship between house price risk and neighborhood household income, we bootstrap (Efron and Tibshirani, 1994) the residuals. We select a random sample of 100 residuals, with replacement, from each of the 7,658 zip codes and re-compute the standard deviations. We then use those estimates of risk in models that relate house price risk to household income and attributes of the local housing stock.

The distributions of house price risk computed from the bootstrapped residuals were very similar to the estimates reported in Table 1. The mean standard deviation of the bootstrapped residuals was 0.2198 (vs. 0.2200 for all transactions) for the first period; 0.2199 (vs. 0.2221) in the second period; and 0.2391 (vs. 0.2416) in the third period. Other distribution summary statistics (e.g. standard deviations, minimums, maximums, etc.) were also similar.

Because all standard deviations are now estimated using 100 observations, we delete the number of observations as an explanatory variable in the house price risk models. Tables 4 and 5 report the regression statistics for the house price risk models using bootstrapped estimates of risk as the dependent variable. Table 4 reports estimated parameters for all 7,658 zip codes and Table 5 reports estimated parameters for the MSA fixed effects model. With one exception, parameter estimates for the bootstrapped risk model are very similar to the estimates reported in Tables 2 and 3: the estimates are statistically significant at conventional levels; the relationship between house price risk and household income is non-linear with risk being high for low-income neighborhoods, lower for moderate income neighborhoods, and higher for upper income neighborhoods. Most of the estimated coefficients that control for the heterogeneity of the local housing stock are positive and statistically significant. The only difference between the bootstrapped results and the initial results is that the estimated coefficients for the turnover variables are now negative, as expected, and statistically different from zero at the 1% level. Figure 3 graphically presents the relationship between (bootstrapped) house price risk and neighborhood household income. The graph was constructed by pricing other attributes at their means. Including MSA fixed effects reduces the average risk (as measured by the intercept), but the other estimated coefficients reported in Table 5 are similar to those reported in Table 4.

The Effect of Valuation Uncertainty on Risk and Returns for Leveraged Acquisitions

The empirical results reported above reflect the relationship between neighborhood household income and valuation risk at one point in time--when a dwelling is bought or sold. Equations (1) through (5) in the Introduction demonstrate that valuation uncertainty influences price at both the time of purchase and the time of sale. Furthermore, most owner-occupied housing is financed. How do valuation errors influence risk and returns to owner-occupied housing over an entire holding period when the acquisitions are financed? To address this question, we simulated the purchase and sale of owner-occupied homes for each of the three periods. In each period, a household purchases the neighborhood median valued home subject to a valuation error drawn randomly from the distribution of hedonic residuals for that time period and for that neighborhood. The acquisition is financed with an interest only, fixed rate mortgage at three alternative leverage ratios: 80% loan-to-value; 90% loan-to-value; and 95% loan-to-value ratio loan. For leveraged acquisitions, the home-buyer pays a transaction cost equal to 1.7% of the purchase price. For all cash acquisitions, the home-buyer avoids the financing costs and is assumed to pay transaction costs that amount to 0.85% of the purchase price. The market value of the home appreciates at the neighborhood average appreciation rate. Appreciation rates are obtained using the estimated coefficients for the sale quarter dummy variables in (6), the $\hat{\delta}_t$. The homeowner sells the property at the end of a five year holding period at a price determined by the average appreciation for properties in the neighborhood plus or minus the valuation error. The valuation error at the end of the period is also randomly selected from the distribution of hedonic residuals. The seller pays a transaction cost assumed to equal 6.5% of the transaction price. Homeowners with negative equity default at no cost. This assumption clearly understates the loss (and the computed return) associated with homeownership. The internal rate of return on the homeowner's equity is computed for each purchase. This transaction is simulated for each random draw of the bootstrap sample—one hundred times for each of 7,658 neighborhoods in each of the three time periods.

Table 6 reports the average internal rate of return (IRR), average risk (measured as the average standard deviation of those IRRs), coefficients of variation and the change in housing wealth per dollar of initial equity for all cash purchases, for 80% loan-to-value (L/V) ratio loans, for 90% L/Vs and for 95% L/Vs and for each of four time periods—the three time periods described above plus one time period encompassing the entire 1996:1 through 2012:3 period.

The across 7,658 neighborhood mean annual IRR on homeowners' unleveraged acquisitions for the 1996:1 through 2000:4 period was 3.6%; the mean standard deviation was 6.1%. The average annual IRR for all cash acquisitions increased to 6.7% in the second period and declined to -7.5% in the third period. The risk associated with these returns stay about the same—6.5% for the second period and 6.2% for the third period. Over the entire 1996:1-2012:3 period, the average annual return was 4.8% and the average standard deviation was 6.6%. Coefficients of variation based on the average returns and average standard deviations were 1.7 for the first period, 0.97 for the second; and -0.27 for the third period. For each dollar of equity used to purchase owner-occupied housing with all cash, a homeowner earned $0.26 in the first period,

$0.46 in the second period and lost $0.27 in the third period. Over the entire 1996:1-2012:3 period, an all cash acquisition earned an average $0.38 per dollar of initial equity.

Leverage changes the risks and returns to owner-occupied housing dramatically. During a period when house prices were approximately constant in real terms (1996:1-2000:4), the average annual return to a house financed with an 80% L/V loan was 2.1%--lower than the average annual return to the unleveraged acquisition. This is attributable to the transaction costs. While combined purchase and sale transaction costs total 8.2% of the transaction price, this amounts to about 30% of the homeowners' initial equity for 80% L/V financing. While debt financing 'leverages' the homeowners' return, the transaction costs absorb a significant portion of that return. The average risk associated with the 80% L/V return increased by more than a factor of 5 to 31.2%. Leverage increased risk substantially. Average annual returns, as measured by the internal rate of return, for the 80% loan-to-value ratio loans increased to 13.7% for the second period and declined to -58.5% for the third period. Overall, the average annual return for the 80% L/V acquisition for entire period was +3.0%, about the rate of inflation and slightly less than the average return for unleveraged acquisitions. The risk was 27.8% for the second period; 33.4% for the third period; and 30.2% for the entire 1996:1-2012:3 period. Additional leverage increased returns and risk for the first two periods, but reduced returns and increased risk during the housing bust.

To examine the relationship between leveraged returns, risk and neighborhood household income, we computed the mean IRR and mean standard deviation of those IRRs for each percentile of the distribution of neighborhood household incomes. The resulting calculations are displayed in Figures 4 through 9. Figures 4, 6 and 8 display average IRRs for each percentile of the distribution of neighborhood household income while Figures 5, 7 and 9 display average standard deviations for those IRRs. Income percentile mean IRRs exhibit considerable noise across all three time periods. IRRs during the first period (Figure 5) exhibit an upward trend with properties in low-income neighborhoods averaging negative returns for properties acquired with 80% L/V loans and slightly positive returns for properties financed with 95% L/V loans. Returns increase with neighborhood household income and, for the 90th percentile of the income distribution, properties financed with 80% L/V ratio loans earn an average annual IRR of around

7.5% while properties financed with 95% L/V loans earn an average annual IRR of around 15%. The uncertainty associated with Period 1 returns (Figure 5) declines as neighborhood incomes increase. For properties financed with 80% L/V ratio loans, the average risk is about 0.375 for properties located in the first decile of the distribution of neighborhood household incomes. Risk declines to about 0.275 for properties located in the 90th percentile of the distribution of neighborhood household incomes. Returns during the housing boom appear flatter across the distribution of neighborhood household incomes (Figure 6) across all three L/Vs. The second period's house price risk, while noisy, exhibits a slightly declining pattern as neighborhood household incomes increase. Period 3 returns (Figure 8) and risk (Figure 9) are extremely volatile. Households experienced significant losses (with annual IRRs below -50%) across the entire distribution of neighborhood incomes. Returns were more negative for higher loan-to-value ratio loans. Risk was in the 30% to 40% range for all L/Vs during the third period.

VI. Conclusion

This paper empirically examines the relationship between neighborhood house price risk and median neighborhood household incomes. The house price risk is measured using residuals of hedonic regressions for about 26 million transactions of single-family homes sold over the 1996:Q1 through 2012:Q3 period provided by Zillow.com. Separate hedonic house price models were estimated for each of 7,658 zip code delineated neighborhoods and for each of three time periods: (1) 1996:Q1 to 2000:Q4; (2) 2001:Q1 to 2007:Q2; and 2007:Q3 to 2012:Q3. House prices in the US were essentially constant in real terms during the first time period; were rapidly appreciating in real terms during the second time period and were declining substantially (in both real and nominal terms) during the third time period.

Results indicate that neighborhood house price risk is systematically related to neighborhood household incomes with greater house price risk for the lowest- and highest income neighborhoods. The pattern appeared in each of the three time periods. In addition, house price risk for leveraged acquisitions was highest for low-income households and declined as neighborhood incomes increased.

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Table 1

Descriptive Statistics

N = 7,658 Zip Codes

Variable	Mean	Std Dev	Min	Max
1996:Q1-2000:Q4				
Number of Transactions	929.1	905.1	100	7,928
Residual Std Dev	0.220	0.071	0.043	0.612
Turnover	0.172	0.116	0.008	1.523
Average (size/1000)	1.730	0.392	0.912	4.331
Average (age/10)	4.182	1.407	1.281	7.193
Average (proportion old)	0.156	0.207	0.000	0.992
Std (size/1000)	0.667	0.276	0.141	2.918
Std average (age/10)	1.727	0.741	0.055	8.978
2001:Q1-2007:Q2				
Number of Transactions	1,712.5	1,630.9	105	14,541
Residual Std Dev	0.222	0.078	0.056	0.664
Turnover	0.336	0.274	0.014	2.973
Average (size/1000)	1.763	0.400	0.923	3.984
Average (age/10)	3.933	1.543	0.834	7.198
Average (proportion old)	0.152	0.205	0.000	0.990
Std (size/1000)	0.795	0.411	0.170	4.878
Std average (age/10)	2.183	1.148	0.032	14.932
2007:Q3-2012:Q3				
Number of Transactions	744.0	600.8	100	6,709
Residual Std Dev	0.242	0.079	0.054	0.706
Turnover	0.146	0.108	0.011	2.211
Average (size/1000)	1.810	0.420	0.962	4.077
Average (age/10)	3.831	1.564	0.619	7.199
Average (proportion old)	0.143	0.197	0.000	0.991
Std (size/1000)	0.722	0.294	0.164	6.667
Std average (age/10)	1.838	0.721	0.006	9.009
2000 Census Zip Code Data				
Median Income/100,000	0.499	0.183	0.135	1.963
Median Value/100,000	1.553	1.021	0.274	10.000

Table 2

House Price Risk for Zip Codes

N = 7,658 Zip Codes

Variable	1996-2001	2002-2007	2007-2012
Intercept	0.2026***	0.2611***	0.3204***
	(0.0081)	(0.0085)	(0.0085)
Median Income	-0.2451***	-0.2816***	-0.3393***
	(0.0174)	(0.0189)	(0.0185)
Median Income Squared	0.0789***	0.1096***	0.1452***
	(0.0122)	(0.0133)	(0.0130)
Median Value	0.0085***	-0.0136***	-0.0250***
	(0.0024)	(0.0026)	(0.0025)
Median Value Squared	0.0002	0.0021***	0.0032***
	(0.0003)	(0.0003)	(0.0003)
Number of Transactions/1000	-0.0214***	-0.0120***	-0.0185***
	(0.0010)	(0.0006)	(0.0014)
Turnover	0.0698***	0.0098***	0.0292
	(0.0076)	(0.0036)	(0.0084)
Average (size/1000)	0.0160***	0.0322***	0.0077***
	(0.0032)	(0.0033)	(0.0034)
Average (age/10)	0.0073***	0.0031***	0.0042***
	(0.0009)	(0.0009)	(0.0009)
Average (proportion old)	0.0557***	0.0755***	0.0582***
	(0.0054)	(0.0059)	(0.0060)
Std (size/1000)	0.0406***	0.0077***	0.0437***
	(0.0037)	(0.0028)	(0.0037)
Std average (age/10)	0.0101***	0.0068***	0.0092***
	(0.0010)	(0.0008)	(0.0011)
Adjusted R-Squared	0.280	0.276	0.317
F Value	271.4***	266.7***	324.6***

Standard Errors in Parethesis

*** statistically significant at 1% level

** statistically significant at 5% level

* statistically significant at 10% level

Table 3

House Price Risk for Zip Codes including MSA Fixed Effects

N = 6,682 Zip Codes

Variable	1996-2001	2002-2007	2007-2012
Intercept	0.0989***	0.1256***	0.1857***
	(0.0089)	(0.0091)	(0.0090)
Median Income	-0.1796***	-0.2201***	-0.2618***
	(0.0187)	(0.0197)	(0.0194)
Median Income Squared	0.0498***	0.0797***	0.1120***
	(0.0115)	(0.0121)	(0.0119)
Median Value	0.0220***	0.0143***	-0.0078**
	(0.0032)	(0.0033)	(0.0032)
Median Value Squared	-0.0007**	-0.0003	0.0015***
	(0.0003)	(0.0003)	(0.0003)
Number of Transactions/1000	-0.0146***	-0.0083***	-0.0145***
	(0.0009)	(0.0005)	(0.0013)
Turnover	0.0497***	0.0009	0.0156**
	(0.0079)	(0.0034)	(0.0077)
Average (size/1000)	0.0134***	0.0204***	0.0068*
	(0.0035)	(0.0035)	(0.0035)
Average (age/10)	0.0119***	0.0093***	0.0110***
	(0.0009)	(0.0009)	(0.0009)
Average (proportion old)	0.0560***	0.0619***	0.0572***
	(0.0051)	(0.0054)	(0.0054)
Std (size/1000)	0.0322***	0.0162***	0.0358***
	(0.0034)	(0.0025)	(0.0033)
Std average (age/10)	0.0102***	0.0060***	0.0119***
	(0.0010)	(0.0007)	(0.0011)
Adjusted R-Squared	0.451	0.457	0.502
F Value	32.1***	33.0***	39.2***

Standard Errors in Parethesis

*** statistically significant at 1% level

** statistically significant at 5% level

* statistically significant at 10% level

Table 4

Bootstrap House Price Risk

N = 7,658 Zip Codes

Variable	1996-2001	2002-2007	2007-2012
Intercept	0.2146***	0.2594***	0.3179***
	(0.0087)	(0.0091)	(0.0090)
Median Income	-0.2777***	-0.3060***	-0.3581***
	(0.0188)	(0.0202)	(0.0194)
Median Income Squared	0.0957***	0.1233***	0.1566***
	(0.0132)	(0.0142)	(0.0137)
Median Value	0.0110***	-0.0118***	-0.0230***
	(0.0026)	(0.0028)	(0.0027)
Median Value Squared	0.0001	0.0020***	0.0030***
	(0.0003)	(0.0004)	(0.0003)
Turnover	-0.0228***	-0.0234***	-0.0118
	(0.0069)	(0.0035)	(0.0081)
Average (size/1000)	0.0199***	0.0379***	0.0085**
	(0.0035)	(0.0035)	(0.0036)
Average (age/10)	0.0050***	0.0016	0.0040***
	(0.0010)	(0.0010)	(0.0009)
Average (proportion old)	0.0726***	0.0958***	0.0663***
	(0.0058)	(0.0063)	(0.0063)
Std (size/1000)	0.0306***	-0.0036	0.0376***
	(0.0040)	(0.0030)	(0.0039)
Std average (age/10)	0.0095***	0.0059***	0.0084***
	(0.0011)	(0.0008)	(0.0012)
Adjusted R-Squared	0.213	0.220	0.280
F Value	207.6***	217.3***	299.1***

Standard Errors in Parethesis

*** statistically significant at 1% level
** statistically significant at 5% level
* statistically significant at 10% level

Table 5

Bootstrap House Price Risk with MSA Fixed Effects

N = 6,682 Zip Codes

Variable	1996-2001	2002-2007	2007-2012
Intercept	0.1099***	0.1245***	0.1876***
	(0.0097)	(0.0099)	(0.0096)
Median Income	-0.2289***	-0.2653***	-0.3032***
	(0.0201)	(0.0210)	(0.0204)
Median Income Squared	0.0705***	0.0971***	0.1295***
	(0.0124)	(0.0130)	(0.0126)
Median Value	0.0297***	0.0209***	-0.0023
	(0.0034)	(0.0036)	(0.0034)
Median Value Squared	-0.0012***	-0.0007*	0.0011***
	(0.0004)	(0.0004)	(0.0004)
Turnover	-0.0070	-0.0177***	-0.0125
	(0.0077)	(0.0034)	(0.0078)
Average (size/1000)	0.0132***	0.0237***	0.0076**
	(0.0038)	(0.0038)	(0.0038)
Average (age/10)	0.0095***	0.0077***	0.0104***
	(0.0010)	(0.0010)	(0.0009)
Average (proportion old)	0.0625***	0.0693***	0.0571***
	(0.0055)	(0.0059)	(0.0058)
Std (size/1000)	0.0263***	0.0099***	0.0318***
	(0.0037)	(0.0027)	(0.0035)
Std average (age/10)	0.0095***	0.0044***	0.0098***
	(0.0011)	(0.0008)	(0.0012)
Adjusted R-Squared	0.395	0.405	0.456
F Value	26.0***	27.0***	33.0***

Standard Errors in Parethesis

*** statistically significant at 1% level
** statistically significant at 5% level
* statistically significant at 10% level

Table 6

Bootstrap Risk and Return for Alternative Loan to Value Ratios

N = 7,658 Zip Codes

Period		Cash	80% L/V	90% L/V	95% L/V
1996:Q1-2000:Q4					
Return vs Risk					
	IRR	3.6%	2.1%	3.6%	8.4%
	Risk	6.1%	31.2%	40.7%	47.9%
	Coefficient of Variation	1.70	14.86	11.42	5.69
Change in Housing Wealth per dollar of initial equity		0.26	1.27	2.48	4.48
2001:Q1-2007:Q2					
Return vs Risk					
	IRR	6.7%	13.7%	19.6%	28.1%
	Risk	6.5%	27.8%	36.6%	43.6%
	Coefficient of Variation	0.97	2.03	1.87	1.55
Change in Housing Wealth per dollar of initial equity		0.46	2.19	4.15	7.34
2007:Q3-2012:Q3					
Return vs Risk					
	IRR	-7.5%	-58.5%	-63.1%	-63.0%
	Risk	6.2%	33.4%	33.7%	35.0%
	Coefficient of Variation	-0.82	-0.57	-0.53	-0.56
Change in Housing Wealth per dollar of initial equity		-0.27	-0.53	-0.37	-0.06
1996:Q1-2012:Q3					
Return vs Risk					
	IRR	4.8%	3.0%	6.4%	13.1%
	Risk	6.6%	30.2%	37.9%	44.1%
	Coefficient of Variation	1.37	9.98	5.92	3.37
Change in Housing Wealth per dollar of initial equity		0.38	1.83	3.55	6.38

Figure 1

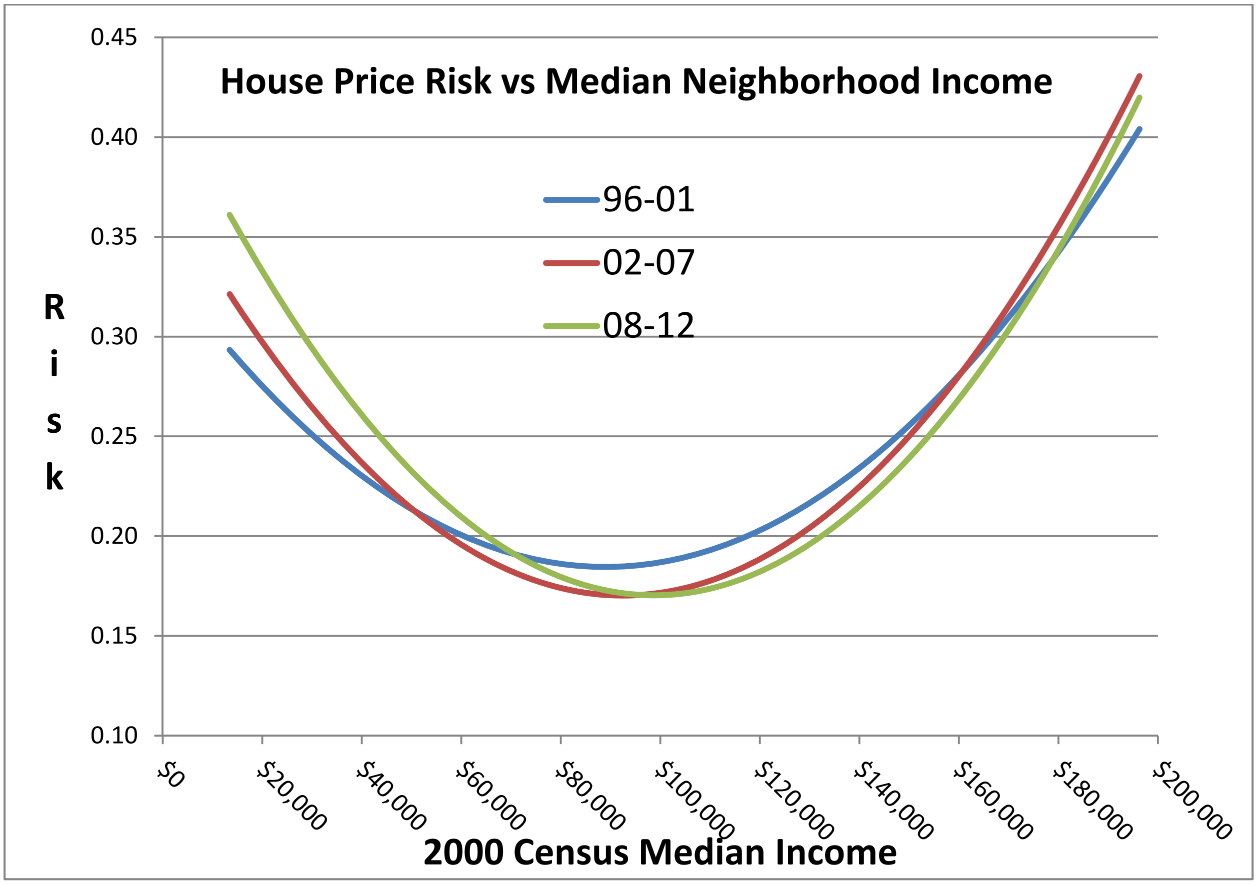

House Price Risk vs Median Neighborhood Income
96-01
02-07
08-12
Risk
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
$0
$20,000
$40,000
$60,000
$80,000
$100,000
$120,000
$140,000
$160,000
$180,000
$200,000
2000 Census Median Income

Figure 2

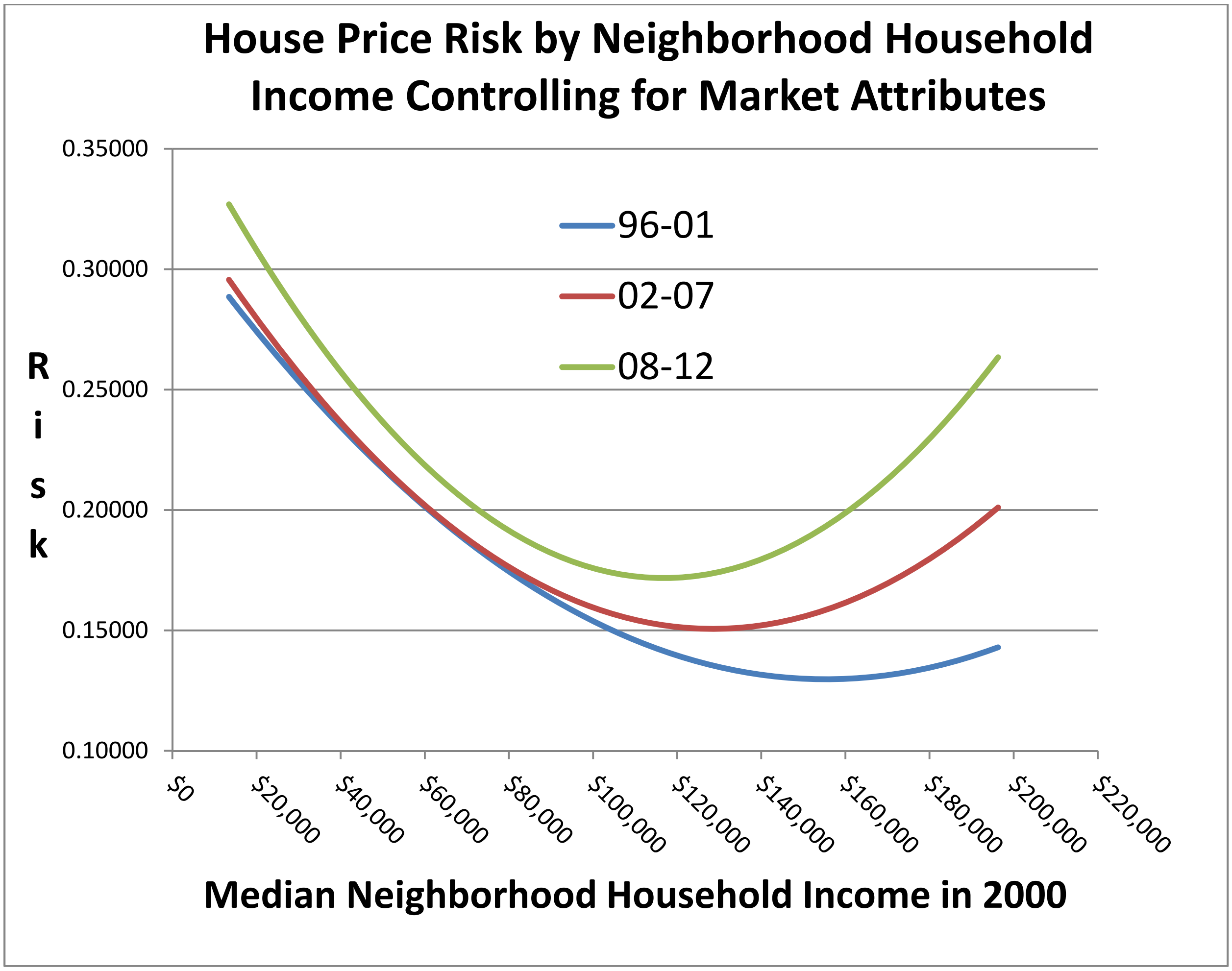

House Price Risk by Neighborhood Household Income Controlling for Market Attributes
96-01
02-07
08-12
Risk
0.35000
0.30000
0.25000
0.20000
0.15000
0.10000
$0
$20,000
$40,000
$60,000
$80,000
$100,000
$120,000
$140,000
$160,000
$180,000
$200,000
$220,000
Median Neighborhood Household Income in 2000

Figure 3

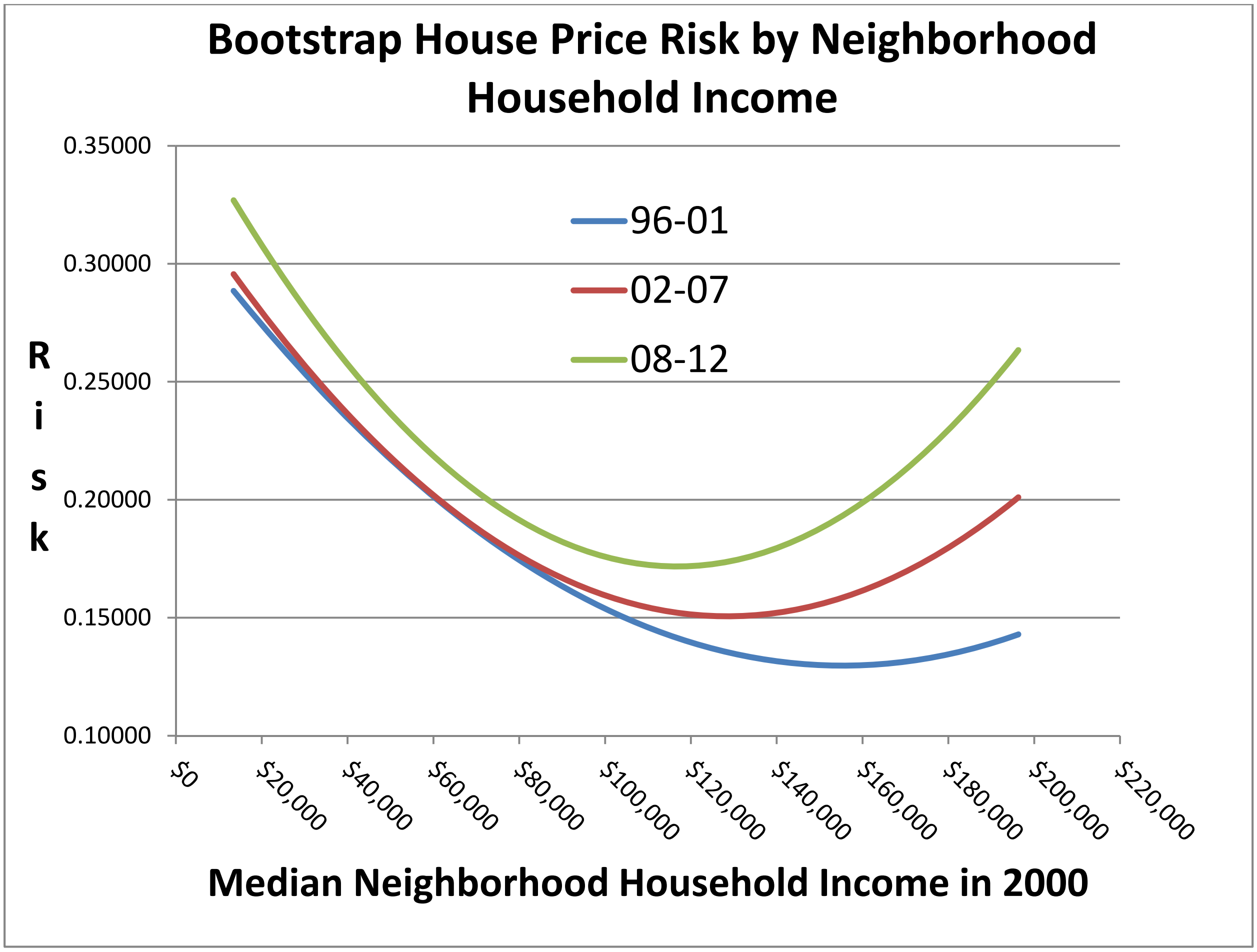
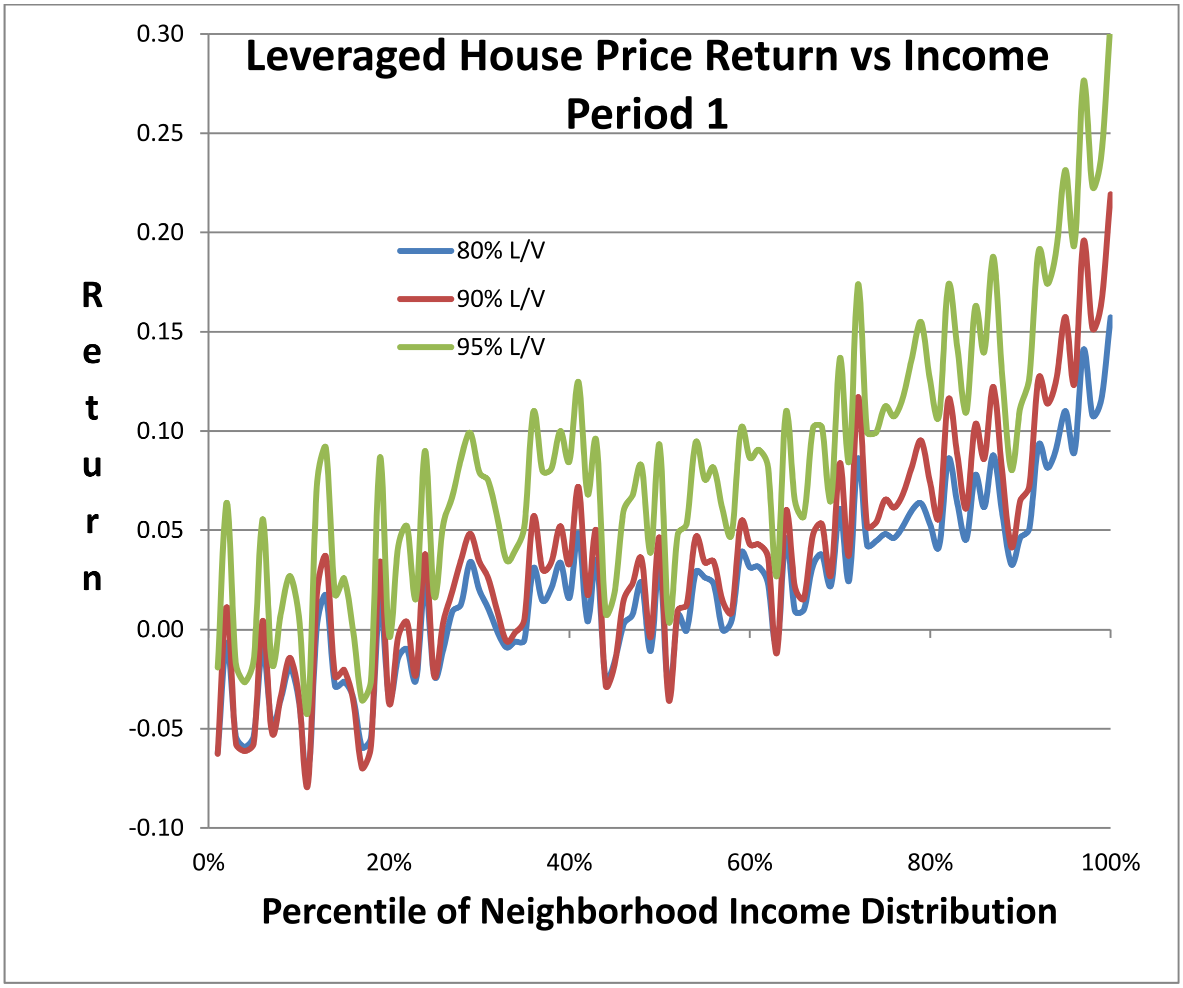

Bootstrap House Price Risk by Neighborhood Household Income
0.35000
0.30000
0.25000
0.20000
0.15000
0.10000
Risk
96-01
02-07
08-12
$0
$20,000
$40,000
$60,000
$80,000
$100,000
$120,000
$140,000
$160,000
$180,000
$200,000
$220,000
Median Neighborhood Household Income in 2000

Figure 4



Leveraged House Price Return vs Income
Period 1
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
R e t u r n
80% L/V
90% L/V
95% L/V
0%
20%
40%
60%
80%
100%
Percentile of Neighborhood Income Distribution

Figure 5

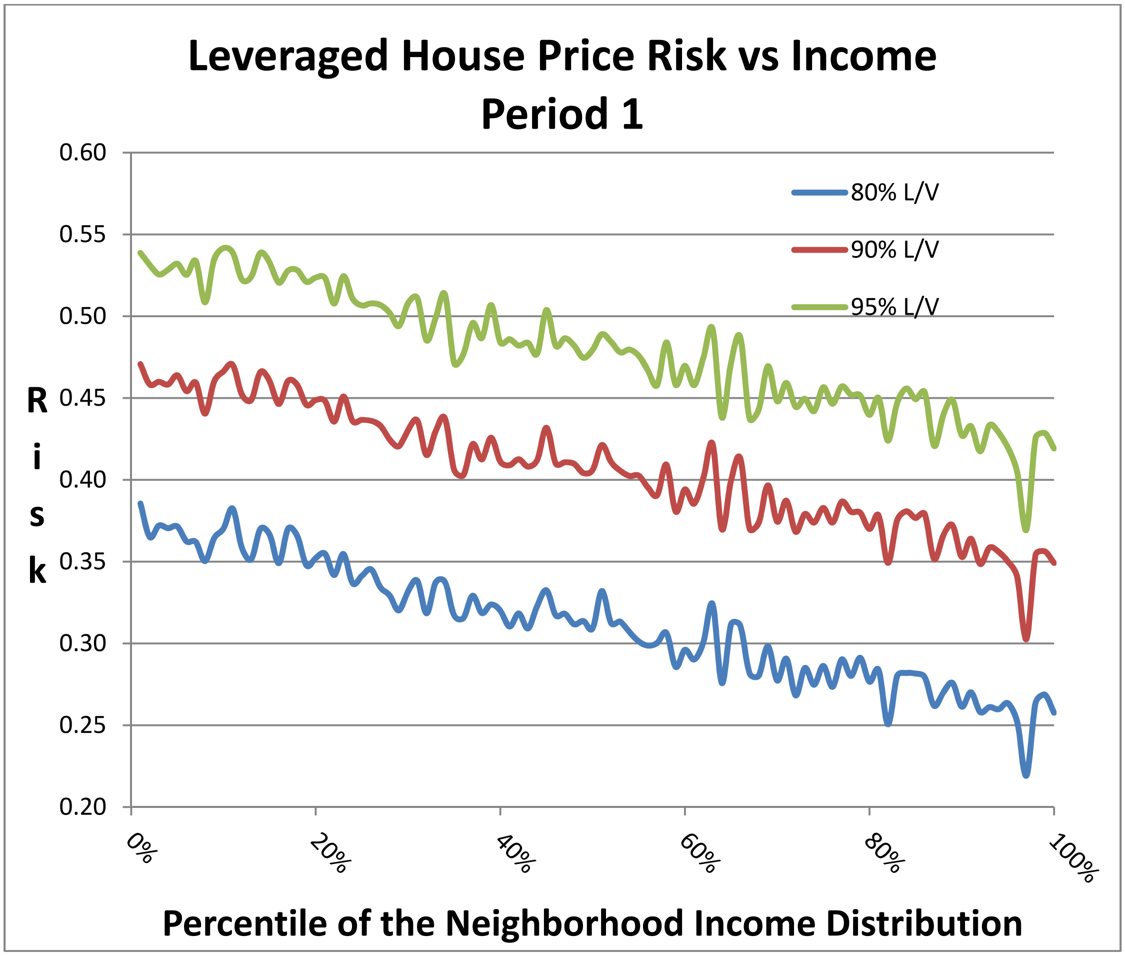
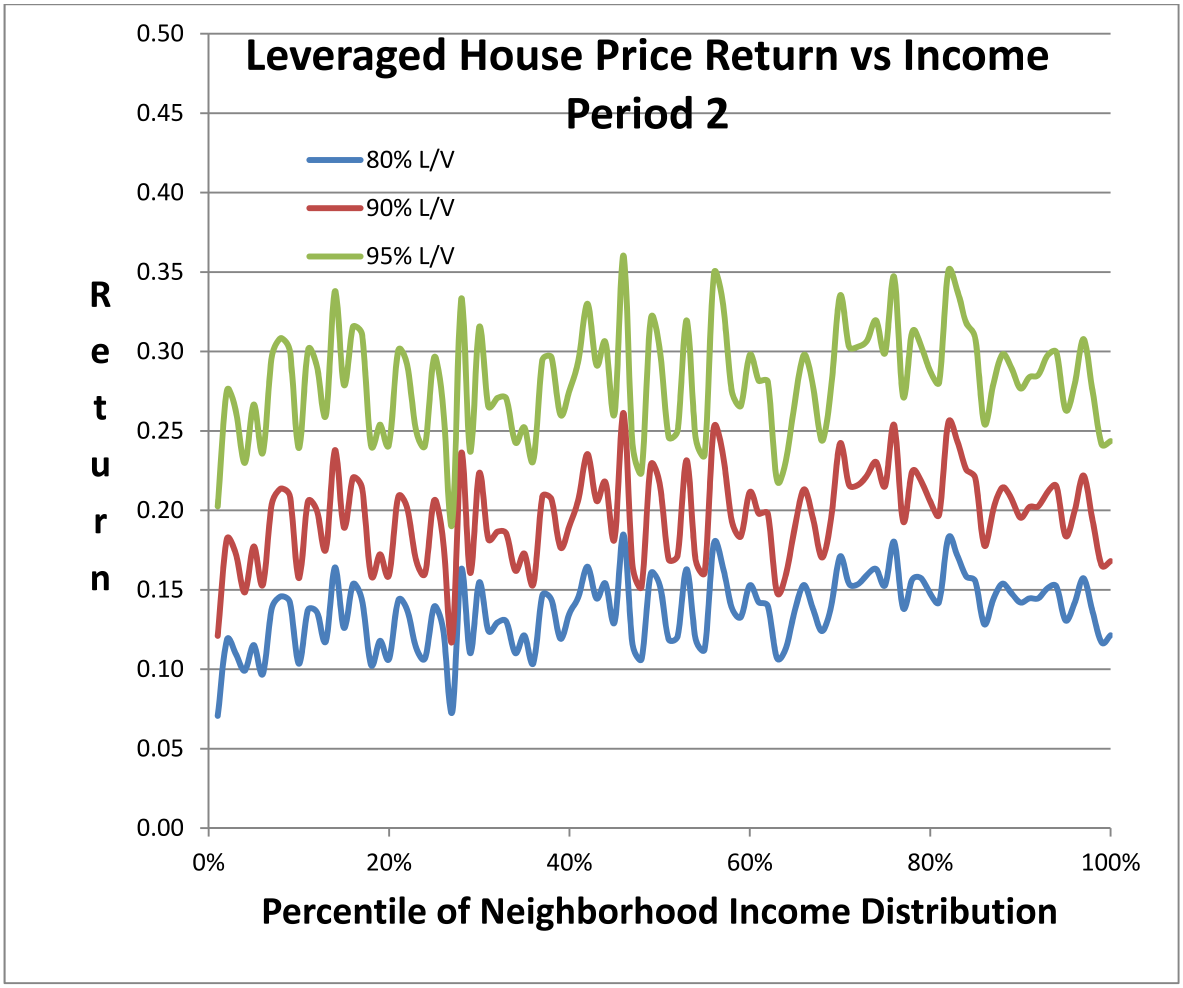

Leveraged House Price Risk vs Income
Period 1
80% L/V
90% L/V
95% L/V
R
i
s
k
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0%
20%
40%
60%
80%
100%
Percentile of the Neighborhood Income Distribution

Figure 6



Leveraged House Price Return vs Income
Period 2
80% L/V
90% L/V
95% L/V
Return
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0%
20%
40%
60%
80%
100%
Percentile of Neighborhood Income Distribution

Figure 7

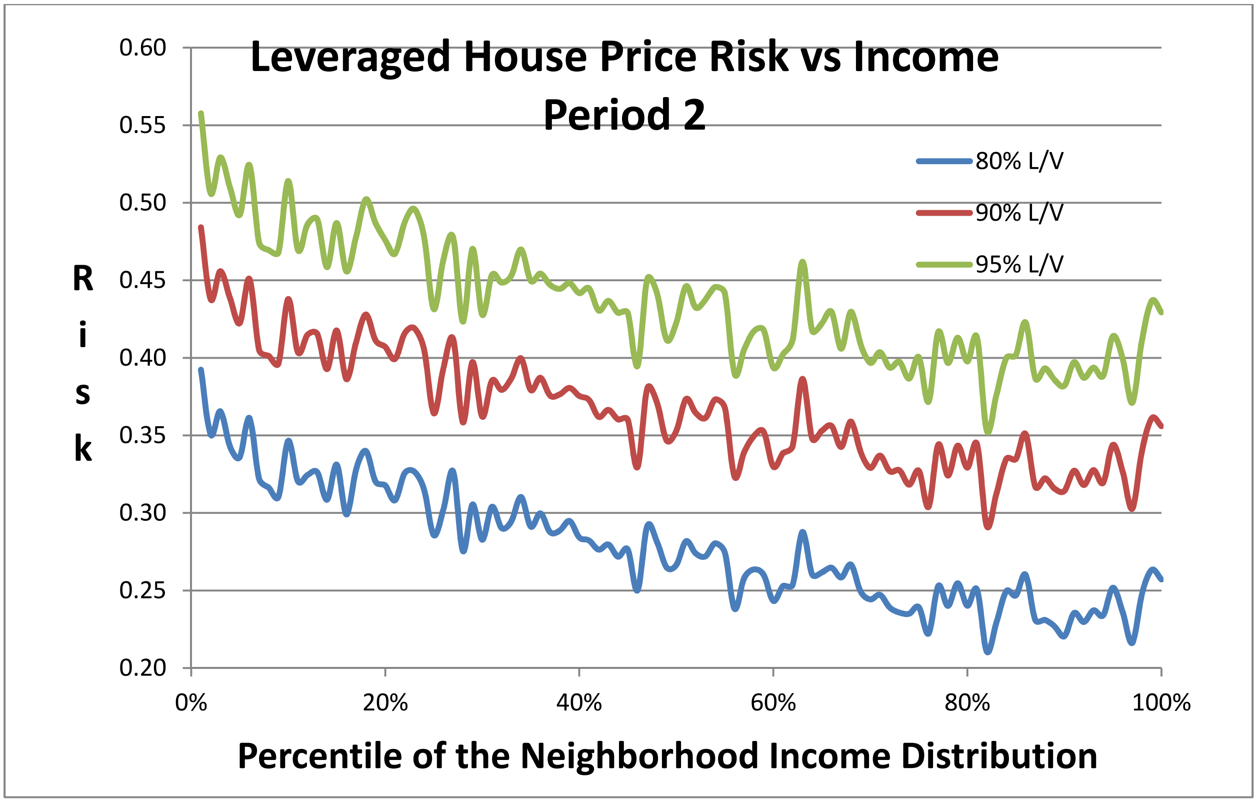
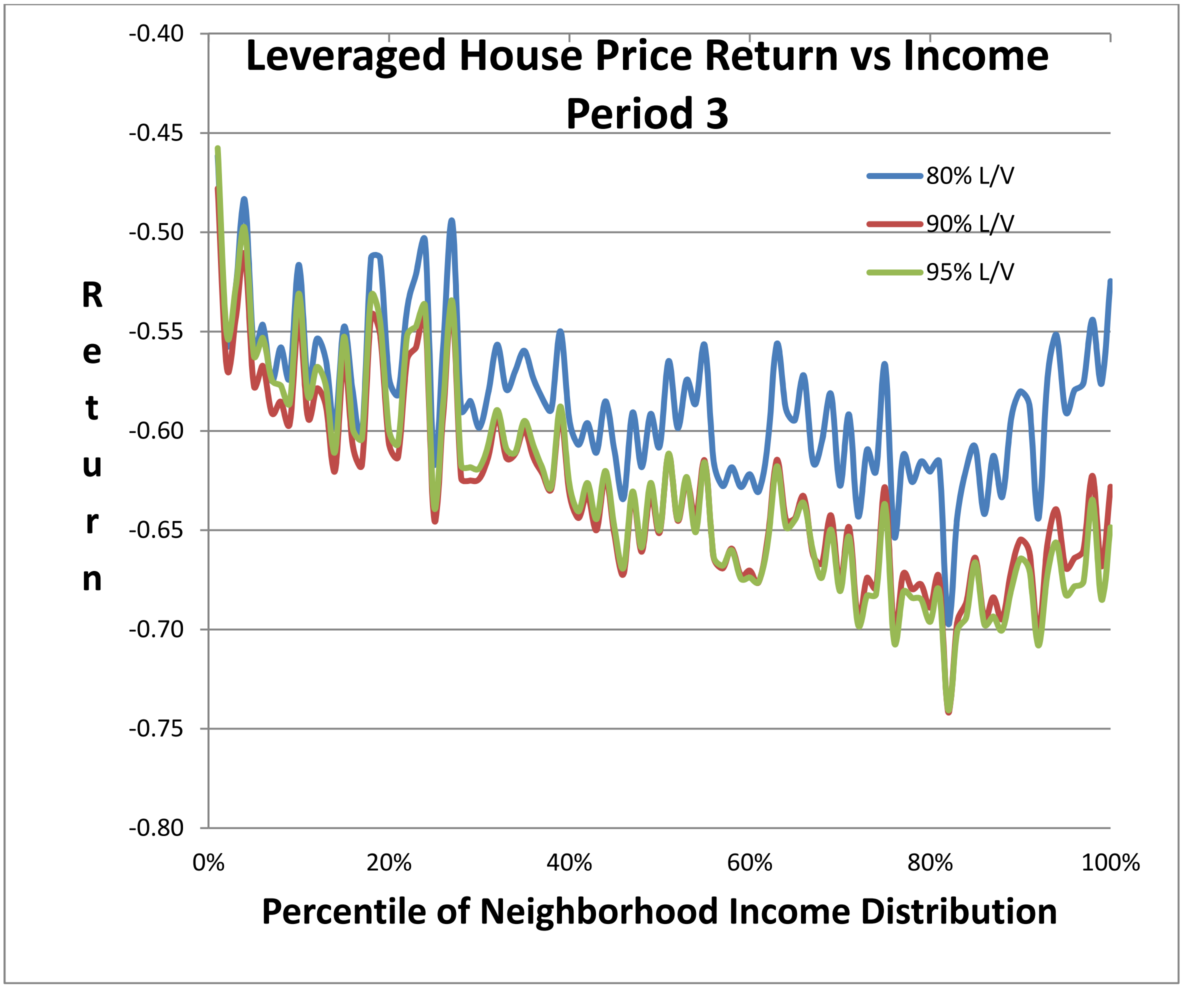
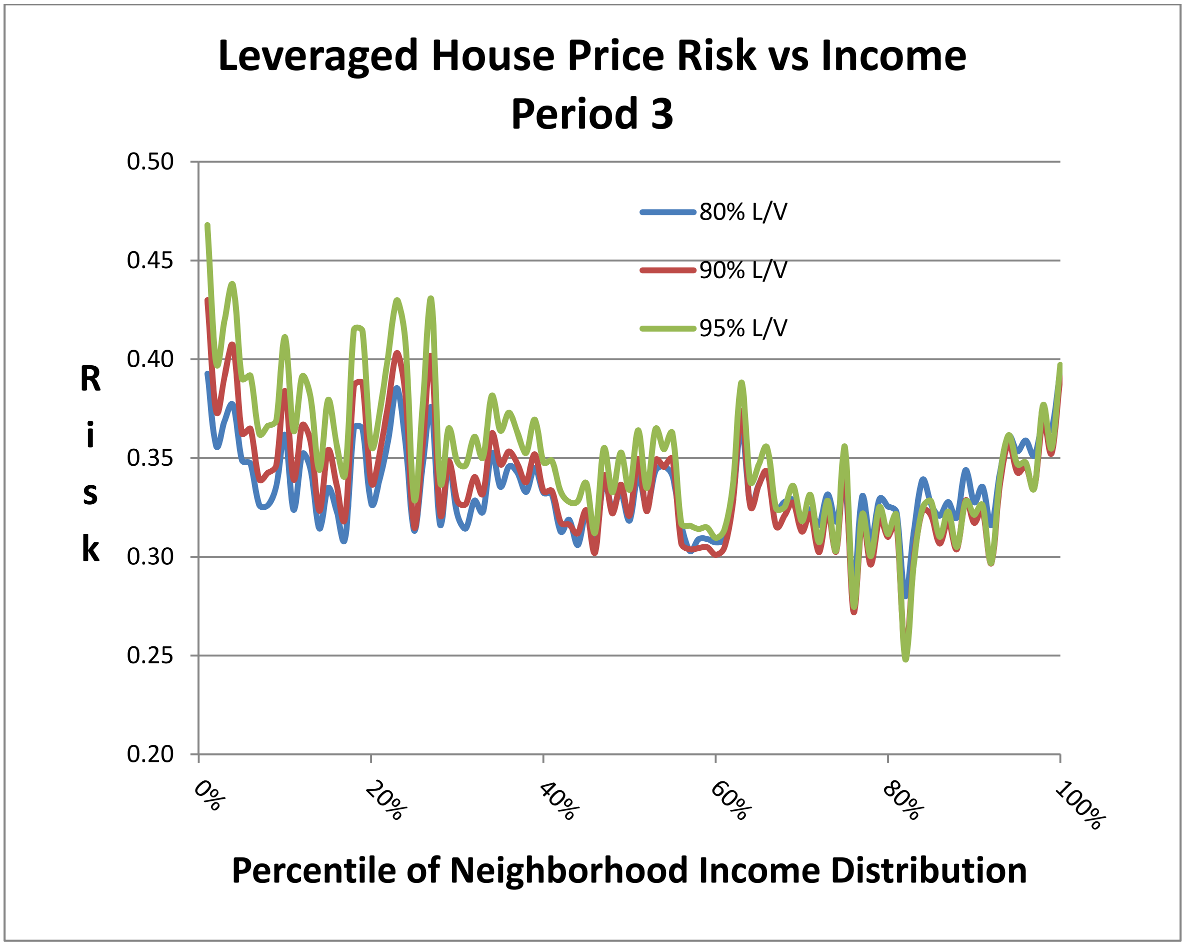

Leveraged House Price Risk vs Income
Period 2
80% L/V
90% L/V
95% L/V
Risk
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0%
20%
40%
60%
80%
100%
Percentile of the Neighborhood Income Distribution

Figure 8



Leveraged House Price Return vs Income
Period 3
80% L/V
90% L/V
95% L/V
R
e
t
u
r
n
-0.40
-0.45
-0.50
-0.55
-0.60
-0.65
-0.70
-0.75
-0.80
0%
20%
40%
60%
80%
100%
Percentile of Neighborhood Income Distribution

Figure 9


Leveraged House Price Risk vs Income
Period 3
0.50
0.45
0.40
0.35
0.30
0.25
0.20
R
i
s
k
80% L/V
90% L/V
95% L/V
0%
20%
40%
60%
80%
100%
Percentile of Neighborhood Income Distribution