FEDERAL RESERVE BANK OF PHILADELPHIA

Ten Independence Mall
Philadelphia, Pennsylvania 19106-1574
(215) 574-6428, www.phil.frb.org

Working Papers

Research Department

WORKING PAPER NO. 98-4

RISK AND RETURN WITHIN THE SINGLE FAMILY HOUSING MARKET

Theodore M. Crone

And

Richard P. Voith

Federal Reserve Bank of Philadelphia

December 1997

WORKING PAPER NO. 98-4

RISK AND RETURN
WITHIN THE SINGLE-FAMILY HOUSING MARKET

Theodore M. Crone

and

Richard P. Voith

Federal Reserve Bank of Philadelphia

The authors thank Julie Northcott-Wilson for excellent research assistance. We would also like to thank two anonymous referees for helpful comments on an earlier draft. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of Philadelphia or of the Federal Reserve System.

Abstract

The trade-off between risk and return in equity markets is well established. This paper examines the existence of the same trade-off in the single-family housing market. That market is dominated by homeowners, who constitute about two-thirds of U.S. households. For them the choice about how much housing and what house to buy is a joint consumption/investment decision. Furthermore, owner-occupied housing is by nature a lumpy investment whose risk cannot be completely diversified. Does this consumption/investment link negate the risk/return trade-off within the single-family housing market? Theory suggests the link still holds. This paper supplies empirical evidence in support of that theoretical result.

The largest single investment for most American families is the house in which they live and that house is often the major part of the family's wealth portfolio. Accordingly, most homeowners consider the property's investment potential or the expected rate of return in deciding whether to buy a house and what house to buy (Case and Shiller, 1988).[1] The decision to buy one's residence is necessarily a joint consumption/investment decision, and the investment is a lumpy one, since equity sharing or partial ownership arrangements are not common (Brueckner, 1997). In practice, then, the unsystematic risk associated with the structure of one's home or the neighborhood in which it is located cannot be eliminated by diversification. Meyer and Wieand (1996) have shown in a theoretical model that even though this risk cannot be diversified away, the price associated with the risk is the market price that applies to any risky asset in a portfolio. And Goetzmann (1993) has demonstrated that, if it were practical, diversification both within and among metropolitan housing markets would reduce risk. These studies imply that the offer price for a house whose returns are riskier will be lower than the offer price for an otherwise similar house, and the expected rate of return will be higher. This paper empirically evaluates the risk/return trade-off within the single-family housing market.[2] Specifically, we ask: Do local housing markets with higher risk, i.e., a larger variation in the returns on individual houses, also have higher average returns?

In section 1 we show how the positive correlation between risk and return in the owner-occupied housing market follows directly from utility maximization. In section 2 we describe the data used to test whether risk and return have been positively related in local housing markets. In

---

[1]Using data from the Miami metropolitan area, Archer, Gratzlaff, and Ling (1996) demonstrated that over five- and 10-year holding periods, there are statistically significant differences in appreciation rates by census tract. They did not, however, examine formally the relationship between uncertainty or risk and these differences in appreciation.

[2]Our purpose is not to compare the risk and return for residential real estate with the risk and return for other investments but rather to examine the risk/return trade-off within the housing market itself. There is evidence that the long-run return on residential real estate has been lower than the return on a representative portfolio of stocks (Ibbotson and Siegel, 1984, and Goetzmann and Ibbotson, 1990). But households are still willing to invest in housing despite the lower average return, in part, because housing *in general* is a less risky investment than stocks, that is, the return to housing is less volatile than the return to stocks.

section 3 we report our empirical results. Section 4 seeks to identify some characteristics of local housing markets associated with higher risk. The basic conclusions of the paper and suggestions for further research are set forth in section 5.

1. Risk and Return Within the Housing Market

A theoretical model demonstrating the positive relationship between risk and expected return in the owner-occupied housing market has been developed by Berkovec (1989). The model was employed by Gat (1994) to examine risk and return in neighborhood housing markets in Tel Aviv. In this section we derive a result similar to Berkovec's on the relationship between risk and return across housing markets. Since we confine our investigation to the single-family housing market, this is not an asset pricing model that attempts to identify the relative risk of housing in a diversified portfolio.

The model is based on the homeowner's maximization of his expected utility. Expected utility depends on expected consumption of a non-housing composite good, X, and the consumption of housing, H, expressed in terms of quality-adjusted housing units. The homeowner's expected income consists of labor income, Y, which is known for certain, and the return on his housing investment with an expected appreciation rate k_i, that is, the expected appreciation for neighborhood i. The variability in appreciation among houses in neighborhood i is denoted σ_i. This variability in appreciation introduces uncertainty in the homeowner's expected income and affects his utility negatively. The expected utility function to be maximized is

$$U(X,H,\sigma_i) \tag{1}$$

where:

$$\frac{\delta U}{\delta X} > 0 \qquad \frac{\delta U}{\delta H} > 0 \qquad \frac{\delta U}{\delta \sigma_i} < 0$$

The maximization is reduced to a one-period problem by assuming that the homeowner's wealth remains the same from one period to the next and all income from labor and the housing investment is used to service the debt on the house and consume the composite good, X. If we assume full leverage, no equity accumulation over time, and normalize the price of X to 1, the amount of X expected to be consumed is

$$X = Y + k_i\, p\, H - mpH \tag{2}$$

where

k_i = the expected appreciation of housing in neighborhood i

p = the price of a quality-adjusted unit of housing, which is assumed to be the same in all neighborhoods in the initial period.[3]

m = the mortgage interest rate, a constant over every neighborhood and homeowner $0 < m < 1$

Substituting the budget constraint (2) into the utility function (1) we obtain

$$U = (Y + (k_i - m)pH,\ H,\ \sigma_i) \tag{3}$$

The first-order condition for maximizing this utility function over H is

---

[3]This assumption is not crucial. We could just as well assume that the *expected* price in the final period is the same across neighborhoods. Then, the initial price would be lower and average appreciation higher in neighborhoods with greater uncertainty about the final price than in other neighborhoods.

$$\frac{\delta U}{\delta H} = \frac{\delta U}{\delta X}(k_i - m)p + \frac{\delta U}{\delta H} = 0 \tag{4}$$

or

$$\frac{\delta U}{\delta H} = (m - k_i)p\frac{\delta U}{\delta X} \tag{5}$$

To keep utility constant, k_i will vary as σ_i changes. To see this we totally differentiate the utility function (3) for a unit change in σ_i.

$$dU = pH\frac{\delta k_i}{\delta \sigma_i}\frac{\delta U}{\delta X} + \frac{\delta U}{\delta X}(k_i - m)p\frac{\delta H}{\delta \sigma_i} + \frac{\delta U}{\delta H}\frac{\delta H}{\delta \sigma_i} + \frac{\delta U}{\delta \sigma_i} = 0 \tag{6}$$

Rearranging we obtain

$$pH\frac{\delta k_i}{\delta \sigma_i}\frac{\delta U}{\delta X} + [\frac{\delta U}{\delta H} - (m - k_i)p\frac{\delta U}{\delta X}]\frac{\delta H}{\delta \sigma_i} + \frac{\delta U}{\delta \sigma_i} = 0 \tag{7}$$

By the first-order condition (5), the expression in brackets is equal to zero. Therefore,

$$pH\frac{\delta k_i}{\delta \sigma_i}\frac{\delta U}{\delta X} = -\frac{\delta U}{\delta \sigma_i} \tag{8}$$

or

$$\frac{\delta k_i}{\delta \sigma_i} = \frac{-\frac{\delta U}{\delta \sigma_i}}{pH\,\frac{\delta U}{\delta X}} \tag{9}$$

The right-hand side of equation (9) is positive and

$$\frac{\delta k_i}{\delta \sigma_i} > 0$$

that is, expected appreciation increases with the variability of appreciation in local housing markets.

2. Data on Risk and Return

To empirically evaluate the risk and return relationship in the housing market we need a data set of individual house sales that includes 1) the location of each house so that houses can be grouped into neighborhoods, 2) more than one sale price and date of sale for each house so that the appreciation rate for individual houses can be computed, and 3) many observations in each neighborhood so that meaningful measures of average neighborhood return and risk can be computed. The appraiser's files from Montgomery County, Pennsylvania, fully satisfy these three requirements.[4] Since at least 1977, Montgomery County has constructed annual files that contain information on all properties in the county. Each annual file includes data on the year and price of the latest sale at the time the file was constructed, the year of the previous sale and the price at that time, the census tract of each property, and a rich set of housing traits.

Although a single annual appraisal file yields a relatively large repeat sale data set,

[4]Montgomery County is one of the suburban counties in the Philadelphia metropolitan area.

linking annual files makes it possible to increase the number of repeat sales by a factor of 3.[5] By combining appraiser files from 1977, 1979-1985, 1987, 1988, 1994, 1995, and 1997, we are able to observe the vast majority of sales of residential properties from 1970 onward.[6] Since we are interested in constructing appreciation rates for individual houses, we must observe at least two sales of a house, and because of the small number of repeat sales observed in the period 1970-1972, we eliminated all transactions whose date of last sale was prior to 1973. We also eliminated all properties except single-family detached houses, all observations for which only one sale was available, properties for which census tract information was missing, and any property whose price was less than $10,000 or more than $1,000,000 in 1982-84 dollars. Because we wanted a sufficient number of sales in each tract to obtain reliable measures of risk and return, we also eliminated from our sample any tract in which the total number of repeat sales over the sample period was less than 50. Our final data set included 63,396 repeat sales of single-family houses in 182 census tracts for an average of 348 observations per tract.[7] The minimum number of observations in a tract is 50; the maximum is 1047.

In our analysis we define a "neighborhood" as a census tract. Each census tract potentially has a different risk and return for housing. For every house in a neighborhood, we

---

[5]In the individual appraisal files, the year and price of the previous sale is frequently missing, lowering the number of repeat sale observations. By combining files, it is often possible to obtain the correct value of the previous sale from an earlier appraisal file, where it will appear as the most recent sale. This greatly increases the size of the data set. More important, by combining annual files, we obtain a more even distribution across holding periods. For example, if only the 1997 cross section were used, the repeat sales observed for houses last sold in 1975 would be limited to the set of houses that were held continuously from 1975 to 1997. By combining additional cross sections, it is possible to observe houses with a sale in 1975 and additional transactions after 1975.

[6]The earliest year with a substantial number of most recent sales is 1973, while the earliest year with a substantial number of previous sales is 1970; thus, it is not possible to use the data to evaluate the Montgomery County housing market prior to 1970.

[7]We use tract boundaries from 1980, at which time Montgomery County had 200 census tracts. We eliminate three tracts whose populations are primarily institutional, and 15 tracts with fewer than 50 repeat sales.

calculate the annualized real appreciation for each observed holding period for the property.[8] Using the data on individual houses, we compute the average annual real appreciation of the houses in each census tract (AVAPP), which is our basic measure of the neighborhood-specific return in the housing market. The standard deviation of the appreciation of the houses *within* each census tract (SDAPP) is the measure of census-tract risk used in the empirical analysis. It reflects both cross-sectional variation at a point in time as well as variation of appreciation rates over time. Increased variation across either of these dimensions can increase the uncertainty about the expected appreciation rate.

Table 1 presents the means, variances, maximum, and minimum of the average annual appreciation and the standard deviation of annual appreciation across our sample of 182 census tracts. The table also displays the same information for the skewness of appreciation (SKEW) and the size of the census tract in square miles (SIZE), which are used as control variables. Across census tracts, annual appreciation rates average 2.54 percent, ranging from a low of -0.73 percent to a high of 5.74 percent. The mean within-tract standard deviation of appreciation rates, 7.79, is relatively high and more than triple the mean appreciation.

Cross-sectional variation in appreciation within a census tract could result from heterogeneity of the housing stock, infrequent sales, or the existence of more than one local housing market within the census tract. Heterogeneity of the housing stock and infrequent sales also increase the uncertainty about expected appreciation so they should be reflected in our measure of risk. The presence of more than one definable neighborhood or local housing market

---

[8]Note that if we have three observed sales on a given property, we can construct two repeat sales observations. To construct the real appreciation rate of an individual house, we deflated the sale prices by the national CPI. The annualized change over the holding period was calculated as the annual log difference in the real price of the house times 100, that is,

$$annual\ appreciation = \left(\frac{lnP_2 - lnP_1}{Y_2 - Y_1}\right) x\ 100\ ,$$

where P_1 and P_2 are the market prices of the house in constant dollars at the time of the first and second sales, respectively, and Y_1 and Y_2 are the years of the first and second sales.

in a census tract, however, can raise the variation in appreciation without increasing the uncertainty with respect to appreciation. Reliable information could be available for each of the neighborhoods, but their expected appreciation could differ markedly, raising the standard deviation of appreciation in the census tract. Therefore, the size of the census tract was used as a proxy for the presence of more than one definable neighborhood in the tract on the assumption that larger census tracts were more likely to have more than one definable neighborhood.[9] Our census tracts average 2.55 square miles, but they vary a great deal in size, from 0.20 to 21.56 square miles, reflecting differing population densities across the county.

In addition to the size of census tracts, we also include a measure of skewness to control for the possible effect of outliers in the data. If some houses in a tract have very large appreciation rates due to major unobserved housing improvements, these observations could increase both the mean and standard deviation of appreciation for the tract and introduce a spurious correlation between our measured risk and return variables. Therefore, for each tract we included the skewness of the appreciation rate in our regression equations. Within-tract skewness is, on average, relatively low, although some tracts have considerable skewness as is reflected in the range of skewness from -3.37 to 2.51.

3. Empirical Models and Results

Our model assumes that decisions on housing investments are based on expected appreciation and that expected appreciation differs by neighborhood. We assume that, on average, expected appreciation in a local market (neighborhood) is realized and that the uncertainty associated with the expectation can be proxied by the variability in appreciation within the neighborhood. Therefore, our empirical analysis relies on realized appreciation and the standard deviation of appreciation among houses within the local market. We also control for factors that could affect the variability in appreciation within a census tract but that are not related to uncertainty about appreciation.

---

[9]The size of the census tract is positively correlated with the standard deviation of appreciation (correlation coefficient = 0.51, which is statistically significant at the .01 percent level).

Basic Model

The basic equation to be estimated is

$$AVAPP = \alpha + \beta_1 SDAPP + \beta_2 SKEW + \beta_3 SIZE \tag{10}$$

The estimated coefficients from equation (10) and their standard errors are presented in Table 2.

As predicted by our theoretical model, the standard deviation of house price appreciation *within* a census tract (SDAPP) is positively related to the average appreciation in the census tract (AVAPP). The estimated coefficient (0.41) is highly significant. The estimated coefficient on the skewness variable (SKEW) is positive as expected, and it is highly significant. The size of the census tract (SIZE) is positive but not statistically significant.

We can calculate the economic significance of the estimate by comparing the predicted difference between the average appreciation for the census tract with the highest standard deviation (13.72) and the tract with the lowest standard deviation (4.64). If we controlling for skewness and the size of the census tract, the difference in the estimated average of real appreciation between these two tracts is approximately 3.74 percentage points. While this difference may seem large, it represents the extreme case. If we consider the difference between a census tract in which the variability in appreciation (standard deviation of appreciation) is two standard deviations above the average of the 182 census tracts in our sample and one whose variability is at the sample mean, the difference in estimated average annual appreciation is approximately 1.33 percentage points.

Accounting for the Timing of Sales

The variability of housing appreciation over time could raise an issue for our analysis of risk. Estimates of yearly appreciation rates for Montgomery County using a repeat sales estimation procedure reveal a great deal of variation from year to year in estimated appreciation rates and a distinct cycle in housing appreciation over our sample period (Figure A1).[10]

[10]See the Appendix for details of the countywide repeat sales index estimation.

Countywide appreciation ranged from a low of -6.1 percent in 1980 to a high of 14.7 percent in 1986. Given the fluctuation in countywide appreciation rates, it is possible that differences in the timing of sales across tracts could affect our measure of average appreciation. Our tractwide average appreciation rates are effectively averages of annualized appreciation rates for every possible holding period weighted by the number of sales that coincide with each holding period. If a disproportionate share of sales in some census tracts occurs in periods of high real appreciation *and* the variation of appreciation rates is also higher in those periods, both the average appreciation and the standard deviation for those tracts will be high.

One way to overcome any problems associated with weighting the tractwide average appreciation by the number of sales per holding period is to construct yearly real appreciation rates for each tract using the repeat sales method described in the Appendix.[11] We had a sufficient number of sales to construct repeat sales indexes for 120 of our 182 tracts. Since this method produced appreciation rates for these tracts in each of the 25 years in our sample period, we could calculate for each tract the standard deviation of appreciation rates across time (SDAPPT). This measure, of course, does not include any variability in housing appreciation within a tract for a given period. Therefore, it is only a partial measure of the risk associated with each census tract. The average appreciation for the tract (AVAPPT) is calculated as the compound annual rate of return for the tract over the 25 years of our sample using the repeat sales estimates.[12] We tested whether the variability of the yearly appreciation for a tract was positively related to this compound annual rate of return. The results are reported in Table 3. The coefficient on the standard deviation is 0.10 and is highly significant. While the size of this

---

[11]The yearly estimates from this method depend not only on the sales that occur in that year but also on the appreciation of any house whose first sale is prior to that year and whose second sale is after that year.

[12]The average compound annual rate of return across tracts was 1.24 percent, i.e., less than half the average across tracts when we used the actual appreciation of the houses to construct the tractwide average. But using the compound annual average over the entire sample period essentially assumes that each house was bought in the first year of our sample and sold in the last. Note that if we use our estimated appreciation rates for each year and apply them to each house's observed holding period and then compute the across-tract mean appreciation, we obtain averages very close to those computed using actual appreciation of the houses.

impact is smaller than that reported in Table 2, it is qualitatively similar. The smaller magnitude is consistent with the fact that risk associated with within-tract variation in appreciation is not reflected in the measure of risk.

Estimations Using an Even Distribution of Sales Over Time

Although the repeat sales method of calculating tractwide appreciation resolves the problems associated with differences in the timing of sales, the resultant measure of variability does not capture the risk associated with differences in appreciation within a tract for a given period. To address the concern about the timing of sales and retain a measure of risk that includes intra-tract variation in appreciation, we re-estimated the original model with a smaller data set that included 123 census tracts for which we could randomly generate an *even* distribution of sales across selected holding periods. To retain a sufficient number of tracts with observations in each holding period, we used a two-year window for the first and second sale. For example, all houses whose latest sale was in 1992 or 1993 and whose previous sale was in 1984 or 1985 were grouped in the same holding period. This grouping did not affect the annualized appreciation, since it was based on the actual year of the first and second sale. For our data set this procedure resulted in 104 possible holding periods. Since several tracts had no sales in some of these holding periods, we had to eliminate those holding periods (mostly very short or very long ones) to get a substantial number of tracts for our regression analysis. By reducing the number of holding periods to 25, we were able to retain data for 123 tracts. We imposed an even distribution of sales across holding periods for each tract. When the number of sales in a tract varied by holding period, sales were randomly selected within holding periods to provide the even distribution of sales. This procedure reduced our sample size from 63,396 sales in 182 tracts to 8,175 sales in 123 tracts. We repeated the random selection process 21 times and re-estimated equation (10) using each of the 21 data sets. For all 21 data sets the coefficient on the standard deviation of appreciation within census tracts was positive and significant. The median coefficient on SDAPP was 0.24, and the coefficients ranged from 0.35 to 0.12 as shown in Table

4.[13]

The results from these regressions in which each census tract had an even distribution of sales across holding periods offer strong evidence that the positive relationship between average house appreciation and the variation in appreciation that we found in our full sample was not due to the timing of sales.

4. Characteristics of Higher Risk Markets

Can we identify any characteristics of the local housing markets that have higher risk, i.e., higher variation in return? Our data set allows us to identify a number of candidates. For most characteristics of dwellings or households, it is the *variation* within a census tract that will increase the uncertainty about the expected appreciation. Therefore, we have examined the standard deviations of lot size (SDLOT), living area (SDLV), age of the dwelling (SDAGE), and income of the household (SDINC) for each census tract. We have also looked at the distance to the CBD from the census tract (DIST) and the population density of the tract in 1980 (DEN). In addition, we include the number of sales in the tract (SALES) to see if thin markets lead to greater risk. We regressed these variables and tract area (SIZE) on the standard deviation of house price appreciation. The results are reported in Table 5.

These variables jointly explain almost half of the variation in the standard deviation of appreciation across census tracts. The standard deviation of the age of homes in the census tract and the size of the tract are the only variables in the list that independently have a statistically significant relationship to our risk measure. The density of the tract is marginally significant**.** To see if any of the variables used to explain standard deviations at the census tract level had effects on appreciation, independent of their effects on the standard deviation, and to check the robustness of our risk-return estimates, we re-estimated the basic model, including the variables used to explain the standard deviation. When we included the other variables in Table 5 in that regression, the coefficient on our measure of risk (SDAPP) remained positive, significant, and of

[13] The results for the two control variables (SKEW and SIZE) in the regressions with the smaller sample size were qualitatively the same as the results from our full sample except the coefficient on the size of the census tract was significantly positive in 15 of the 21 regressions.

the same magnitude as the earlier regression. We conclude that the standard deviation of appreciation rates within the census tract reflects not only the factors we have been able to isolate but other factors that affect the uncertainty surrounding expected appreciation.

5. Conclusion and Suggestions for Future Research

Using a large data set of repeat sales transactions that occured over 25 years, we examined the relationship between appreciation rates at the census tract level and the risk or uncertainty of that return. Risk was measured by tract-level standard deviations in appreciation. We found a statistically and economically significant relationship with the expected sign, that is, increased risk yields an increased return.

We were able to identify a few characteristics of census tracts associated with increased risk or uncertainty. But the research suggests the need for additional investigation into the characteristics of tract-level risk. In particular, is it the variation in the appreciation rates within tracts in any given period that drives the risk premium, or is it the variation across tracts over time? The research also points to the need to investigate further why risks may differ across census tracts. Are the risks associated with informational problems associated with thin markets? Do the risks differ depending on the elasticity of the supply of housing? Does higher risk reflect greater variation in economic performance at easily accessible employment centers? Our results show a strong relationship between housing-market risk and return, but the underlying determinants of the risk differentials are not yet well understood.

References

Archer, Wayne R., Dean H. Gratzlaff, and David C. Ling, “Measuring the Importance of Location in House Price Appreciation,” *Journal of Urban Economics*, 40 (1996) pp. 334-353.

Brueckner, Jan K. “Consumption and Investment Motives and the Portfolio Choices of Homeowners,” *Journal of Real Estate Finance and Economics*, 15 (1997) pp. 159-180.

Berkovec, James, “A General Equilibrium Model of Housing Consumption and Investment,” *Journal of Real Estate Finance and Economics*, 2 (1989) pp. 157-172.

Case, Carl E. and Robert J. Shiller, “The Behavior of Home Buyers in Boom and Post-Boom Markets,” *New England Economic Review* (November/December, 1988) pp. 29-46.

Case, Carl E. and Robert J. Shiller, “The Efficiency of the Market for Single-Family Homes,” *American Economic Review*, 79 (1989), pp.125-137.

Crone, Theodore M. and Richard P. Voith, “Estimating House Price Appreciation: A Comparison of Methods,” *Journal of Housing Economics*, 2 (1992), pp. 324-338.

Gat, Daniel, "Risk and Return in Residential Spatial Markets: An Empiric and Theoretic Model," *Journal of Real Estate Finance and Economics*, 9 (1994) pp. 51-67.

Goetzmann, William N. “The Single Family Home in the Investment Portfolio,” *Journal of Real Estate Finance and Economics*, 6 (1993) pp. 201-222.

Goetzmann, William N. and Roger G. Ibbotson, “The Performance of Real Estate as an Asset Class,” *Journal of Applied Corporate Finance*, 3 (Spring, 1990), pp. 65-76.

Ibbotson, Roger G. and Lawrence B. Siegel, “Real Estate Returns: A Comparison with Other Investments,” *Journal of the American Real Estate and Urban Economics Association*, 12 (1984), pp. 219-242.

Meyer, Richard and Kenneth Wieand. “Risk and Return to Housing, Tenure Choice and the Value of Housing in an Asset Pricing Context,” *Real Estate Economics*. 24 (1996), pp. 113-131.

Voith, Richard P. “Changing Capitalization of CBD-Oriented Transportation Systems: Evidence from Philadelphia, 1970-1988,” *Journal of Urban Economics*, 33, (1993) pp. 361-376.

Appendix

The annual appreciation for Montgomery County was estimated by the repeat sales method described in Crone and Voith (1992). All 63,396 repeat sale observations in the county were used to estimate the following equation

$$\ln(\frac{P_2}{P_1}) = \sum_{h=1}^{n} \delta_h D_h + \varepsilon \qquad \text{(A1)}$$

where

P_1 = the initial sale price in constant dollars

P_2 = the second sale price in constant dollars

D_h = a year dummy for years 1 to n in our sample.

The estimated coefficient δ_h will equal the difference between $\ln P_h$ and $\ln P_{h-1}$ for the average house in Montgomery County. The regression results are shown in Table A1.

As the pattern of appreciation in Table A1 and the accompanying Figure A1 indicates, the Montgomery County housing market has been characterized by cycles of high and low real appreciation in the past 25 years. Since our data span several housing cycles, it is possible that some census tracts could have a disproportionately high percentage of sales in high appreciation periods relative to the percentage for other tracts. Thus, their average appreciation rates over the entire sample period would be high. If periods of high appreciation are accompanied by a large variation in appreciation rates, a positive correlation between high appreciation rates and the variation in appreciation could be spurious.

Table 1

MEANS, VARIANCES, MAXIMUM, AND MINIMUM OF VARIABLES FOR 182 MONTGOMERY COUNTY CENSUS TRACTS

Variable	Mean	Variance	Maximum	Minimum
AVAPP	2.54	1.37	5.74	-0.73
SDAPP	7.79	2.60	13.72	4.64
SKEW	0.07	1.34	2.51	-3.37
SIZE	2.55	11.21	21.56	0.20

Table 2

REGRESSION RESULTS FROM THE EQUATION FOR AVERAGE REAL APPRECIATION

Variable	**Estimated Coefficient**	**Standard Error**
Constant	-0.71	0.377
SDAPP	0.41**	0.051
SKEW	0.36**	0.061
SIZE	0.0035	0.024

Adjusted $R^2 = 0.37$ N = 182

**Denotes significance at the 99 percent confidence level.

Table 3

REGRESSION RESULTS FROM THE EQUATION
FOR COMPOUND ANNUAL AVERAGE REAL APPRECIATION
AND THE STANDARD DEVIATION OVER TIME

Variable	**Estimated Coefficient**	**Standard Error**
Constant	0.0015	0.0027
SDAPPT	0.10**	0.024

Adjusted $R^2 = 0.12$ N = 120

**Denotes significance at the 99 percent confidence level.

Table 4

DISTRIBUTION OF COEFFICIENTS ON THE STANDARD DEVIATION OF APPRECIATION
FROM 21 REGRESSIONS USING SAMPLES WITH AN EQUAL DISTRIBUTION OF SALES ACROSS HOLDING PERIODS

Rank among 21 regression results	**Estimated Coefficient on SDAPP**	**Standard Error**
median	0.24	0.054
maximum	0.35	0.055
minimum	0.12	0.061

TABLE 5

EFFECTS OF CENSUS-TRACT CHARACTERISTICS ON THE STANDARD DEVIATION OF THE RETURN TO HOUSING

Dependent Variable = SDAPP, standard deviation of housing appreciation within the census tract

Independent Variable	Estimated Coefficient	Standard Error
Constant	4.93**	0.61
SDLOT	0.18	0.19
SDLV/1000	-0.11	0.56
SDAGE	0.083**	0.015
SDINC/1000	0.16	0.14
DIST	0.012	0.012
DEN/1000	0.076	0.040
SIZE	0.11*	0.049
SALES/1000	-0.72	0.56
Adjusted R^2 =0.48	N=182	

*Denotes significance at the 95 percent level.

**Denotes significance at the 99 percent level.

Table A1

Regression Results from Equation (A1)

Variable	Estimated Coefficient	Standard Error
D71	0.031**	0.0121
D72	0.058**	0.0079
D73	0.083**	0.0073
D74	0.032**	0.0072
D75	-0.027**	0.0073
D76	0.024**	0.0069
D77	0.004	0.0061
D78	0.014*	0.0057
D79	-0.010	0.0057
D80	-0.061**	0.0061
D81	-0.052**	0.0069
D82	-0.036**	0.0073
D83	0.041**	0.0068
D84	0.041**	0.0060
D85	0.058**	0.0058
D86	0.147**	0.0054
D87	0.137**	0.0054
D88	0.113**	0.0057
D89	0.024**	0.0061
D90	-0.038**	0.0067
D91	-0.047**	0.0071
D92	-0.017*	0.0071
D93	-0.026**	0.0071
D94	0.002	0.0073
D95	-0.042**	0.0076
D96	-0.025**	0.0077
D97	-0.0010	0.0103

Adjusted R^2 = 0.35 N = 63396

*Denotes significance at 95% level

**Denotes significance at 99% level

Figure A1

Average Appreciation in Montgomery County