Journal of Housing Research • Volume 7, Issue 2 **145**

House Price Dynamics: A Survey of Theoretical and Empirical Issues

Man Cho*

Abstract

During the past decade, the number of studies on intertemporal changes in house prices has increased rapidly because of wider availability of extensive micro-level data sets, improvements in modeling techniques, and expanded business applications. This article reviews the main theoretical, empirical, and methodological issues related to analyzing house price dynamics.

The theoretical issue that has received the most attention is informational efficiency. The literature in this regard generally supports our intuition that real estate markets are not efficient—that is, short-run intertemporal changes in house prices and excess returns are found to be positively serially correlated. No trading rule has emerged that consistently yields above-normal returns, however, because of the substantial transaction costs. The second part of the article surveys various methodological issues in estimating house price indices and excess returns. Given severe measurement problems and biases in models, the literature increasingly indicates that any result might be an artifact of the price index used rather than a real feature of the market. More research is needed before firm conclusions can be reached about inefficiency in the residential real estate market.

Keywords: house price dynamics; housing market efficiency; house price indices

Introduction

In recent years, studies dealing with dynamic house price models have increased in number. The main analytical issues examined by these studies include testing housing market efficiency, pricing the values of contingent claims embedded in mortgages and mortgage-backed securities, and establishing a hedging mechanism for house price volatility. The increasing availability of extensive micro-level data sets and recent progress in modeling techniques have contributed to the surge in the study of house prices.

This article reviews this growing literature as it relates to house price dynamics. In particular, four main areas of research are surveyed: (1) theoretical issues regarding asset pricing and the efficient market hypothesis, (2) empirical tests of housing market efficiency, (3) sampling and modeling issues in estimating repeat sales models, and (4) measuring excess returns on holding residential real estate. Gatzlaff and Tirtiroglu (1995) provide a similar literature review. However, their article focuses on studies testing real estate market efficiency, while this article deals with both market efficiency

* Man Cho is at the Credit Policy Department of Fannie Mae. When this study was completed, he was at the Fannie Mae Foundation. The author thanks Peter Chinloy, John M. Clapp, Isaac F. Megbolugbe, Tom Thibodeau, Dogan Tirtiroglu, and anonymous referees for their valuable comments and suggestions. All remaining errors are the sole responsibility of the author. The views expressed in this article do not necessarily reflect the views or policies of Fannie Mae or the Fannie Mae Foundation.

and various measurement issues related to estimating house price indices and excess returns.

The theoretical issue that has received the most attention from housing researchers is the efficient market hypothesis (EMH): that is, whether housing markets are informationally efficient. The history of housing literature on this topic goes back only about 10 years to the studies by Hamilton and Schwab (1985) and Linneman (1986).[1] Since then, numerous studies have tested the EMH in various housing markets in the United States and other countries. The consensus in this literature is that both house prices and excess returns exhibit systematic short-run and long-run behavior: a positive serial correlation in the short run (indicating that the housing market is not informationally efficient) and a negative serial correlation, or mean reversion, in the long run. However, the literature also indicates that establishing trading rules that consistently yield above-normal returns is generally not possible because of high transaction costs in the housing market.

The conclusion of existing studies, however, should be accepted with caution given various measurement problems and biases that have been extensively documented in the literature. Housing is a type of asset that has severe measurement problems in its valuation, caused by heterogeneity in attributes (both structural and locational), infrequent trade, and a negotiated pricing process (rather than an auction). Consequently, the research in this area increasingly indicates that the result of a particular study of housing market efficiency might actually be an artifact of the house price index used rather than a true feature of the housing market. For example, the serial autocorrelation embedded in the repeat sales price indices has been noted in several recent studies (Case and Shiller 1989; Kuo 1996). Without proper control of this problem, using a repeat sales index is likely to increase the probability of rejecting the EMH. In this connection, it is interesting to note that while Linneman (1986), who relies on a hedonic house price model in testing the EMH, does not reject the hypothesis of semistrong-form efficiency, Case and Shiller (1989), who employ a repeat sales price index, reject the EMH for the four cities in their sample.

To deal with this and other measurement problems in estimating house prices and excess returns, a growing number of studies examine related methodological issues. In particular, a number of recent studies test the effects of different biases in estimating a repeat sales model, caused by major structural changes between sales (Gatzlaff and Haurin 1994), by time-varying structural attributes such as age of structure (Goodman and Thibodeau 1996), by frequency of trade (Case, Pollakowski, and Wachter 1997), and by sample selectivity (Haurin and Hendershott 1991; Steele and Goy 1997). Several recent studies also deal with the issue of how to come up with an adequate measure of excess returns on holding residential real estate.

The rest of the article consists of five sections. The first delineates the theoretical underpinnings for testing EMH with a standard asset-pricing model. The second reviews empirical studies on housing market efficiency, categorizing the reviewed studies into four groups: (1) conventional tests of weak-form efficiency, (2) conventional tests of semistrong-form efficiency, (3) tests of efficiency with market fundamentals, and (4) tests of speculative bubbles. The third and fourth sections survey methodological issues in

[1] In the U.S. stock market, the history of testing the EMH goes back about 30 years to the classic works by Fama (1965) and Samuelson (1965).

estimating the repeat sales model and in computing excess returns, respectively. The last section summarizes and concludes by discussing future research directions and some promising new modeling techniques.

Efficient Market Hypothesis: Theoretical Issues

Asset Pricing Model and the EMH

In his seminal article, Fama (1970) defined an efficient market as one in which market prices fully and instantaneously reflect all relevant information. Therefore, under the condition that new information arrives randomly, the current price of an asset is an unbiased predictor of its future value. Assuming a discrete time, let the expected rate of return on holding one unit of an asset from time t to time $t + 1$ be

$$E_t\,[r_{t+1}] = E_t\left[\frac{P_{t+1} - P_t + d_{t+1}}{P_t}\right], \tag{1}$$

where E is an expectation operator, P represents the unit price of the asset, and d is an appropriate dividend (or rent).[2]

A stochastic process r_t is termed a *martingale* with respect to the sequence of information sets available at time t (F_t), if and only if the first-order difference $r_{t+1} - r_t$ is a fair game (that is, $E_t[r_{t+1} \mid \mathsf{F}_t] - r_t = 0$).[3] Suppose that $E_t[r_{t+1}] - r = 0$ is a fair game, where r is constant. Substituting equation (1) into the identity and rearranging terms yields

$$P_t = \frac{E_t\,[P_{t+1} + d_{t+1}]}{(1+\rho)}\,. \tag{2}$$

Solving equation (2) one period forward generates $P_t = E_t[(1 + r)^{-1}\mathrm{E}_{t+1}[P_{t+2} + d_{t+2}] + d_{t+1}]$ $(1 + r)^{-1}$. After iterative expectations for n periods and under the assumption of a constant discount factor (i.e., $r_t = r$ for all t), it can be shown that

$$P_t = \left[\sum_{i=0}^{n} \frac{E_t\,[d_{t+i}]}{(1+\rho)^i}\right] + \left[\frac{E_t\,[P_{t+n}]}{(1+\rho)^n}\right] = P_t^* + B_t\,. \tag{3}$$

If the second bracketed expression in equation (3) converges to zero for sufficiently large n, then equation (3) represents the long-run equilibrium price P_t^*. The current asset value is represented as the sum of the expected present values of all future dividends. In this case, no trading rule can outperform the buy-and-hold strategy because all available information is used by the market in pricing the asset.

If the second bracketed term does not converge to zero, then the asset price includes speculative bubbles B_t. The bubble term B_t can be specified as a bubble builder (representing

[2] The asset pricing model specified in this section is based on those of Flood and Hodrick (1990) and Gatzlaff and Tirtiroglu (1995).

[3] A stochastic process y_t is considered a fair game if $E_t[y_{t+1}] = 0$, where $E_t[y_{t+1}] = E_t[r_{t+1}] - r_t = 0$. Samuelson (1965) proves that a sequence of asset prices is a martingale with respect to a sequence of information sets if investors are assumed (1) to be risk neutral, (2) to have common and constant-time preferences, and (3) to have common expectations probabilities.

the expectation of future price appreciation) or a bubble burster (the possibility of price drop if P_t exceeds P_t^* by a certain limit).

Testing the EMH

Fama (1970) further defines three forms of informational efficiency: strong, semistrong, and weak. Strong-form efficiency states that investors cannot consistently earn above-normal risk-adjusted returns using any information, private or public. Semistrong-form efficiency includes the information subset consisting of all available public information (newly released government economic statistics, investment advisory data, etc.). Finally, weak-form efficiency implies that the information set is further restricted to include only publicly available data on past prices and returns.

Most empirical studies that test semistrong-form or weak-form efficiency[4] employ the following general framework:

$$r_t = \mu + e_t \ , \tag{4}$$

where m is the mean return, and e_t is an error term (which is usually assumed to be serially uncorrelated and orthogonal to any element of F_t, the available information set at time t).

In this setting, market efficiency is normally tested in two ways: (1) by adding regressors drawn from the available information set F_t and testing the hypothesis that their coefficients equal zero (semistrong-form efficiency), or (2) by adding lagged returns as independent variables and testing the hypothesis that e_t follows a random-walk process (weak-form efficiency). The conventional tests of semistrong-form efficiency usually take the form of event studies (evaluating whether new relevant information is immediately and fully capitalized in contemporaneous asset prices). On the other hand, to fully reject the hypothesis of weak-form efficiency requires identifying trading strategies that, after taking into account transaction costs, can exploit any serial dependence and consistently earn above-normal returns.

The main skepticism about testing the EMH in the above framework stems from the fact that the tests are in effect joint tests of market efficiency and the model specification. If any component of either the ex post returns or the market information is misspecified, then the test may yield spurious results. Because of this, definitive measures of efficiency of a market are likely to remain challenging. To deal with this problem, various schemes are proposed for testing the EMH in different asset markets.[5]

Testing the EMH in Financial Markets. In the case of the U.S. stock market, the evidence on whether the EMH holds has varied over time (Shleifer and Summers 1990). It has rallied following Samuelson's (1965) proof that stock prices should follow a random walk if rational competitive investors require a fixed rate of return and Fama's (1965)

[4] Testing strong-form efficiency requires examining the ability of "informed" investors, acting on private information, to consistently earn excess returns. Grossman and Stiglitz (1980) demonstrate that testing such efficiency is impossible because costless information is both a sufficient and a necessary condition for prices to fully reflect all available information.

[5] For example, Poterba and Summers (1988, 30–31) propose variance ratio tests, which exploit the fact that if the logarithm of stock prices follows a random walk then the return variance should be proportional to the return horizon.

demonstration that stock prices are indeed close to a random walk. However, such strong sentiments lost ground rapidly following the publication of Shiller's (1981) and Leroy and Porter's (1981) volatility tests, both of which found stock market volatility to be far greater than could be justified by changes in dividends. But the EMH rallied back following the articles of Kleidon (1986) and Marsh and Merton (1986). Then again, one of the earlier proponents of the EMH, Fama, has relented somewhat in recent years, by indicating that fundamentals such as the price-to-earnings ratio and the ratio of book value to market value are predictors of stock returns (Fama and French 1992).

Other recent studies on financial market efficiency include those of Poterba and Summers (1988) and Cutler, Poterba, and Summers (1991). Both studies indicate that asset returns show positive autocorrelation over short periods but negative autocorrelation over longer periods. For example, Cutler, Poterba, and Summers characterize the speculative dynamics of returns on stocks, bonds, foreign exchange, real estate (using the house price indices for four cities used by Case and Shiller [1989]), collectibles, and precious metals. They tested time intervals for returns of 1 month, 12 months, and 48 months. They report that, while returns on these assets tend to be positively serially correlated at short intervals, the serial correlation is weakly negative over long horizons.

Testing Mean Reversion. As done by Cutler, Poterba, and Summers (1991), various financial market studies test whether asset prices will revert to their long-term means after some range of divergence between market and fundamental values. If so, then returns must be negatively serially correlated at some frequency as "erroneous" market moves are eventually corrected by speculative forces. De Bondt and Thaler (1989) report that stock returns display significant negative correlation if one takes a long-term perspective (three to seven years). Poterba and Summers (1988) further report that mean reversion is more pronounced in less broad-based and less sophisticated equity markets.

Testing Speculative Bubbles. As mentioned earlier, one alternative defense of the rationality principle in asset valuation is the presence of a speculative bubble. That is, if B_t in equation (3) does not converge to zero, then the asset price is influenced by a pure demand for future capital gain.[6] Numerous researchers have empirically tested the existence of bubbles in diverse asset markets: in stock price volatility (e.g., Shiller 1981), in price determination under a monetary model (Flood and Garber 1980; Flood, Garber, and Scott 1984), and in exchange rate volatility (Meese 1986; West 1987). However, specifying the right testing model involves a number of nontrivial modeling issues.

The first such issue is related to the problem called *indeterminacy of solution*. That is, under the rational-expectations model, agents' decisions depend on both current market price and expected future prices, implying that current prices are functions of future prices and vice versa. Therefore, there are two endogenous variables to solve for, but only one equation.

The second issue stems from the joint-test nature of bubble models, similar to the problem in testing the EMH: Both the null hypothesis of no self-fulfilling deviations from fundamental price and the specification of asset market model are jointly tested.

[6] The bubble B_t can take various forms, such as the *deterministic bubble* and the *stochastic bubble*. See Blanchard (1979), Blanchard and Kahn (1980), and Blanchard and Watson (1982) for further detail. Flood and Hodrick (1990) review empirical studies on speculative bubbles.

Therefore, apparent evidence of bubbles in the data can always be interpreted as misspecification of the model.

The third issue is related to the fact that the rational bubble model implies an explosive path of asset price when a bubble exists. As the crash probability of the bubble increases, the price path of the asset must be more and more explosive and steeper. Given these difficulties, it is fair to say that the literature on modeling speculative bubbles is still evolving.[7]

Empirical Studies on Housing Market Efficiency

Among the first formal tests of housing market efficiency are those of Hamilton and Schwab (1985) and Linneman (1986). Both studies rely on a cross-sectional model using data from the mid-1970s. Since the well-publicized article by Case and Shiller (1989), the number of studies on housing market efficiency with time-series models has increased dramatically. These studies generally fall into four categories: (1) conventional tests of weak-form efficiency, (2) conventional tests of semistrong-form efficiency, (3) tests of efficiency using market fundamentals, and (4) tests for speculative bubbles. The articles reviewed in this section are summarized in table 1.

Conventional Tests of Weak-Form Efficiency

Two early studies on weak-form efficiency provide opposite results. Using average sale prices of existing homes from 49 metropolitan statistical areas (MSAs), Hamilton and Schwab (1985) report that households systematically failed to incorporate past appreciation information into their expectations about house price appreciation. Therefore, they reject the EMH hypothesis. On the other hand, Guntermann and Smith (1987) argue that the results of Hamilton and Schwab are not robust in a sample covering a longer period and more MSAs. Using Federal Housing Administration (FHA) house price data for 57 MSAs, they report no correlation in unanticipated returns on housing for lags of 1 to 3 years and a weak negative correlation in returns for lags of 4 to 10 years. They also argue that the trading rule established did not outperform a buy-and-hold strategy after transaction costs were considered.

Two additional studies report results similar to those of Hamilton and Schwab. Rayburn, Devaney, and Evans (1987) find a serial correlation in returns in 7 of the 10 submarkets in Memphis, Tennessee. A buy-and-hold strategy could not be outperformed for the sample period assuming transaction costs as low as 2 percent. Therefore, the weak-form efficiency hypothesis could not be rejected. Green, Marx, and Essayyad (1988) report similar findings by using annual FHA Section 203(b) data for 73 MSAs. However, both studies suffer from two major shortcomings: First, they rely on the changes in house prices (rather than implicit rent or other return measures), and second, they do not employ constant-quality house price indices.

[7] For example, Froot and Obstfeld (1991, 1189) state, “no one has produced a specific bubble parameterization that is both parsimonious and capable of explaining the data.”

Table 1. **Studies Testing Housing Market Efficiency**

Study	Sample	Main Findings
Conventional tests of weak-form efficiency		
Hamilton and Schwab (1985)	Average sales price; 49 MSAs; 1974–76	Rejecting the EMH.
Guntermann and Smith (1987)	Average sales price; 57 MSAs; 1967–82	Not rejecting the EMH; no profitable trading rule.
Rayburn, Devaney, and Evans (1987)	Median sales price; 7 submarkets, Memphis, TN; 1970–84	Rejecting the EMH; no profitable trading rule.
Green, Marx, and Essayyad (1988)	Average returns; 73 MSAs; 1966–73	Not rejecting the EMH; North Central and Northeast are more efficient than West or South.
Case and Shiller (1989)	Repeat sales data; 4 MSAs; 1970–86	Rejecting the EMH; possible profitable trading rule.
Hosios and Pesando (1991)	Micro-level transaction data; Toronto; 1974–89	Rejecting the EMH; finding a significant seasonal component.
Ito and Hirono (1993)	Aggregate returns; Tokyo; 1981–91	Rejecting weak-form efficiency.
Gatzlaff (1990)	Micro-level transaction data; 4 MSAs; 1970–86	Findings of Case and Shiller (1989) are not substantially altered.
Gatzlaff (1994)	Transaction microdata; 4 MSAs; 1970–86	Finding a positive correlation of expected and unexpected inflation with excess returns.
Guntermann and Norrbin (1991)	Mean price per square foot; Lubbock, TX; 1970–81	Not rejecting the EMH.

Table 1. **Studies Testing Housing Market Efficiency** *(continued)*

Study	Sample	Main Findings
Conventional tests of semistrong-form efficiency		
Linneman (1986)	Micro-level assessment data; Philadelphia; 1975–78	Rejecting the EMH; no profitable trading rule.
Evans and Rayburn (1991)	Mean transaction price per square foot; Memphis, TN; 1970–84	Not rejecting the EMH; impacts of school segregation are reflected in price movements.
Delaney and Smith (1989)	Transaction microdata; Pinellas County, FL; 1971–82	Not rejecting the EMH; impact fees are capitalized into property values.
Ford and Gilligan (1988)	Transaction microdata (from multiple listing service); Baltimore; 1984	Not rejecting the EMH; house values well reflect the impact of lead paint.
Skantz and Strickland (1987)	Micro-level transaction data; Houston; 1979	Not rejecting the EMH; the effect of flood is well capitalized into values.
Turnbull, Sirmans, and Benjamin (1990)	Transaction microdata; Baton Rouge, LA; 1984–88	Not rejecting the EMH; homes sold by firms do not have discount.
Tests of efficiency using market fundamentals		
Mankiw and Weil (1989)	National aggregate; 1947–87	Rejecting the EMH.
Capozza and Seguin (1996)	MSA house prices and rents; perennial census data; 1920–90	Rent-to-price ratios have a disequilibrium component that has a forecasting power.
Poterba (1991)	National Association of Realtors aggregate house price data	Income and construction costs have important effects, but demographic factors do not.

Table 1. **Studies Testing Housing Market Efficiency** *(continued)*

Study	Sample	Main Findings
Tests of efficiency using market fundamentals *(continued)*		
Case and Shiller (1990)	Micro-level transaction data; 4 MSAs; 1970–86	Rejecting the EMH.
Clapp and Giaccotto (1994)	Assessed value index for 4 towns in Connecticut; 1982–88	Rejecting the EMH; changes in unemployment, population, and income predict price changes.
Meese and Wallace (1993)	Micro-level transaction data; San Francisco Bay Area; 1970–88	Appropriately specified market fundamentals explain house price changes.
Meese and Wallace (1994)	Micro-level transaction data; Alameda and San Francisco Counties, CA; 1970–88	Rejecting present value model in the short run but not in the long run.
Tests for speculative bubbles		
Abraham and Hendershott (1996)	Repeat sales price indices; 30 MSAs; 1977–92 (annual)	Mixed evidence on price bubbles; cities in Northeast and West show stronger effects of bubble variables.
Clayton (1994)	Vancouver, British Columbia; 1979–91	Rejecting the null hypothesis of rational expectations.
Kim and Suh (1993)	National land and house prices; Korea and Japan; 1974–89	Finding a growing rational bubble in land prices, but not in house prices.
Ito and Iwaisako (1995)	Land and stock prices in Japan; 1956–93	Finding a significant effect of bubble on Japanese real estate and stock markets in the boom periods of the 1980s.

Note: MSA = metropolitan statistical area.

Case and Shiller (1989) improve on earlier studies by addressing a number of their limitations. Using repeat sales databases from four MSAs (Atlanta, Chicago, Dallas, and San Francisco), they test for autocorrelation both in annual changes in real house prices and in estimated after-tax excess housing returns. Their findings reject weak-form efficiency in the housing market: Both changes in house prices and after-tax excess returns are positively autocorrelated. They speculate that the most likely reason for the apparent inefficiencies is that "predictable" real interest rates were not priced by the housing market during the study period. Case and Shiller further indicate that it is possible to construct a trading rule that yields abnormal returns to home buyers.

Both Hosios and Pesando (1991) and Ito and Hirono (1993) employ methods similar to Case and Shiller's in testing housing market efficiency. Hosios and Pesando report a first-order autocorrelation for the Toronto single-family housing market. They also report evidence of a strong seasonal component in the intertemporal pattern of house prices and speculate that it may be related to the northern climate. Ito and Hirono test weak-form efficiency with excess returns on holding housing in the Tokyo housing market. Their results reject weak-form efficiency in the 1981–91 period.

Gatzlaff (1990, 1994) and Guntermann and Norrbin (1991) investigate the effects of individual components on excess returns. In the 1990 article, Gatzlaff examines the possible impact that time-varying marginal tax rates and return volatility have on the serial dependence of after-tax excess returns. He reports the impacts to be negligible. In the 1994 article, however, Gatzlaff indicates that when after-tax excess returns are adjusted to allow for autocorrelated inflationary shocks, the serial dependence in the after-tax excess returns reported by Case and Shiller for each market is substantially diminished.

Guntermann and Norrbin (1991) examine the role of inflation in the pattern of serial housing returns, with data from 20 census tracts in Lubbock, Texas. In most census tracts, they report significant two- to three-quarter lagged correlations of real house price changes. They interpret this as a relatively rapid adjustment process, given the substantial transaction and search costs in the market.

Conventional Tests of Semistrong-Form Efficiency

Linneman (1986) provides the first formal test of semistrong-form efficiency in the Philadelphia housing market. In his model, owners' contemporaneous assessments were regressed on various structural and neighborhood characteristics. The main hypothesis tested is whether houses undervalued in 1975 (those with negative residuals) increase in value over a three-year holding period at a greater rate than other homes in the sample. The results indicate abnormal increases in the subsequent values of the undervalued properties. However, when transaction costs are considered, an insignificant number of properties are judged to be profitable arbitrage candidates. Therefore, the hypothesis of semistrong-form efficiency is not rejected.

Other studies testing semistrong-form efficiency of the housing market in the conventional testing framework (i.e., the market's reaction to new public information and events) include those of Evans and Rayburn (1991), Voith (1991), Delaney and Smith

(1989), Ford and Gilligan (1988), and Skantz and Strickland (1987). These studies report that the market is generally responsive to new information. While they have examined the reaction of implicit house prices associated with changes in the economic, legal, or physical environment, few report how quickly prices respond to new information.

Turnbull, Sirmans, and Benjamin (1990) estimate a cross-sectional model to test whether homes sold by corporations (for relocating employees) were sold at a discount relative to other homes. In an efficient market, such a difference should not exist. Their results do not reject the hypothesis that corporation-sold and individual-sold homes sell for equivalent prices.

Tests of Efficiency Using Market Fundamentals

A number of studies test housing market efficiency with variables representing market fundamentals. Mankiw and Weil (1989) demonstrate that while the entry of the baby boom generation into its home-buying years was the major cause of the increase in real house prices in the 1970s, the entry of the baby bust generation into the housing market should slow the rate of increase in demand in the 1990s. In particular, they forecast real house prices in 2007 that are 47 percent lower than 1987 levels. Mankiw and Weil further claim that because these demographic shifts are perfectly foreseeable, they should not affect asset prices under the EMH. Therefore, their results, which counter this rational-expectations hypothesis, indicate that “naive expectations” better characterize the housing market than perfect foresight does.

However, Mankiw and Weil argue that the failure of the random-walk hypothesis need not imply the existence of profit opportunities. If the rent-to-price ratio moves in the opposite direction from the expected capital gain, then the total return could be unforecastable. Examining a similar issue (with decennial census data from 1920 to 1990), Capozza and Seguin (1996) report that expectations included in the rent-to-price ratio at the beginning of the decade successfully predict appreciation rates, but only if cross-sectional differences in the quality of rental and owner-occupied housing are controlled for. They also demonstrate that observed rent-to-price ratios contain a disequilibrium component that has the power to forecast subsequent appreciation rates.

Poterba (1991) offers three alternative explanations for price movements. The first relies on shocks to construction costs: Systematic changes in construction costs could raise house prices relative to the gross national product deflator. If this construction cost view holds, then different-quality houses should experience roughly equal rates of appreciation.

The second possible explanation is a favorable and unexpected demand shock resulting from the interaction of inflation (unanticipated) and the tax system. This user cost view implies a higher volatility for appreciation rates for larger houses than for smaller ones because the relative demand for the houses typically purchased by high-income households is expected to increase during the 1970s but to decline in the 1980s.

Poterba’s third explanation is, as mentioned by Mankiw and Weil, the entry of a large cohort in the 20–34 age bracket into the housing market. This demographic view of price changes suggests the opposite of what the user cost view suggests. That is, the entry of baby boomers into the housing market should have boosted the demand for starter houses relative to larger trade-up houses in the late 1970s and 1980s.

Poterba used a database (from the National Association of Realtors) of median house price information for 1980 to 1990 for 39 cities to test relative magnitudes of these three alternative determinants of house price movements. The results indicate that shifts in income and in construction costs have important effects on real house price changes but provide little support for the importance of demographic factors. Poterba's findings also confirm earlier evidence that house price movements are predictable on the basis of lagged information—both lagged house price appreciation and the lagged change in real per capita income help forecast future price movement. However, he claims that there was no evidence that house prices revert toward some common mean in the long run.

Some interesting comments are attached to Poterba's 1991 paper. For example, Robert Gordon reasons that the different dynamics of house prices and quantities before and after 1982 could be explained by the deregulation of financial institutions (i.e., Regulation Q). Before the 1980s, because tight money raised market interest rates, attracting deposits out of thrift institutions and forcing them to reduce the volume of home mortgages, it had a major effect on the timing of movements in both housing prices and construction. In addition, Gordon notes that the better integration of the mortgage market with other financial markets and the development of adjustable-rate mortgages were other innovations making the 1980s different from earlier periods.

Other studies testing market efficiency with market fundamentals include those of Case and Shiller (1990), Clapp and Giaccotto (1994), and Meese and Wallace (1993, 1994). Case and Shiller and Clapp and Giaccotto correlate house prices with currently available public economic information, such as construction costs, income growth, tax rates, and unemployment rates. Both studies report evidence that macroeconomic variables can be used to forecast house prices and conclude that housing markets are not consistent with the EMH.

Meese and Wallace (1993, 1994) test various specifications of housing market models and estimate them with microdata from the San Francisco Bay Area. In the 1993 study, they test the explanatory power of housing market supply and demand fundamentals (such as construction cost, user cost, and income of potential homeowners), along with a disequilibrium variable.[8] On the basis of their results, they conclude that over long periods fundamentals tend to explain house price movements, but short-run fluctuations are more difficult to explain on this basis.

In the 1994 article, Meese and Wallace test housing market efficiency with a transactions database for Alameda and San Francisco Counties in northern California. They reject both constant- and nonconstant-discount-rate versions of the housing price present value relation in the short run, but long-run results were consistent with the housing price present value relation when they adjusted the discount factor for changes in both tax rates and borrowing costs. Their explanation for the short-run rejection of, but long-run

[8] The disequilibrium variable is defined as $e_{t-1} = P_{t-1} - P^*_{t-1}$, where P^*_{t-1} is the estimated fundamental price from the structural model. This variable is expected to have a negative impact on price movement: That is, all else being equal, when the price index P_{t-1} exceeds (is less than) the fundamental price, actual prices of individual properties are expected to fall (rise) relative to the value of the price index in the previous period.

consistency with, the present value model is the high transaction costs that characterize the housing market.

Tests for Speculative Bubbles

Only a handful of studies explicitly test for the existence of speculative bubbles in the housing market. Abraham and Hendershott (1996) used repeat sales price indices for 30 cities over the 1977–92 period. With the first-order price difference on the left-hand side, their independent variables include changes in market fundamentals (e.g., income, employment, real interest rates), a bubble builder (caused by the expectation of price appreciation over time), and a bubble burster (indicating the periods with actual prices higher than the equilibrium). Their results show that either changes in market fundamentals or adjustment dynamics (represented by the bubble variables) explain a little over two-fifths of the variation in price movements. The two together explain about three-fifths.

Clayton (1994) tests the ability of a forward-looking rational-expectations housing price model to explain short-run fluctuations in real house prices. Tests of cross-equation restrictions reject the joint null hypothesis of rational expectations and the asset-based housing price model for quarterly prices of single-family detached houses in the city of Vancouver, British Columbia, over the 1979–91 sample period.

Kim and Suh (1993) specify an asset demand for housing by incorporating a pure demand for future capital gain as one argument. With the asset supply function, they derive the equilibrium price equation through the method of forward expectation—similar to the one employed by Blanchard and Kahn (1980). By using the national land and house price data from Japan and Korea (for periods between 1974 and 1989), they report that a growing rational bubble existed in both countries' land prices, while the evidence of a bubble was much less obvious in Korean *house* price series.

Ito and Iwaisako (1995) also examine whether the booms in stock and real estate prices in Japan (between 1956 and 1993) can be justified by changes in the fundamental economic variables such as interest rates or the growth of the real economy. They report three major findings: (1) a considerable correlation of movements in stock and land prices over the study period, (2) a significant correlation between asset price increases from mid-1987 to mid-1989 and the movement of fundamentals, and (3) the lack of explanatory power of any model of fundamentals or bubbles for the stock price increase in the second half of 1989 and the land price increase in 1990.

Measurement Issues

In summary, the studies reviewed in this section generally support our intuition that the housing market is not informationally efficient. However, as mentioned in the introduction, there are a number of difficult measurement issues in estimating intertemporal house price movements. Given these difficulties, one can hypothesize that the conclusions of these studies are in effect an artifact of the type of house price index used, rather than a feature of the housing market.[9] Although a specific linkage between the research findings and the index used can be established only through formal research, it is interesting to note that Linneman (1986), who relies on a hedonic model, fails to reject the EMH, whereas the famous Case and Shiller (1989) study rejects it while using a repeat sales house price index.

In fact, Case and Shiller raise the issue of autocorrelation in estimated repeat sales indices; that is, the fact that the same property is usually represented in multiple periods in the repeat sales model can cause a positive serial correlation, which in turn can create an errors-in-variable problem for both dependent and independent variables in the repeat sales model.[10] In addition, current studies identify other sources of bias in repeat sales price indices and propose new methods to deal with those problems. The following section reviews those measurement issues and new models.

Sampling and Modeling Issues in Estimating the Repeat Sales Model

In estimating intertemporal house price indices, three main categories of house price models have been used: hedonic, repeat sales, and hybrid (a combination of the first two). In recent years, the repeat sales model (RSM) has gained popularity both for research and for business applications. There are two main reasons for this trend: its capability of controlling for the heterogeneity in housing attributes and the parsimonious data requirement in the estimation. By specifying the RSM, one mainly regresses price changes of identical properties between two sales on time dummies indicating time points of the sales. As such, it can yield price indices that control the heterogeneity of structural and location characteristics. In terms of data, estimating such a model requires only transaction prices and sales dates for properties; there is no need to assemble massive amounts of information on housing characteristics.

However, numerous recent studies examine various potential biases in the repeat sales house price indices. For example, in estimating the RSM, one has to assume that biases caused by structural changes between sales or by some time-varying structural attributes (e.g., age of structure) are not significant. In particular, this study examines five types of bias in the repeat sales indices: (1) renovation bias, (2) hedonic bias, (3) trading-frequency bias, (4) sample-selection bias, and (5) aggregation bias. As remedies of these problems, various alternative RSMs have been proposed in recent studies. Examples of this new generation of RSMs include the *hedonic RSM* (Case and Quigley 1991; Hill, Knight, and Sirmans 1995; Quigley 1995), the *intercept RSM* (Shiller 1993; Steele and Goy 1997), and the *distance-weighted RSM* (Goetzmann and Spiegel 1995, 1997). To document the current state of research, the main sampling and modeling issues discussed by these studies are reviewed in this section. Methodological changes in RSMs are summarized in table 2.

---

[9] I owe this point to Tom Thibodeau.

[10] To deal with this problem, Case and Shiller employ two alternative specifications for testing market efficiency. First, they use mutually exclusive subsamples of repeat sales (within each city) in the estimation and formulate a dependent variable and independent variables from different subsamples. The second procedure involves regressing changes in *individual* housing prices between times t and $t-1$ on the information available only at time $t-1$. In particular, they reestimate the repeat sales index anew for each quarter, using only data available up to that quarter—yielding T different estimated price indices, with from 1 to T periods.

Table 2. **Main Methodological Changes in Repeat Sales Models**

Study	Model and Estimator	Methodological Issues Examined
Bailey, Muth, and Nourse (1963)	Conventional RSM, OLS	First study to control heterogeneity in housing structure by using repeat sales sample
Webb (1981)	Conventional RSM, GLS	Controlling near multicollinearity to obtain more efficient parameter estimates
Case and Shiller (1987)	Conventional RSM, 3S-GLS	Proposing three-stage GLS to control heteroskedasticity caused by the time intervals between the two sales
Case and Quigley (1991)	Hybrid RSM, maximum likelihood	Comparing three house price models—hedonic, repeat sales, and hybrid—and proposing the hybrid model as the best of the three in terms of efficiency
Shiller (1991)	Geometric and arithmetic RSM, 3S-GLS	Comparing geometric and arithmetic models of house price appreciation
Goetzmann (1992)	Conventional RSM, GLS, 3S-GLS, Bayesian, Stein-like	Comparing alternative estimators, including OLS, GLS, Stein-like estimator, and Bayesian estimators
Shiller (1993)	Intercept RSM, GLS	Revising the conventional RSM by including the intercept to capture a temporal change in price
Goetzmann and Spiegel (1995)	Intercept RSM, maximum likelihood	Incorporating a nontemporal, or fixed-effect, component into the RSM and estimating the mean and variance of the fixed and temporal components of repeat sales indices

Table 2. **Main Methodological Changes in Repeat Sales Models** *(continued)*

Study	Model and Estimator	Methodological Issues Examined
Hill, Knight, and Sirmans (1995)	Hedonic RSM, maximum likelihood	Providing joint estimation method for hedonic and repeat sales models via a maximum-likelihood procedure
Goetzmann and Spiegel (1997)	Distance-weighted RSM, maximum likelihood	Decomposing the price appreciation into three components: the per-period expected return, the jurisdiction-specific return, and random changes peculiar to a house

Note: OLS = ordinary least squares, GLS = generalized least squares, and 3S-GLS = three-stage generalized least squares.

Evolution of RSMs: An Overview

Since originally introduced by Bailey, Muth, and Nourse (1963) and modified by Case and Shiller (1989), the RSM has gained popularity in studies of dynamic housing markets. The main idea behind the RSM is to regress price changes of the same properties between two sales on a set of dummy variables in which the time points of the two transactions are indicated. Following Goetzmann (1992), the general specification of the RSM can be shown as

$$y_i = \log\left(\frac{P_{i,s_i}}{P_{i,b_i}}\right) = \sum_{t=b_i+1}^{s_i} \mu_t + \sum_{t=b_i+1}^{s_i} \epsilon_{i,t}. \qquad (5)$$

For an individual property i bought at time b_i and sold at time s_i, the total price appreciation during the holding period (i.e., $s_i - b_i - 1$) y_i is represented as the logarithm of the ratio between the selling price (P_{i,s_i}) and the buying price (P_{i,b_i}). For estimation, y_i is further specified as the sum of per-period price appreciation m_t and error term $e_{i,t}$ (with no constant term).

The appreciation level m_t in equation (5) represents a vector of parameters to be estimated b multiplied by the matrix of independent variables $\mathbf{X}$—that is, $b\mathbf{X}$. The ith row of $\mathbf{X}$ (corresponding to the ith individual property in a repeat sales sample) consists of a series of dummy variables corresponding to the appreciation periods (monthly, quarterly, yearly, etc.). The shorter the interval for which the price appreciation is measured, the more columns the matrix $\mathbf{X}$ has (i.e., the greater the number of independent variables). In each row of $\mathbf{X}$, the first nonzero dummy appears immediately after the purchase time b_i, and the last nonzero dummy appears at the sales time s_i—for example, $\mathbf{x}_i = [0 \cdots 1\ 1 \cdots 1\ 0 \cdots 0]$.[11]

If the error term $e_{i,t}$ in equation (5) satisfies the classical econometric assumptions (i.e., independently identically distributed with zero mean and constant variance), then ordinary least squares (OLS) is the proper estimation technique. In fact, Bailey, Muth, and Nourse (1963) use OLS to estimate equation (5).

As a first challenge to OLS estimation, Webb (1981) raised the issue of *near multicollinearity*. When only a small percentage of the portfolio changes in a given period (i.e., small frequencies of transactions occurred during given time intervals), two columns of dummy variables in the design matrix $\mathbf{X}$ are nearly identical. This problem results in unreliable estimates of the coefficients and an extremely variable series. The simple solution to this problem is to drop certain right-hand variables (i.e., estimating longer term price appreciations). As a remedy, Webb proposes a generalized least squares (GLS) procedure, which is equivalent to a maximum-likelihood estimator.

[11] Other specifications of the matrix $\mathbf{X}$ are suggested in the literature. They include geometric specification, $\mathbf{x}_i = [\cdots\ 0\ 0\ 0\ {-1}\ 0\ 0\ 0\ 1\ 0\ 0\ 0 \cdots]$ (i.e., $b_i = -1$ and $s_i = 1$) (Shiller 1991; Stephens et al. 1995); arithmetic specification, $\mathbf{x}_i = [\cdots\ 0\ 0\ 0\ 1\ 1\ 1\ 1\ 1\ 0\ 0\ 0 \cdots]$ (Case and Shiller 1989; Crone and Voith 1992); value-weighted specification, $\mathbf{x}_i = [\cdots\ 0\ 0\ 0\ {-B_i}\ 0\ 0\ 0\ S_i\ 0\ 0\ 0 \cdots]$, where B_i and S_i are buying and selling prices (Shiller 1991); and piecewide linear specification, $\mathbf{x}_i = [\cdots\ 0\ 0\ 0\ (u_b/m)\ 1\ 1\ 1\ 1\ (u_s/m)\ 0\ 0\ 0 \cdots]$, where u_b is the time of the first transaction, u_s is the time of the second transaction, and m is the interval used (e.g., $u_b/m = 6/30$ if the first transaction happens on the 6th day of the month and the price index is monthly) (Bryan and Colwell 1982).

The second innovation in the estimation technique came from Case and Shiller (1987), who proposed the three-stage generalized least squares (3S-GLS) procedure to control a specific type of heteroskedasticity caused by time intervals between purchase and sale. The procedure involves three estimation steps:

1. Equation (5) is estimated with OLS.

2. The squared residuals in the first step are regressed on a constant and the time interval between sales.

3. A weighted least squares regression is run by first dividing each observation by the square root of the predicted value from the second step and estimating equation (5) again.

The 3S-GLS procedure is widely used in the housing finance industry (see Stephens et al. 1995 for the structure and application of this model).

As an alternative estimator for correcting the problem of near multicollinearity, Goetzmann (1992) proposes a modified version of the "Stein-like" estimator, originally suggested by Hill and Zeimer (1984). This estimation technique offers more efficient parameter estimates at the cost of bias. Goetzmann claims that the proposed Stein-like estimator can significantly improve efficiency, especially when there are a small number of frequencies in a large number of estimated periods.

Goetzmann (1992) also proposes three different Bayesian estimators (two stage, varying interval, and random walk), as a more general estimation procedure with fewer a priori assumptions about data structure. The Bayesian model allows the specification of the distribution of the parameters to be estimated, by restricting the behavior of the regression coefficients to conform to a given distribution. The Bayesian estimators proposed by Goetzmann are in essence modified versions of the ridge regression estimator, which has been proven to have smaller mean squared errors than the OLS estimator. However, the Bayesian estimators generally involve cumbersome computational procedures, which can be costly if the sample is large.

Potential Biases in Estimating the RSM

Besides the improvement in the estimation technique, recent studies discuss various sources of bias in repeat sales price indices and propose new model specifications that can correct that bias. In the following sections, five types of bias are briefly reviewed: (1) renovation bias, (2) hedonic bias, (3) trading-frequency bias, (4) sample-selection bias, and (5) aggregation bias.[12]

Renovation Bias. The easiest problem to understand in estimating the RSM is the possibility of structural changes between two sales. As discussed earlier, the repeat sales price index is truly a constant-quality index only if properties retain the same physical

[12] There is another type of bias, caused by the transformation of estimated parameters to price indices (due to the concavity of the log function). That is, from Jensen's inequality it can be shown that the average of the logs is less than the log of the average (see Goetzmann 1992).

attributes and those attributes are valued the same by the market over time. Taylor (1992), Gatzlaff and Haurin (1994), and Goodman and Thibodeau (1996) examine this issue.

In particular, Goodman and Thibodeau examine whether the likelihood that houses have different-vintage renovations can contribute to heteroskedasticity. For example, owner-occupied homes tend to be improved (by the seller or the buyer or both) at the time of sale. In their empirical analysis, Goodman and Thibodeau hypothesize that the shorter the time between sales, the less extensive the undocumented improvements are likely to be, and hence the more accurate the predictions of house prices and of subsequent appreciation rates can be. They report that the interval between two sales contributes significantly to the size of residual variance.

Hedonic Bias. As a related issue, values of some structural and locational attributes can vary over time. A good example of such time-varying attributes is the age of structure. To examine this issue, Goodman and Thibodeau (1996) test the impact of heteroskedasticity attributable to dwelling age on price appreciation rates estimated from the RSM. In particular, they examine the influence that dwelling age and length of time between sales have on residual variance in repeat sales house price equations and assess their relative importance. Using an estimation procedure that explicitly models the residual variance as a function of the two factors, they report that the repeat sales heteroskedasticity is a function of both dwelling age and time between sales. Cannady and Yang (1996) provide a method that controls for the age effect in estimating the RSM.

Trading-Frequency Bias. There is increasing evidence that the measured rate of appreciation is systematically related to trading frequency. In particular, Case, Pollakowski, and Wachter (1997) investigate whether mean appreciation rates and their reliability vary with the frequency of transactions. They estimate identically specified hedonic price models on each group of properties by frequency of transactions and report that the estimated standard deviation of the disturbance term decreases markedly as the transaction frequency increases. Thus, the RSM may yield an estimated standard deviation of the disturbance term that is downward biased as a measure of the cross-sectional variation of house prices for less frequently transacting properties. They also report that the rate of measured house price appreciation is systematically higher among properties that transact more frequently.

In terms of particular property types, several researchers hypothesize that "starter homes"—generally defined as relatively small and with few amenities—may be both more homogeneous and more likely to transact than larger homes with more amenities. Moreover, some properties may be less likely to transact because their occupants have invested in the development of "specific capital"—that is, modifications that are valued highly by the current owner but may be valued only slightly by prospective buyers (Gatzlaff and Haurin 1997).

Sample-Selection Bias. The fact that the repeat sales sample includes only transacted properties and the fact that it further truncates the sample to include only properties transacted more than once both reduce the sample's ability to represent all properties.[13] In consequence, the repeat sales indices can be biased estimates of the changes in the value of the stock of housing.

As a remedy to the selectivity bias, Gatzlaff and Haurin (1997) employ a method that jointly estimates the probability that a house will be on the market and the sale price. Using data from Dade County, Florida, they document that a house value index constructed from a sample of homes selling more than once, rather than all houses in a locality, is biased. The bias is highly correlated with changes in economic conditions, such as population growth, construction activity, employment rates, and changes in per capita income.

As in other studies on sample selectivity, Haurin and Hendershott (1991) report that repeat sales properties that are starter homes tend to appreciate quickly. Steele and Goy (1997) test for bias in first transactions (i.e., whether the fact that a transaction is the first of a repeat pair affects the price). They find that the answer is yes—the first transaction in a repeat pair occurs at a statistically significant discount (and the second at a slight, but not statistically significant, premium).

Aggregation Bias. The time interval in estimating the RSM can be set flexibly (yearly, twice yearly, quarterly, monthly, etc.). Any specific interval employed can have both the problem of including irrelevant information and that of excluding relevant information. In other words, the quarterly index will include irrelevant information if the monthly interval is the right time span, while it will exclude relevant information if the twice-yearly interval is the proper choice. Calhoun, Chinloy, and Megbolugbe (1995) estimate the RSM over the various intervals and demonstrate that aggregation bias arises for all intervals greater than one month and that the bias is positively correlated with the level and rate of change in house prices. Also, Dombrow, Knight, and Sirmans (1997) report evidence of the bias caused by both included and excluded independent variables.

New Generation of RSMs

To solve the measurement problems discussed above, a new generation of RSMs has been proposed in the recent literature. In this section, three such models are surveyed: the hedonic RSM (often termed a hybrid model), the intercept RSM, and the distance-weighted RSM.

Hedonic RSM. In the first study on this type of model, Case and Quigley (1991) propose a stacked estimation procedure that combines a cross-sectional hedonic model with the RSM. Hill, Knight, and Sirmans (1995) further generalize Case and Quigley's hybrid model, with the specification of the joint likelihood function for hedonic and repeat sales

[13] In the case of the Fannie Mae–Freddie Mac repeat sales database, there are two additional sources of bias identified in the literature. First, the sample includes only those loans and properties that are subject to historical agency purchase patterns and loan amount restrictions (Abraham and Schauman 1991; Calhoun 1991; and Stephens et al. 1995). Second, Cho and Megbolugbe (1996) and Chinloy, Cho, and Megbolugbe (1997) raise the issue of appraisal bias; that is, the inclusion of refinancing transactions whose property values represent estimates by appraisers can bias a derived price index. Both studies present evidence of upward bias in appraisal values over transaction values.

models. They explicitly model the effects of the age of structure, a vector of time dummies in the hedonic model, and a set of time dummies in the RSM on the covariance between hedonic residuals and repeat sales residuals. They use simulation analysis to illustrate the potential efficiency gains associated with the proposed maximum-likelihood procedure. In particular, they demonstrate that the asymptotic standard errors of forecasts based on the pooling procedure developed are smaller than the corresponding standard errors from other models.

Quigley (1995) relates residual variance of a hybrid model to a quadratic in the length of time between sales and estimates parameters using a GLS procedure. The model allows the residual variance to increase with the length of time between sales at a decreasing rate. Quigley estimates price indices with data on 843 sales of 584 different Los Angeles condominiums using the GLS procedure and reports substantial efficiency gains over OLS-generated hybrid house price indices.

Intercept RSM. As an amendment of the conventional model, several recent studies propose to include the intercept in the RSM (Goetzmann and Spiegel 1995; Shiller 1993; Steele and Goy 1997). They claim that, under certain conditions, such a model will capture a true temporal change in price.

Specifically, Goetzmann and Spiegel (1995) add a nontemporal, or fixed-effect, component to the RSM and estimate the mean and variance of the fixed and temporal components of repeat sales indices using a maximum-likelihood procedure. They report a statistically significant nontemporal component in two of the four cities Case and Shiller (1989) examined. They argue that home improvement occurs that is associated not with the length of time the property is held but with the act of selling. Thus one component of the change in the price of a repeat sales house arises from a change in the characteristics of the house—possibly, as with painting and other cosmetic improvements, a change that is not observed. This component is nontemporal and therefore must be eliminated in the construction of any price index. Steele and Goy (1997) further document that the estimate of bias derived from an intercept repeat sales regression is much higher than the direct estimate of bias obtained from the hedonic regression.

Distance-Weighted RSM. Building on their first study, Goetzmann and Spiegel (1997) decompose the price appreciation into three components: the per-period expected return (which is uniform across jurisdictions), the jurisdiction-specific return, and random changes peculiar to a house.[14] By assuming specific distributional characteristics of included error terms, Goetzmann and Spiegel specify covariance between housing returns of two jurisdictions as a function of differences in various location variables (spatial proximity, education level, median income, racial composition, etc.). Based on this covariance function, jurisdiction-specific price indices are estimated. They use 131,603 repeat sales in the San Francisco Bay Area between 1980 and 1994 to compute ZIP code level price indices. Among geographic proximity, median household income, average educational attainment, and racial composition, Goetzman and Spiegel find that median income is the salient variable explaining covariance of neighborhood housing returns.

[14] Gyourko and Voith (1992) use a similar decomposition of house price appreciations for their analysis of MSA price changes.

Issues in Measuring Excess Returns

As mentioned earlier, obtaining a proper measure of house price movement is only part of the story in analyzing certain issues in research (e.g., testing the EMH) or business (e.g., managing geographically diversified real estate portfolios). A more important variable for these issues is the excess returns on holding real estate, for which other stochastic components must be computed. Conceptually, the excess returns can be defined as total gains (for owning real estate) minus total costs net of the yield on risk-free bonds (r^f). Specific items for the gains include the net expected capital gain g^r (i.e., the expected capital gain in excess of the inflation rate) and the sum of imputed rents R. The cost items include depreciation rate d, maintenance cost m, property taxes t_p, and forgone interest rate (or mortgage interest rate) r^m. In a simple form, per-period excess returns on holding residential real estate can be specified as

$$\mathrm{ER} = \left[g^r + \left(\frac{R}{P} \right) \right] - \left[\delta + m + t_p + r^m \right] - r^f , \tag{6}$$

where P is the asset value and d, m, t_p, and r^m are all measured in terms of the ratio to asset value. The first bracketed term in equation (6) refers to total gains, while the second includes cost components.[15]

It is mostly an empirical issue to determine which components of equation (6) vary serially and which vary cross-sectionally and, hence, should be included in a particular testing model. For example, the risk-free rate r^f is usually regarded as varying intertemporally but not contemporaneously. Different short-term Treasury bill rates are used for this variable—for example, 90-day rates (Poterba 1991) or one-year rates (Case and Shiller 1989).

On the other hand, most cost and benefit items in equation (6) (except, probably, the mortgage interest rate r^m) vary both over time and across space. The intertemporal house price indices are used as input for computing such variables as the rate of capital gain g^r. However, some variables in equation (6), such as the rental income R (for owner-occupied properties) and maintenance expense m, pose a serious measurement problem. Existing studies employ various variables to deal with the nonobservability of these variables. For example, Case and Shiller (1989) include the city-specific index for residential rent, which is derived from a constant defined as the "dividend price ratio."

On the other hand, Chinloy (1992) defines a house price function with a vector of state variables $\mathbf{S}$ and time trend t; that is, $P = P(\mathbf{S}, t)$. Each state variable is assumed to follow a log-normal diffusion process. By deriving a total derivative from the house price function (i.e., dP), the aggregate marginal rate of return is computed. Chinloy's empirical analysis (with repeat sales data for single-family homes from the San Francisco Bay Area between the first quarter of 1976 and the second quarter of 1986) shows that, other than inflation, aggregate factors are not correlated with returns on real estate.

While the measurement of the rental stream has been dealt with by the above studies and others, maintenance cost, another difficult-to-compute variable, has rarely been

[15] For simplicity, two tax factors relevant to excess returns are not included: tax rate on investment income and capital gains tax rate. See Follain and Ling (1988) for a specification of the user cost of capital that incorporates these two components.

examined in the existing literature. Further conceptual and empirical analyses of these variables are required for the advancement of our understanding of variation in excess returns on holding residential real estate, which is crucial information for various economic and financial issues.

Summary and Conclusion

In summary, the reviewed studies generally conclude that real estate markets are not informationally efficient: Both house prices and excess returns exhibit a positive serial correlation in the short run. However, the literature also indicates that establishing trading rules that consistently yield above-normal returns is generally not possible because of high transaction costs in the housing market.

Given this general conclusion, there are two useful avenues for future research: improvements in theoretical models and improvements in empirical measurement. The first direction includes the enhancement of the various rational-expectations models, such as different forms of market efficiency, speculative bubbles, and mean reversion. Testing these rational-expectations hypotheses is in fact a joint test of the model specification and the hypotheses themselves. Therefore, a better model specification that properly incorporates market fundamentals and disequilibrating factors will help generate more sound evidence on housing market efficiency. Furthermore, future research focusing on specific elements of housing transaction costs (such as brokerage fees, search costs, and effects of nonprice factors in mortgage lending) will produce findings that will better characterize the role of those particular items of transaction costs in home purchase and mortgage lending and therefore will lead to more specific policy recommendations to reduce such costs.

The second direction involves improving the measurement of house price indices and excess returns. Research in this direction can be pursued by further modifying the house price models discussed in this article as well as by applying new modeling techniques. In fact, some new techniques are being employed now. For example, various simulations and related numerical techniques (such as randomization, Monte Carlo simulation, and bootstrapping) are suggested by several studies as alternatives to traditional econometric methods (Goetzmann 1992; Knight, Hill, and Sirmans 1993; Pollakowski and Ray 1995; Yang, Cho, and Megbolugbe 1996). These numerical techniques will be useful for assessing different house price models in terms of controlling various serial and contemporaneous biases. As another example of new techniques, both Chinloy, Cho, and Megbolugbe (1997) and Nothaft, Gao, and Wang (1995) apply the GARCH (generalized autoregressive conditional heteroskedasticity) model in analyzing house price volatilities. This current time-series model, which is widely used in financial market studies, mainly relaxes the assumption of constant error variance. As such, it will provide a more general modeling framework for house price movement patterns in diverse geographic areas.

References

Abraham, Jesse M., and Patric H. Hendershott. 1996. Bubbles in Metropolitan Housing Markets. *Journal of Housing Research* 7(2):191–207.

Abraham, Jesse M., and William S. Schauman. 1991. New Evidence on House Prices from Freddie Mac Repeat Sales. *AREUEA Journal* 19(3):333–52.

Bailey, Martin J., Richard F. Muth, and Hugh O. Nourse. 1963. A Regression Method for Real Estate Price Index Construction. *Journal of the American Statistical Association* 58:933–42.

Blanchard, Olivier Jean. 1979. Speculative Bubbles, Crashes, and Rational Expectations. *Economic Letters* 3:387–89.

Blanchard, Olivier Jean, and Charles M. Kahn. 1980. The Solution of Linear Difference Models under Rational Expectations. *Econometrica* 48:1305–11.

Blanchard, Olivier Jean, and Mark W. Watson. 1982. Bubbles, Rational Expectations, and Financial Markets. In *Crises in the Economic and Financial Structure*, ed. Paul Wachtel. Lexington, MA: Lexington Books, pp. 295–315.

Bryan, Thomas B., and Peter F. Colwell. 1982. Housing Price Indexes. *Research in Real Estate* 2:57–84.

Calhoun, Charles A. 1991. Estimating Changes in Housing Values from Repeat Transactions. Paper read at the Western Economic Association meeting, Seattle.

Calhoun, Charles A., Peter Chinloy, and Isaac F. Megbolugbe. 1995. Temporal Aggregation and House Price Index Construction. *Journal of Housing Research* 6(3):419–38.

Cannady, Roger E., and T. L. Tyler Yang. 1996. A Generalized Repeat Sales House Price Index. Paper read at the American Real Estate and Urban Economics Association meeting, San Francisco.

Capozza, Dennis R., and Paul J. Seguin. 1996. Expectations, Efficiency, and Euphoria in the Housing Market. *Regional Science and Urban Economics* 26(3–4):369–86.

Case, Bradford, Henry O. Pollakowski, and Susan M. Wachter. 1997. Frequency of Transaction and House Price Modeling. *Journal of Real Estate Finance and Economics* 14(2), forthcoming.

Case, Bradford, and John M. Quigley. 1991. The Dynamics of Real Estate Prices. *Review of Economics and Statistics* 73(1):50–58.

Case, Karl E., and Robert J. Shiller. 1987. Prices of Single-Family Homes since 1970: New Indexes for Four Cities. *New England Economic Review*, September–October, pp. 45–56.

Case, Karl E., and Robert J. Shiller. 1989. The Efficiency of the Market for Single Family Homes. *American Economic Review* 79(1):125–37.

Case, Karl E., and Robert J. Shiller. 1990. Forecasting Prices and Excess Returns in the Housing Market. *AREUEA Journal* 18:253–73.

Chinloy, Peter. 1992. Returns to Holding Housing. *Journal of Housing Economics* 2(4):310–23.

Chinloy, Peter, Man Cho, Isaac F. Megbolugbe. 1997. Appraisals, Transaction Incentives, and Smoothing. *Journal of Real Estate Finance and Economics* 14(1), forthcoming.

Cho, Man, and Isaac F. Megbolugbe. 1996. An Empirical Analysis of Property Appraisal and Mortgage Redlining. *Journal of Real Estate Finance and Economics* 13:45–55.

Clapp, John M., and Carmelo Giaccotto. 1994. The Influence of Economic Variables on Local House Price Dynamics. *Journal of Urban Economics* 36(2):161–83.

Clayton, Jim. 1994. Expectations, Fundamentals, and Housing Price Volatility. Working paper. Saint Mary's University, Halifax, Canada.

Crone, Theodore M., and Richard P. Voith. 1992. Estimating House Price Appreciation: A Comparison of Methods. *Journal of Housing Economics* 2(4):324–38.

Cutler, David M., James M. Poterba, and Lawrence Summers. 1991. Speculative Dynamics. *Review of Economic Studies* 58:529–46.

De Bondt, Werner F. M., and Richard H. Thaler. 1989. A Mean-Reverting Walk down Wall Street. *Journal of Economic Perspectives* 3:189–202.

Delaney, Charles J., and Marc T. Smith. 1989. Impact Fees and the Price of New Housing: An Empirical Study. *AREUEA Journal* 17:41–54.

Dombrow, Jonathan, John R. Knight, and C. F. Sirmans. 1996. Aggregation Bias in Repeat Sales Indices. *Journal of Real Estate Finance and Economics* 14(1), forthcoming.

Evans, Richard D., and William B. Rayburn. 1991. The Effect of School Desegregation Decisions on Single-Family Housing Prices. *Journal of Real Estate Research* 6:207–16.

Fama, Eugene F. 1965. The Behaviour of Stock Market Prices. *Journal of Business* 38:34–105.

Fama, Eugene F. 1970. Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance* 25:383–420.

Fama, Eugene F., and Kenneth R. French. 1992. The Cross-Section of Expected Stock Returns. *Journal of Finance* 47(2):427–65.

Flood, Robert P., and Peter M. Garber. 1980. An Economic Theory of Monetary Reform. *Journal of Political Economy* 88:246–73.

Flood, Robert P., Peter M. Garber, and Louis O. Scott. 1984. Multi-Country Tests for Price Level Bubbles. *Journal of Economic Dynamics and Control* 8:329–40.

Flood, Robert P., and Robert J. Hodrick. 1990. On Testing for Speculative Bubbles. *Journal of Economic Perspectives* 4(2):85–101.

Follain, James R., and David C. Ling. 1988. Another Look at Tenure Choice, Inflation, and Taxes. *AREUEA Journal* 16(3):207–29.

Ford, Deborah Ann, and Michele Gilligan. 1988. The Effect of Lead Paint Abatement Laws on Rental Property Values. *AREUEA Journal* 16:84–94.

Froot, Kenneth A., and Maurice Obstfeld. 1991. Intrinsic Bubbles: The Case of Stock Prices. *American Economic Review* 81:1189–214.

Gatzlaff, Dean H. 1990. The Efficiency of the Single Family Housing Market: An Empirical Study. Ph.D. dissertation, University of Florida.

Gatzlaff, Dean H. 1994. Excess Returns, Inflation, and the Efficiency of the Housing Market. *Journal of the American Real Estate and Urban Economics Association* 22(4):553–81.

Gatzlaff, Dean H., and Donald R. Haurin. 1994. Selection Bias and Real Estate Index Construction. Working paper. Florida State University.

Gatzlaff, Dean H., and Donald R. Haurin. 1997. Sample Selection Bias and Repeat-Sales Index Estimates. *Journal of Real Estate Finance and Economics* 14(1), forthcoming.

Gatzlaff, Dean H., and Dogan Tirtiroglu. 1995. Real Estate Market Efficiency: Issues and Evidence. *Journal of Real Estate Literature* 3:157–92.

Goetzmann, William N. 1992. The Accuracy of Real Estate Indices: Repeat Sales Estimators. *Journal of Real Estate Finance and Economics* 5(1):5–54.

Goetzmann, William N., and Matthew Spiegel. 1995. Non-Temporal Components of Residential Real Estate Appreciation. *Review of Economics and Statistics* 77(1):199–206.

Goetzmann, William N., and Matthew Spiegel. 1997. A Spatial Model of Housing Returns and Neighborhood Substitutability. *Journal of Real Estate Finance and Economics* 14(1), forthcoming.

Goodman, Allan C., and Thomas G. Thibodeau. 1996. Heteroskedasticity in Repeat Sales House Price Equations. Paper read at the American Real Estate and Urban Economics Association meeting, San Francisco.

Green, G. Hayden, Donald Marx, and Musa Essayyad. 1988. The Effect of Inter-Regional Efficiency on Appraising Single Family Homes. *Real Estate Appraiser and Analyst* 54:25–29.

Grossman, Sanford J., and Joseph Stiglitz. 1980. On the Impossibility of Informationally Efficient Markets. *American Economic Review* 66:246–53.

Guntermann, Karl L., and Stefan C. Norrbin. 1991. Empirical Tests of Real Estate Market Efficiency. *Journal of Real Estate Finance and Economics* 4:297–314.

Guntermann, Karl L., and Richard L. Smith. 1987. Efficiency of the Market for Residential Real Estate. *Land Economics* 63:34–43.

Gyourko, Joseph, and Richard Voith. 1992. Local Market and National Components in House Price Appreciation. *Journal of Urban Economics* 32(1):52–69.

Hamilton, Bruce W., and Charles Schwab. 1985. Expected Appreciation in Urban Housing Markets. *Journal of Urban Economics* 18:103–18.

Haurin, Donald, and Patric Hendershott. 1991. House Price Indexes: Issues and Results. *AREUEA Journal* 19(3):259–69.

Hill, R. Carter, John R. Knight, and C. F. Sirmans. 1995. Estimating Capital Asset Price Indexes. Working paper. Center for Real Estate and Urban Economic Studies, University of Connecticut.

Hill, R. Carter, and R. F. Zeimer. 1984. The Risk of General Stein-Like Estimators in the Presence of Multicollinearity. *Journal of Econometrics* 25:205–16.

Hosios, Arthur J., and James E. Pesando. 1991. Measuring Prices in Resale Housing Markets in Canada: Evidence and Implications. *Journal of Housing Economics* 1(4):303–17.

Ito, Takatoshi, and Keiko N. Hirono. 1993. Efficiency of the Tokyo Housing Market. *Bank of Japan Monetary and Economic Studies* 11(1):1–32.

Ito, Takatoshi, and Tokuo Iwaisako. 1995. Explaining Asset Bubbles in Japan. Working paper. International Monetary Fund.

Kim, Kyung-Hwan, and Seong H. Suh. 1993. Speculation and Price Bubbles in the Korean and Japanese Real Estate Markets. *Journal of Real Estate Finance and Economics* 6:73–87.

Kleidon, Allan W. 1986. Anomalies in Financial Economics. *Journal of Business* 59:S285–316.

Knight, John R., R. Carter Hill, and C. F. Sirmans. 1993. Estimation of Hedonic Housing Price Models Using Non-Sample Information: A Monte Carlo Study. *Journal of Urban Economics* 34:319–46.

Kuo, Chion-long. 1996. Serial Correlation and Seasonality in the Real Estate Market. *Journal of Real Estate Finance and Economics* 12(2):139–62.

Leroy, Stephen F., and Richard D. Porter. 1981. Stock Price Volatility: Tests Based on Implied Variance Bounds. *Econometrica* 49:97–113.

Linneman, Peter. 1986. An Empirical Test of the Efficiency of the Housing Market. *Journal of Urban Economics* 20:140–54.

Mankiw, N. Gregory, and David N. Weil. 1989. The Baby Boom, the Baby Bust, and the Housing Market. *Regional Science and Urban Economics* 19:235–58.

Marsh, Terry A., and Robert C. Merton. 1986. Dividend Variability and Variance Bounds Tests for the Rationality of Stock Market Prices. *American Economic Review* 76:483–98.

Meese, Richard A. 1986. Testing for Bubbles in Exchange Markets: A Case for Sparkling Rates? *Journal of Political Economy* 94:345–71.

Meese, Richard A., and Nancy Wallace. 1993. Residential Housing Prices in the San Francisco Bay Area: New Tests of the Explanatory Power of Economic Fundamentals. Working paper. University of California at Berkeley.

Meese, Richard A., and Nancy Wallace. 1994. Testing the Present Value Relation for House Prices: Should I Leave My House in San Francisco? *Journal of Urban Economics* 35:245–66.

Nothaft, Frank E., Andre H. Gao, and George H. K. Wang. 1995. The Stochastic Behavior of the Freddie Mac/Fannie Mae Conventional Mortgage Home Price Index. Paper read at the American Real Estate and Urban Economics Association annual meeting, San Francisco.

Pollakowski, Henry O., and Traci S. Ray. 1995. Housing Price Diffusion Patterns among U.S. Census Divisions: An Examination of Housing Market Efficiency. Working paper. Boston College.

Poterba, James M. 1991. House Price Dynamics: The Role of Tax Policy and Demography. *Brookings Papers on Economic Activity*, no. 2:143–203.

Poterba, James M., and Lawrence H. Summers. 1988. Mean Reversion in Stock Prices: Evidence and Implications. *Journal of Financial Economics* 22:27–59.

Quigley, John M. 1995. A Simple Hybrid Model for Estimating Real Estate Price Indexes. *Journal of Housing Economics* 4(1):1–12.

Rayburn, William B., Michael Devaney, and Richard D. Evans. 1987. A Test of Weak-Form Efficiency in Residential Real Estate Returns. *AREUEA Journal* 15:220–33.

Samuelson, Paul A. 1965. Proof That Poorly Anticipated Prices Fluctuate Randomly. *Industrial Management Review* 6:41–49.

Shiller, Robert J. 1981. Do Stock Prices Move Too Much to Be Justified by Subsequent Changes in Dividends? *American Economic Review* 71:421–36.

Shiller, Robert J. 1991. Arithmetic Repeat Sales Price Estimators. *Journal of Housing Economics* 1(1):110–26.

Shiller, Robert J. 1993. Measuring Asset Values for Cash Settlement in Derivative Markets: Hedonic Repeated Measures Indices and Perpetual Futures. *Journal of Finance* 48:911–31.

Shleifer, Andrei, and Lawrence H. Summers. 1990. The Noise Trader Approach to Finance. *Journal of Economic Perspectives* 4:19–33.

Skantz, Terrence R., and Thomas H. Strickland. 1987. House Prices and a Flood Event: An Empirical Investigation of Market Efficiency. *Journal of Real Estate Research* 2:75–83.

Steele, Marion, and Richard Goy. 1997. Short Holds, the Distributions of First and Second Sales, and Bias in the Repeat Sales Price Index. *Journal of Real Estate Finance and Economics* 14(1), forthcoming.

Stephens, William, Ying Li, Vassilis Lekkas, Jesse Abraham, Charles Calhoun, and Thomas Kimner. 1995. Conventional Mortgage Home Price Index. *Journal of Housing Research* 6(3):389–418.

Taylor, William M. 1992. The Estimation of Quality-Adjusted Auction Returns with Varying Transaction Intervals. *Journal of Financial and Quantitative Analysis* 27:131–42.

Turnbull, Geoffrey K., C. F. Sirmans, and John D. Benjamin. 1990. Do Corporations Sell Houses for Less? A Test of Housing Market Efficiency. *Applied Economics* 22:1389–98.

Voith, Richard P. 1991. Capitalization of Local and Regional Attributes into Wages and Rents: Differences across Residential, Commercial, and Mixed-Use Communities. *Journal of Regional Science* 31:127–45.

Webb, Cray. 1981. The Expected Accuracy of a Real Estate Price Index. Working paper. Department of Mathematics, Chicago State University.

West, Kenneth B. 1987. A Standard Monetary Model and the Variability of the Deutschmark-Dollar Exchange Rate. *Journal of International Economics* 23:57–76.

Yang, T. L. Tyler, Man Cho, and Isaac F. Megbolugbe. 1996. Methods for Estimating Repeat Sales House Price Indices: A Validation through Simulations. Paper read at the 5th Annual American Real Estate and Urban Economics Association International Real Estate Conference, Orlando, FL.