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In Search of Empirical Evidence That Links Rent and User Cost

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ABSTRACT

Most models of the rental housing market assume a close linkage between the level of residential rents and the after-tax user cost of rental housing capital. However, little empirical evidence exists to establish the strength of this linkage or the speed with which rents adjust to changes in user cost or tax policy. This paper develops and estimates an econometric model of the rental housing market in order to shed light on both of these issues. United States annual data for 1964 through 1993 are used to generate two-stage least squares estimates of a four equation structural model. Although the results are generally consistent with expectations and reveal several interesting relationships among the system variables, the estimates fail to identify a strong relationship between rent and user cost. Only half of an increase in user cost is ultimately passed along as higher rents. The adjustment process also takes a long time, with only about half of the long-run effect realized within ten years of a user cost shock. The fundamental reason for this result is that our estimate of the user cost series, based upon widely accepted procedures with by to calculate user cost, is much more volatile than the residential rent series. In a recent paper, DiPasquale and Wheaton also find a slow adjustment process. Nonetheless, such sluggishness is surely different than many economists believe. We offer several possible explanations for this result. Among these is the possibility that the linkage between rent and user cost is too complex to be identified using 30 years of national data.

IN SEARCH OF EMPIRICAL EVIDENCE THAT LINKS RENT AND USER COSTS

Introduction

The proposition that residential rents ultimately reflect rental user cost, as measured by changes the real after-tax cost of capital used to produce rental housing, is widely held. A corollary to this proposition implies that changes in the tax treatment of rental housing which affect user cost generate changes in the level of rents. However, little empirical evidence currently exists to support these propositions, and even less is known about the speed with which rents adjust to changes in user cost or tax policy.

These relationships are central to answering at least two important questions, First, who benefits from tax policies designed to reduce rents? If these policies do not generate lower rents, then the beneficiaries are owners of rental housing units and not the tenants who occupy them. This outcome is not the goal of such tax policies. Second, how do these policies affect the asset price of rental housing? If rent levels adjust slowly to changes in tax policy, then large changes in the asset price of rental housing can result. Consequently, windfall gains can accrue to owners of this housing if favorable tax policies are enacted. Alternatively, unfavorable policies can generate windfall losses for owners and others with a stake in this housing. For example, lenders who collateralize mortgages with this housing may suffer from an unfavorable tax policy such as the Tax Reform Act of 1986 (TRA) because asset prices will decline and defaults will rise.

Hendershott, Follain and Ling (HFL) (1987) and Follain, Hendershott and Ling (FHL) (1987) have considered these questions in simulation analysis of the rental housing market. They focus primarily on TRA's impact upon long-run equilibrium rents, but they also consider its effects upon asset prices using rather ad hoc assumptions about the speed at which rents adjust to user cost. Ling's recent simulation analysis (1992) extends the HFL approach. Unfortunately, none of this work provides strong empirical evidence to support the parameterization of the model, especially the speed with which rents adjust to long-run equilibrium.

Alm and Follain (1994) develop a theoretical basis for empirical work on these questions. Their central message is that the linkage between user cost and rent depends upon the structure of the rental housing market. A four equation discrete dynamic model is developed and examined to explore the linkage. The system consists of a demand equation for housing, an accounting identity that monitors the size of the housing stock, a construction equation, and an asset price equation. This last equation is the key to the analysis and posits that the asset price of housing equals replacement cost plus the sum of the future or expected gap between rent in period t + i and user cost. They also consider various specifications of household expectations about future movements in market rent. Their simulations demonstrate the factors that affect the speed with which rents adjust, but like HFL, the parameterization of the simulation model is not supported by empirical evidence.

Follain, Leavens and Velz (FLV) (1993) examine the empirical relationship between rent and user cost. They estimate a reduced form model of the rental housing market using pooled time-series and cross-section data at the metropolitan level. They find that changes in user cost significantly affect construction, but not the level of rents. Their results do not necessarily indicate that such a link does not exist because data limitations prohibit estimation of the exact structural model suggested by Alm and Follain. However, coupled with casual observation of the data and the number of specifications considered, they suggest that if a strong relationship does exist, it is a subtle one that will not be easily uncovered.

DiPasquale and Wheaton (1992) offer the most comprehensive empirical analysis to date of the linkage between rent and user cost. They estimate a two equation model of the demand for rental housing and the construction of multifamily units using United States data for 1964 through

1989. Their estimates suggest that rents rise modestly in response to an increase in user cost. In contrast are Hendershott's (1994) recent results. He estimates a single equation model using office rents in Australia and finds a much stronger relationship between rents and user cost.

This paper seeks to develop and estimate an econometric model of the rental housing market. The basic elements of the model draw upon the papers noted above, especially Alm-Follain and DiPasquale-Wheaton. Like both papers, the model emphasizes the structural equations underlying the rental housing market and the dynamic characteristics of the housing market as it adjusts to long-run equilibrium values. Unlike both papers, it attempts to model both the demand for rental housing **services** and the demand for rental housing **units**. Alm-Follain model only the demand for housing services, while DiPasquale-Wheaton model only the demand for housing units.

The paper first presents an econometric model of the rental housing market and discusses its underlying theoretical framework. Then the data used to estimate the model are described. The empirical results are presented and evaluated, and finally the important conclusions of the analysis are highlighted.

Model Specification

The econometric model is derived from a larger and more detailed structural framework. This structural model is represented by a six-equation, six-unknown system of linear simultaneous equations. The system includes equations determining the demand for rental housing per household, the number of renter households, the aggregate supply of rental housing, construction, the asset price of rental housing, and rental price adjustment.

The demand side of the rental housing market includes equations representing the demand per household and the number of renter households. The demand for rental housing services per household (q_t) in period t depends upon the real rental price (pr_t) per unit of constant quality rental housing and the permanent income (YP_t) of a typical renter household.

$$q_t = f(pr_t, YP_t) \quad \textbf{(1)}$$

Standard consumer theory suggests housing demand varies inversely with rental price and directly with income. Tenure choice is reflected in the renter households equation. The number of renter households (NR_t) depends upon the relative price of rental and owner-occupied housing (pr_t/PO_t), the permanent income of a typical household, and the size of the adult population (POP_t).

$$NR_t = f(pr_t/PO_t, YP_t, POP_t) \quad \textbf{(2)}$$

Increases in the relative price of renting or household income will encourage home ownership and reduce the demand for rental dwellings. Assuming demand per household is typical of renter households generally, the aggregate demand for rental housing services (QD_t) is the product of housing services demanded per renter household from (1) and the number of renter households from (2), or $QD_t = q_t NR_t$.

The supply side of the rental housing market includes equations for aggregate supply and construction. Each period's aggregate supply (QS_t) of rental housing equals last period's aggregate supply, net of depreciation, plus this period's construction (C_t).[1]

$$QS_t = (1 - d)\, QS_{t-1} + C_t , \quad \textbf{(3)}$$

where d equals the housing depreciation rate. Construction in period t depends upon profit opportunities as reflected in the difference between asset price (PR_t) and replacement cost (PRC_t).

$$C_t = \alpha\, (PR_t - PRC_t), \quad \textbf{(4)}$$

[1]This formulation assumes that new construction is completed in one period.

where α reflects the responsiveness of construction to the gap between asset price and replacement cost.[2]

The asset price of rental housing each period equals the discounted value of the future "net income" of rental housing each period. With net income equal to rent less depreciation and an interest rate r, the asset price each period is given by:

$$PR_t = \sum_{i=1}^{\infty} [(pr_{t+i} - d\,PR_t)/(1 = R)^i]. \quad \textbf{(5)}$$

The asset price adjusts each period as future net income is capitalized into the current price of rental housing so that the long-run equilibrium asset price (PR^*) equals replacement cost.

The final equation in the system recognizes that the rental housing market may adjust gradually to changes in the exogenous variables that drive it. This process is similar to those used by DiPasquale-Wheaton and Alm-Follain. Movements in rental price respond to excess aggregate supply according to:

$$pr_t / pr_{t-1} = \phi\,(QS_t - QD_t), \quad \textbf{(6)}$$

where ϕ measures the responsiveness of rental price to excess supply ($-\infty \le \phi \le 0$), QS is aggregate housing supply and QD is aggregate housing demand.

This six-equation system is modified in four ways to arrive at the econometric model for estimation. First, a proxy for the current asset price is needed in the empirical analysis because an index of the asset price of rental housing is unavailable. We assume the current asset price is proxied by the gap between the current level of rents and the user cost of capital. It is apparent from equation (5) that the current asset price is a complex function that depends upon the manner

[2] A more elaborate construction equation like (3) can be derived as the outcome of an intertemporal profit maximization problem as in Turnbull (1988). We use this simple specification because it is a quite common specification and because a more elaborate construction equation adds little to the central message of this paper.

in which expectations about the future gap between rent and replacement cost are formed. Alm and Follain (1994), DiPasquale and Wheaton (1995), Mankiw and Weil (1989) and others investigate various assumptions such as perfect foresight, adaptive expectations, and rational expectations. Testing these various models poses difficult econometric problems and strict data requirements. Given the limitations imposed by our data, a simpler approach is adopted here, but one which still captures the essence of the underlying model.[3] This simplification should be kept in mind in assessing the performance of the supply equation because the rejection of a strong relationship between the supply of housing and the rent-user cost gap is actually a test of two separate hypotheses; one relates to the user cost model and one relates to the rent adjustment process. Substituting this asset price formulation into the construction equation, and then into the accounting relationship in (3) yields:

$$QS_t = (1 - d)\, QS_{t-1} + \alpha\, \lambda\, (pr_t - pr_t^*) \qquad \textbf{(3')}$$

where λ is a parameter which captures the complex relationship between the asset price-replacement cost gap and the rental price-user cost gap.

Second, the supply equation is modified to include the lagged excess supply $[(QS - QD)_{t-1}]$. This implies that builders may respond not only to the rental price-user cost gap, but also to the quantity gap. This could arise because prospective developers are just as hampered by the lack of information about current asset prices as are builders of econometric models. As such,

[3]A formal justification for this proxy can be developed if one assumes that rents follow a partial adjustment process, for example, $(pr_t - pr_{t-1}) = (1-g)(pr_t - pr^*)$ where g is the rate of adjustment parameter. In such a case, it can be shown that the asset price in equation (5) simplifies to $PR = (pr - pr^*)/(g + r)$.

they may use an easier to obtain measure of the tightness of a housing market, like vacancies. In a units oriented model like DiPasquale-Wheaton, the vacancy rate serves this role directly.[4]

Third, the rent adjustment equation includes the lagged difference between rental price and user cost. Increases in the magnitude of this gap will tend to slow the rate of increase in rent. This proves to be a powerful channel in the estimated model.

Fourth, previous work suggests that autocorrelation will likely arise with the data used to estimate the model. Anticipating this, both the services and units demand equations are specified in partial adjustment forms. This approach allows both short-run and long-run elasticities to be defined for these equations. Each of the other equations in the system already includes its lagged value among the regressors.

Model Summary

Assuming log-linear functional forms, these modifications yield the following specification of the econometric model to be estimated:

Demand Per Household

$$\ln(q_t) = \alpha_0 + \alpha_1 \ln(pr_t) + \alpha_2 \ln(YP_t) + \alpha_3 \ln(q_{t-1})$$

Number of Renter Households

$$\ln(NR_t) = \gamma_0 - \gamma_1[\ln(pr_t) - (\ln(uco_t) + \ln(PR_t))] - \gamma_2 \ln(YP_t) + \gamma_3 \ln(POP_t) + \gamma_4 \ln(NR_{t-1})$$

Aggregate Supply Equation

$$\ln(QS_t) = \beta_0 + \beta_1 \ln(pr_t) - \beta_2[\ln(ucr_t) + \ln(PRC_t)] - \beta_3[\ln(QS) - \ln(QD)]_{t-1} + \beta_4 \ln(QS_{t-1})$$

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[4]We also experimented with variables suggested by an accelerator theory of investment like the rate of change in gross national product. These generally performed poorly and are excluded from the supply equation.

Rent Adjustment

$$\ln(pr_t) = \delta_0 + \delta_1 \ln(pr_{t-1}) - \delta_2[\ln(pr) - \ln(ucr * PRC)]_{t-1} - \delta_3[\ln(QS) - \ln(QD)]_{t-1}$$

The expected signs of the coefficients are indicated in this summary. It also shows explicitly several coefficient restrictions implied by the underlying theoretical model which will be empirically examined.

Data Description

The econometric model is estimated using United States aggregate annual data from 1964 through 1993. Data of this type are not ideally suited to examine the issues addressed in this paper. One potentially important weakness is the absence of a direct measure of the asset price of rental housing. We incorporate its effects by relying on proxies for it. The limited number of available observations poses another problem, just as it does for most macroeconomic studies. Furthermore, these data aggregate over a wide variety of local housing markets that respond in different ways to nationally triggered shocks. Despite these weaknesses, we believe these data can be reasonably used to address the questions posed in this study. Our data set includes measures of more relevant variables than can be obtained for smaller geographic regions.[5] More importantly, identifying a strong linkage between rent and user cost using data with obvious deficiencies would constitute convincing evidence of the user cost model and the power of tax policy. Conversely, failure to identify a strong linkage would not constitute a powerful rejection of the theory. Weak evidence may direct researchers to other and better data to identify the

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[5]Follain, Levens and Velz discuss some weaknesses associated with using metropolitan level data.

linkage. Alternatively, it may suggest that the standard user cost model of HFL, FHL, and others ought to be modified to account for less than full adjustment of rent to changes in user cost.

Summary statistics are presented in Table 1 for all variables used in the estimation. The data are obtained primarily from the CitiCorp data base and the Department of Commerce. The definitions of the supply and demand for rental housing distinguish our approach from some other studies of the rental housing market, in particular, DiPasquale and Wheaton (1992). Our approach seeks to incorporate both units and services concepts. The aggregate supply of rental housing stock (QS) is the Department of Commerce's series for the constant cost value of the net stock of privately owned tenant-occupied housing (Musgrave, 1993, Table 12).[6] Changes in this stock series represent new construction or new investment in rental housing.

Multifamily starts are also frequently employed as a measure of investment in rental housing. We prefer the stock series because it represents rental housing specifically and, in theory, allows a distinction to be made between the number of new housing units and the services provided by these units. The multifamily starts series includes some units destined to

[6]1993 values were provided by Michael Glenn of the Department of Commerce. The constant cost series is in 1987 dollars.

TABLE 1

DESCRIPTIVE STATISTICS

Name	Description[a]	Mean	Standard Deviation
q	Rental Quantity per HH	$29,507	$2,917
NR	Number of Renters (thousands)	27,569	4,691
QS	Real Aggregate Rental Supply ($bill)	$880.40	$220.25
QD	Real Aggregate Rental Demand ($bill)	$824.12	$203.29
QS-QD	Excess Rental Supply ($bill)	$56.28	$19.21
pr	Real Rent ($)	$1,507.28	$86.34
pgdp	GDP Deflator (1987=100, SA)	0.685	0.326
YP	Real Consumption per HH (dollars)	$30,898	$2,660
uco	Owner User Cost Rate (percents)	4.41%	1.17%
ucr	Rental User Cost Rate (percents)	8.82%	3.54%
PR	Real Asset Price of Rental Unit (dollars)	$23,746	$1,618
ucr*PRC	Real Rental User Cost (dollars)	$2,235.12	$965.46
pr-ucr*PRC	Real Rent-User Cost Gap (dollars)	-$727.83	$962.89
PRC	Real Replacement Cost of Apartment	$25,152.55	$1,530.00
POP	Adult Population (≥ 16 yrs. mill)	165.704	21.949

[a]Real values are expressed in constant 1987 dollars.

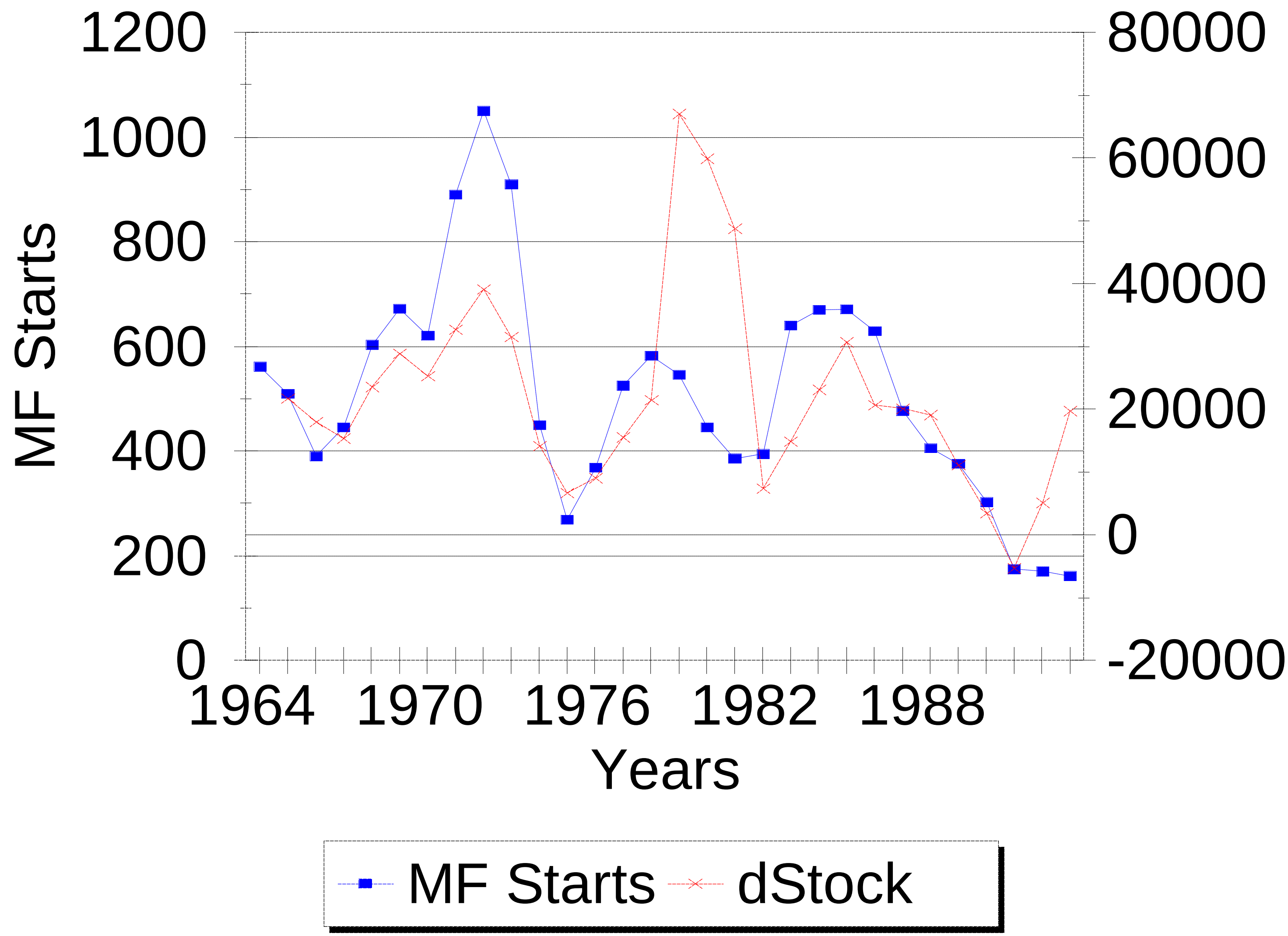
be owner-occupied and omits single family rental housing units, improvement expenditures for rental housing, and conversions in occupancy status. Figure 1 presents an investment series based on the Commerce data and the multi-family starts series. Although the series are highly correlated, discrepancies occur in the early 1970s, the late 1970s, and the early 1990s. Identifying the reasons for these discrepancies is a difficult task, but they do seem to lend support to our preference for the stock series, which, in theory, provides appropriate measures of aggregate supply and investment in rental housing.

The aggregate demand for rental housing is the occupied rental housing stock (QD), defined as aggregate supply multiplied by one minus the rental vacancy rate. The Census H-111 series on vacancy rates is used to measure the rental housing vacancy rate. This may understate demand because vacant units are probably below the average value of all rental housing units, but we uncovered no data or method by which to incorporate this into the demand series.

The aggregate demand for rental housing may also be viewed as the product of the quantity of housing services generated by the average occupied rental housing unit and the total number of occupied rental housing units. The number of renter households (NR) equals the total number of households multiplied by one minus the home ownership rate. The latter two series are obtained from the Census. The demand per renter household (q) equals aggregate demand divided by the number of renter households (QD/NR). Indexes of the two components of rental housing demand are presented in Figure 2. Per household demand rises relatively quickly until the late 1970s, falls briefly, and then levels off. The number of renter households grows at about 2.3 percent per year, although its growth was well above this average during most of the 1980s.

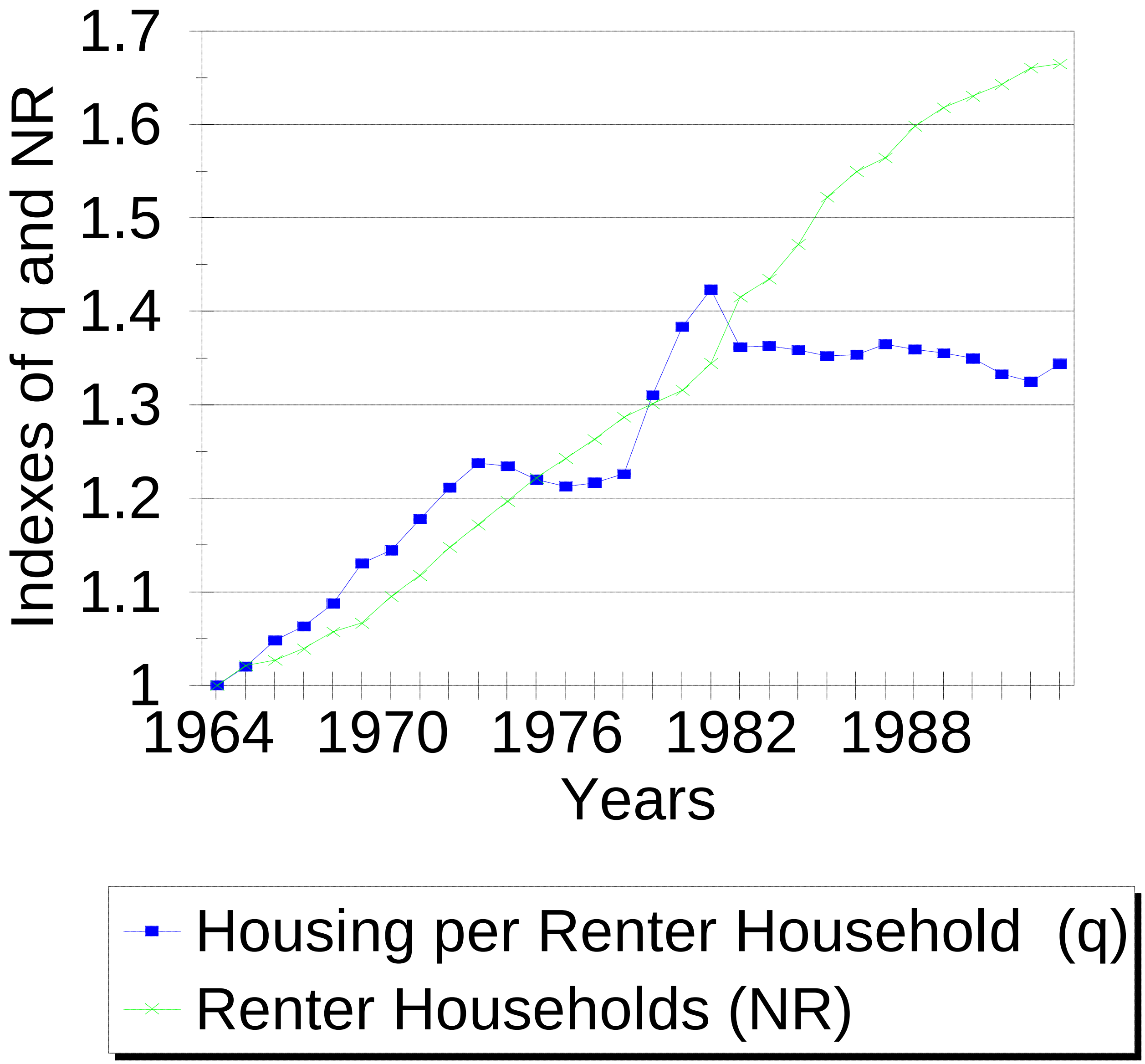
MF Starts and Change in Stock

Figure 1



q and NR

Figure 2

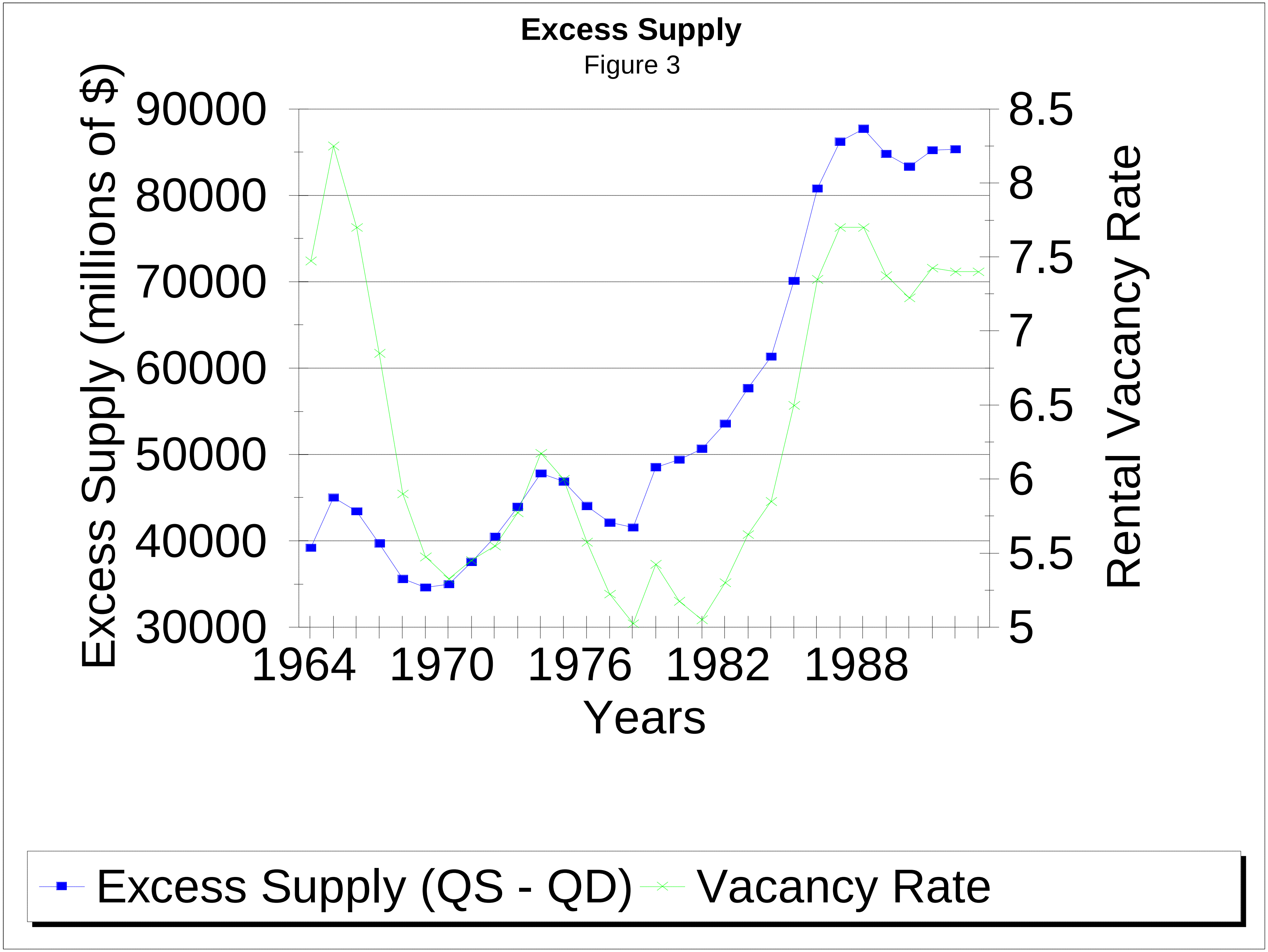


Excess supply is defined as the difference between aggregate supply and aggregate demand. The excess supply series in millions of dollars and the vacancy rate are plotted in Figure 3. Since the vacancy rate is used to derive the demand series, excess supply tracts the vacancy rate closely. Both series show the substantial rise in excess supply during the middle and late 1980s. In dollar terms, the amount of the excess supply totals nearly $90 billion dollars. As may be expected, this large overhang of excess capacity has a dampening effect upon the current status and near term future of the market for new rental housing.

The rental price (pr) of rental housing plays an important role in the model presented in the previous section. This measure is generated by modifying the residential rent component of the Consumer Price Index in three ways. First, the index is adjusted upward by 0.5 percent per year to offset a potential downward bias in the index due to its likely underestimation of depreciation. This bias arises because the rent index is based upon the average rent among a sample of existing properties. As such changes in the average rent among this sample is likely to understate movements in the market price of rental housing.[7] Second, the series is converted to a real rent series using the GDP deflator. Third, the index is applied to the average value of a rental unit in 1964.

A critical variable in this analysis is rental user cost. Our approach follows closely that used by HFL, FHL, and Follain and Ling. In essence, a multiperiod present value model is used to compute the first period rent that sets the net present value of the project equal to zero. The cash flows of the project include rent less operating expenses, real appreciation less physical depreciation of the project, tax benefits, and other costs associated with the construction and sale of the unit. The principle difference between our series and the others

[7]Others have noted this bias and made similar adjustments. See Apgar et al. (1987) and DiPasquale and Wheaton (1992).


Excess Supply
Figure 3
Excess Supply (millions of $)
90000
80000
70000
60000
50000
40000
30000
8.5
8
7.5
7
6.5
6
5.5
5
Rental Vacancy Rate
1964
1970
1976
1982
1988
Years
Excess Supply (QS - QD)
Vacancy Rate

deal with the complexities of computing user cost for an annual time series. The other work focuses on one or two time periods.

One key component of the user cost calculations is the expected inflation series. We use quarterly data to estimate an adaptive expectations model in which the current value of the GDP deflator is regressed on four lags. Expected inflation is a three year moving average of the quarterly predicted values of the GDP deflator. We investigated various versions of this approach and chose this one because it is both reasonable and less likely to generate sharp and short-lived spikes in expected inflation.

The cash flows of the project do not include payments on a mortgage. The discount rate is an after-tax discount rate that represents a weighted average cost of capital. As discussed by FHL, this is done to eliminate the need to continuously update the optimal debt to equity ratio and to remain consistent with the corporate finance approach to capital budgeting. The discount rate (IER) is:

$$IER = (1 - MTRR)\, ID [\, 1 + (1 - MTRPR)\, MRP\,] \qquad \textbf{(7)}$$

where MTRR and MTRPR are the marginal tax rates of the investor for ordinary income and equity income, respectively. These may differ because of the tax treatment of capital gains. ID is the nominal interest rate represented by the ten year Treasury rate and MRP is a risk premium. The only difference between this discount rate and FHL's is that the risk premium is proportional rather than additive to the nominal discount rate, which seems appropriate in a time series context.

Several parameters must be assigned to complete the present value calculations. Some are invariant to the tax regime, including the property tax rate (.02), the sales commission rate (.06), and the land to property value ratio (.85). Several others vary by tax regime. The marginal tax rate of the investor in rental property equals .50 prior to 1982, .45 for 1982 through 1986, and

.36 after 1986. The capital gains tax rate equals .5 prior to 1978, .4 for 1978 through 1986, and 1 after 1986. The useful life of a property for tax purposes equals 30 years prior to 1982, 15 years for 1982-83, 18 years for 1984, 19 years for 1985-86, and 27.5 years since 1987. The method of depreciation is 200 percent of straight line until 1982, 175 percent for 1982-86, and straight line since 1987. The optimal determination of whether to use the accelerated or straight line method is taken into account. The holding period for rental property investments is allowed to vary among tax regimes. With two exceptions, the holding period is set equal to the useful tax life of the property, which is a result that is produced by simulations in which the holding period is chosen as the one that minimizes user cost. The two exceptions pertain to the 1964-68 period when the optimal holding period is 12 years and the 1982-86 period in which we allow for multiple trading.[8] Otherwise, only one trade is allowed because multiple trading, or churning, has little impact on the size of user cost. FHL explain the reasoning underlying this approach in more detail.

User cost and rent expressed in real dollars are plotted in Figures 4 and 5. Figure 4 also includes the user cost rate in percent. Several aspects of these patterns are noteworthy. The user cost series in real dollars and as a rate are quite comparable. The user cost rate fluctuates around 6 and 7 percent until the latter part of the 1970s when it declines substantially. This is probably a response to an increase in expected inflation and a less than full adjustment of nominal interest rates to it. The rapid rise in the early 1980s is due primarily to higher interest rates and lower inflationary expectations, and occurred despite

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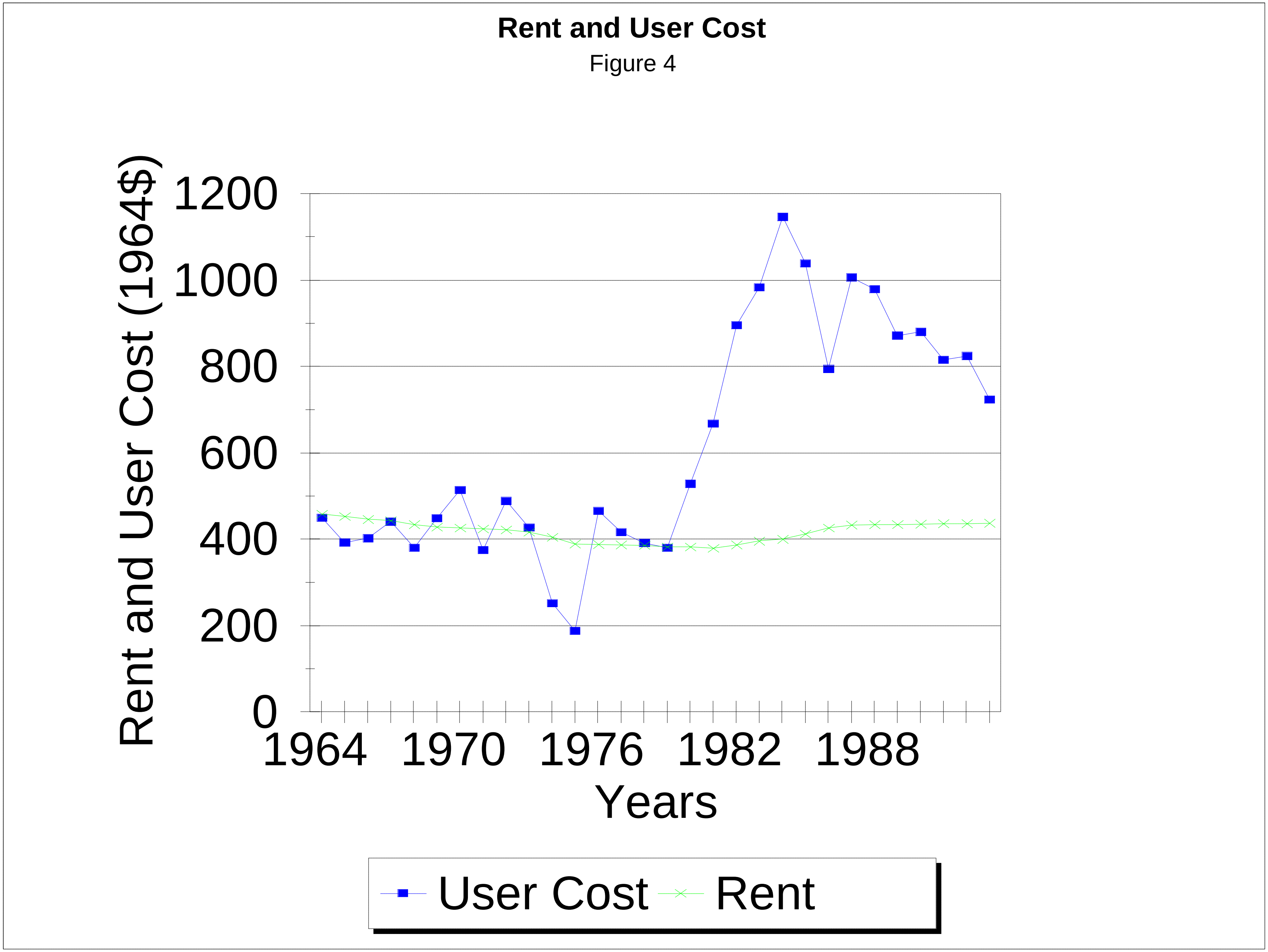
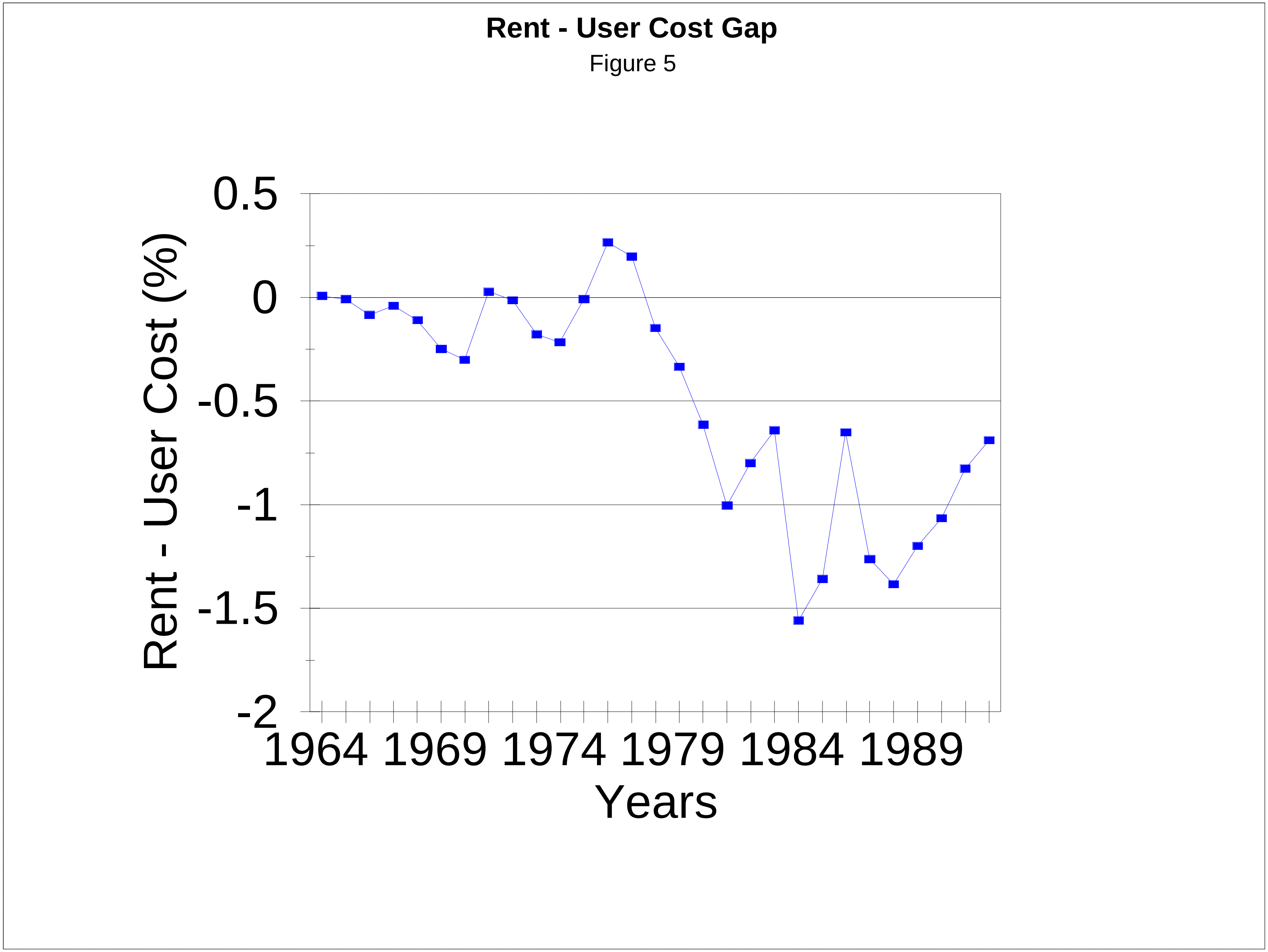
[8]The key in the 1964-68 period is the recapture provision, which changed in 1969 to discourage multiple trading. FHL analyze the impact of multiple trading and show that user cost declines modestly if multiple trading is allowed. Although the allowance for multiple trading is appropriate and produces a modest change in the user cost series for these years, it has no impact upon the basic results in this paper.


Rent and User Cost
Figure 4
Rent and User Cost (1964$)
1200
1000
800
600
400
200
0
1964
1970
1976
1982
1988
Years
User Cost
Rent



Rent - User Cost Gap
Figure 5
0.5
0
-0.5
-1
-1.5
-2
Rent - User Cost (%)
1964 1969 1974 1979 1984 1989
Years

generous tax policy. FHL and others have noted and discussed this previously. A sharp rise in user cost occurs in 1987 because of TRA, but user cost has declined since then due to the general decline in interest rates.

The most important point to note about these series is the relative volatility of rent and user cost. Rent is a stable, slow-moving series compared to user cost. This pattern portends a result that emerges from the econometric investigation below. Such disparities in the volatility of the rent and user cost series make it difficult to identify a strong linkage between rent and user cost.

A series on the user cost of owner-occupied housing is also produced by a similar but less complicated procedure because the tax treatment of owner-occupied housing is simpler. The two main differences are that the discount rate equals 90 percent of the investor's discount rate and the tax rate of the marginal home owner equals the Barro and Sahasakul (1984) series prior to 1987 and 0.25 since then.

Three other variables are used in the estimation of the model. Consumption expenditures per household converted to real dollars by the GDP deflator serve as a proxy for permanent income (YP). The United States population age 16 and over measures adult population (POP). Replacement cost (PRC) equals the national Boeckh construction cost index for apartments.

Estimation Procedure and Results

This section describes the estimation procedures and discusses the empirical results. Several alternative specifications were examined and evaluated. We focus attention on our sense of the "best" model.

Estimation Procedure

The econometric model summarized above is a four equation simultaneous system. Parameter estimates are generated using 2SLS with a modification described in Kmenta (1986) to account for the presence of lagged endogenous variables among the regressors. Kmenta suggests treating lagged endogenous variables as if they are current endogenous variables and using current and lagged purely exogenous variables as instruments in 2SLS. This approach generates consistent 2SLS parameter estimates when lagged endogenous variables are among the regressors. The further issue of serial correlation is addressed by Greene (1993), Fair (1970), and others who offer procedures for estimating simultaneous equation models with lagged endogenous variables and serially correlated errors.

Coefficient Estimates

Table 2 presents 2SLS estimates for the model's four equations. The sign patterns are largely as expected and several parameters are significant at the 5 percent level. The short-run rent and income elasticities of rental housing demand per household equal -0.267 and 0.174. The partial adjustment coefficient equals 0.262, indicating that about 26 percent of the gap between current demand and its long-run equilibrium value is closed in one year, and about 60 percent after three years. The long-run rent elasticity is -1.019 and the long-run income elasticity is 0.664. The results reported in Table 2 are not corrected for serial correlation, although Durbin's h statistic of 2.66 indicates that it is present.[9]

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[9]If the null hypothesis of no serial correlation is true, then Durbin's h statistic has a standard normal distribution in large samples. An iterative Prais-Winsten procedure produces a serial correlation coefficient of 0.772 for the services demand equation, assuming an AR(1) error structure. Corrected for serial correlation, the estimated demand equation is:

$$\ln(q) = \underset{(1.782)}{9.344} - \underset{(0.167)}{0.705}\ln(pr) + \underset{(0.115)}{0.591}\ln(YP) + \underset{(0.099)}{0.396}\ln(q_{-1})$$

The demand for rental units is reflected in the renter households equation. The partial adjustment coefficient of 0.083 implies that adjustment to long-run equilibrium is considerably slower for units demand than for services demand. Only 8 percent of the gap between the current number of renters and the long-run equilibrium value is closed each year, and about 23 percent after three years. Increases in both the price of renting relative to owning and average household income reduce the number of renter households. The relative housing price elasticity equals -0.016 in the short-run and -0.193 in the long-run. The relative price coefficient is significantly negative at the 5 percent level, but the housing price effects on tenure choice are rather modest. The hypothesis that an increase in rent and a decrease in the user cost of home ownership have the same impact on tenure choice is not rejected at standard significance levels. The short-run and long-run income elasticities are -0.111 and -1.337. Their magnitudes imply that household income levels play a larger role in tenure choice than do relative housing prices. Their negative signs suggest a preference for home ownership which can be more readily satisfied as average household income increases. However, the income coefficient is significantly negative only at the 10 percent level. Population growth increases the number of renter households modestly in the short-run and more than proportionally in the long-run. One percent growth in the adult population produces 0.134 percent short-run growth in the number of renter households and 1.614 percent long-run growth. At the sample means, this represents 1.657 million more people and 36,942 more renter households in the short-run and 444,964 more in the long-run. Again, the

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The coefficients are statistically significant and the sign pattern is consistent with economic theory. The short-run elasticities are more than twice as large as the uncorrected estimates, and both long-run elasticities are about unity.

TABLE 2

2SLS ESTIMATES OF A RENTAL HOUSING MARKET MODEL

Variable	Parameter Estimate	Standard Error	t-Ratio
Demand: Depandant Variable = ln(q) Log of Rental Demand per Household			
Adjusted R^2 = 0.960 Root MSE = 0.019	DW stat = 1.130	Durbin's h = 2.66	
Constant	4.063	1.432	2.837
ln(pr)	-0.267	0.122	-2.185
ln(YP)	0.174	0.101	1.715
$\ln(q_{-1})$	0.738	0.088	8.388
Supply: Dependant Variable = ln(QS) Log of Aggregate Real Rental Supply			
Adjusted R^2 = 0.996 Root MSE = 0.016	DW stat = 1.058	Durbin's h = 2.56	
Constant	-0.365	1.212	-0.301
ln(pr)	0.121	0.147	0.817
ln(ucr*PRC)	0.0005	0.012	0.040
ln(QS/QD)	-1.310	0.023	-1.794
$\ln(QS_{-1})$	0.970	0.023	41.342
Renter Households: Dependant Variable = ln(NR) Log of Number of Renter HHs			
Adjusted R^2 = 0.998 Root MSE = 0.008	DW stat = 2.114	Durbin's h = -0.382	
Constant	-0.009	0.367	-0.024
ln(pr/(uco*PR))	-0.016	0.010	-1.633
ln(YP)	-0.111	0.083	-1.332
ln(POP)	0.134	0.099	1.351
$\ln(NR_{-1})$	0.917	0.111	8.286
Rent Adjustment: Dependant Variable = $\ln(pr/pr_{-1})$ Log of Ratio of Current to Lagged Real Rent			
Adjusted R^2 = 0.966 Root MSE = 0.010	DW stat = 1.749		
Constant	0.009	0.013	0.699
$\ln(pr/(ucr*PRC))_{-1}$	-0.027	0.004	-6.228
$\ln(QS/QD)_{-1}$	-0.278	0.193	-1.442

coefficient is significantly positive only at the 10 percent level. Durbin's h statistic equals -0.382 and indicates that serial correlation is not present.

The rent elasticity of aggregate rental housing supply equals 0.121, but is not significantly positive. Although this coefficient indicates the short-run response of supply to a change in rental price, the magnitude seems small. A one percent increase in rental price would expand aggregate supply by $1.065 billion when evaluated at its mean. The average annual change in aggregate supply equals $22.369 billion for 1964 through 1993. If this change approximates new construction, then an additional $1.065 billion represents a 4.8 percent increase in new construction. The simulation results below that take account of lags generate a larger but still modest response. A more disturbing result is the rental user cost elasticity of 0.0005, which is unexpectedly positive, insignificant, and considerably smaller than the rent elasticity.[10] The modest magnitudes and statistical insignificance of the rental price and user cost coefficients suggest that the gap between rent and user cost may be less than adequate as a proxy for the gap between asset price and replacement cost, the theoretically relevant relationship.

Increases in last year's excess supply discourage new construction that would increase aggregate rental supply. A one percent increase in last year's excess supply decreases current aggregate rental housing supply by 1.131 percent. The coefficient on lagged aggregate supply equals 0.97. We intended to recover an estimate of the depreciation rate from this coefficient in combination with some restrictions regarding the interpretation of the intercept. Unfortunately,

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[10]The theoretical model suggests that additions to aggregate supply depend upon profit opportunities reflected in the difference between rent and user cost. An alternative supply equation imposed this restriction by including a variable defined as the difference in the logs of rent and user cost [ln(pr)-ln(ucr*PRC)]. Given the insignificance of the individual parameters, it is not surprising that the restricted parameter is insignificant, but the restriction implied by this variable is not rejected at standard significance levels. The excess supply coefficient is half as large, while the lagged stock coefficient is essentially identical. Both coefficients are significant as well.

our attempts yielded implausible depreciation estimates. Durbin's h statistic of 2.56 indicates that serial correlation is present. However, in the corrected equation, the signs of the rent, user cost and excess supply elasticities are opposite of those suggested by economic theory.[11] Given this inconsistency, the relatively short time series, and the reasonableness of the uncorrected estimates, the results reported in Table 2 are not corrected for serial correlation.

The rent adjustment estimates show that the real rent ratio varies inversely with both the ratio of rent to user cost and the ratio of aggregate supply to aggregate demand.[12] A 1 percent decrease in rental user cost would increase the ratio of rent to user cost by approximately 1 percent. In the following year, this reduces the rate of growth in real rent by 0.027 percentage points. A 1 percentage point increase in last year's growth rate of excess supply reduces this year's growth rate of real rent by 0.278 percentage points, or ten times as much as a user cost increase. Thus, real rents are more responsive the quantity changes reflected in the supply to demand ratio than to price changes reflected in the rent to user cost ratio. However, the excess

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[11]An iterative Prais-Winsten procedure yields a serial correlation coefficient of 0.542, assuming an AR(1) error structure. Corrected for serial correlation, the estimated supply equation is:

$$\ln(QS) = \underset{(1.216)}{2.772} - \underset{(0.149)}{0.268}\ \ln(pr) + \underset{(0.012)}{0.016}\ \ln(ucr * PRC) + \underset{(0.693)}{0.528}\ \ln(QS/QD)_{-1} + \underset{(0.027)}{0.931}\ \ln(QS)_{-1}.$$

[12]The rent adjustment equation was first estimated exactly as indicated in the model summary.

$$\ln(pr) = \underset{(0.452)}{0.631} + \underset{(0.064)}{0.911}\ \ln(pr)_{-1} - \underset{(0.004)}{0.025}\ [\ln(pr) - \ln(ucr * PRC)]_{-1} + \underset{(0.369)}{0.159}\ [\ln(QS) - \ln(QD)]_{-1}.$$

Two of the three coefficients are significant and have the expected signs. The lagged excess supply ratio has a positive, but insignificant, coefficient. Since the coefficient on lagged rent is not significantly different from one, that restriction is imposed in Table 2. The dependent variable becomes $\ln(pr/pr_{-1})$, which is approximately equal to the rate of growth in real rent.

supply coefficient is significantly negative only at the 10 percent level. Durbin's h statistic is not computed for this equation since the lagged real rent ratio is not among the regressors. If the Durbin-Watson statistic is approximately valid, then serial correlation is not present in the rent adjustment equation.[13]

Empirical Analysis of the Structural Model

The empirical properties of the estimated model are evaluated in two ways. First, the stability of the model is assessed by examining the path to convergence of the endogenous variables. Second, the impact of a shock to rental user cost is determined.

To assess the stability of the model, all exogenous variables are held at their 1993 levels while the endogenous variables are forecast for 100 years. This exercise reveals the model does indeed converge. Aggregate supply and aggregate demand both rise by about 8 percent as the model approaches its long-run equilibrium values. Aggregate supply increases from $1,173 billion in 1993 to $1,272 billion after 100 years, while aggregate demand increases from $1,086 billion to $1,175 billion. Most of the rise in aggregate demand results from the 6 percent increase in the number of renters from 34.7 million to 36.8 million. Demand per household rises from $31,306 to $31,913, or about 2 percent. Real rent is essentially flat, rising from $1,582 in 1993 to $1,586. Roughly 40 percent of the change in aggregate supply, aggregate demand, and the number of renters occurs within the first five years, while more than 70 percent of the change in demand per household is achieved. Real rent actually rises for the first decade or so, but only by 0.66 percent, before approaching its equilibrium level.

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[13]Durbin's h equals 0.79 for the estimated model reported in the previous note which does not restrict the coefficient on lagged real rent to equal one. The null hypothesis of no serial correlation is not rejected.

An important issue in analyzing the rental housing market is the speed and magnitude of the response of market rents to changes in the user cost of capital. Changes in rental user cost may be generated by a variety of factors, including interest rates, expected inflation and tax policy. The simulations conducted by HFL and FHL predict that the Tax Reform Act of 1986 generates a 10 percent increase in the user cost of rental housing capital. Based upon their assumptions regarding the nature of the rental housing market, they predict that market rents will also rise by 10 percent in the long-run. We investigate this process with our estimated model by assuming rental user cost rises by 10 percent in the initial year. The simulation results indicate that rent increases by about 5 percent, but only after 100 years! Real rent increases very gradually in the initial years following the user cost shock, while the supply and demand variables decline over time. After five years, real rent is 1.1 percent higher and other endogenous variables are smaller by 0.7 percent or less. Excess supply rises for several periods since aggregate demand is declining faster than aggregate supply, and thus offsets some of the shock's effect on real rent. After ten years, real rent is 1.8 percent higher than initially, while the remaining system variables are smaller by 1.5 percent or less. Real rent is 4.0 percent higher after 50 years, so the adjustment process is indeed a very long one.

Although a detailed comparison of our results with those of DiPasquale and Wheaton (1992) is difficult because of the many differences in variable definition and model specification, a rough comparison is instructive. Both studies estimate similar magnitudes for the own price elasticity of the demand for rental housing. However, DiPasquale and Wheaton find a positive relationship between income and the demand for rental units, whereas our results convey a more consistent role for income. We find a positive income elasticity of housing demand per renter household and a negative income elasticity of the probability of renting. The most important comparison pertains to the responsiveness of rent to changes in user cost. Both find less than a complete response of rent to a change in user cost triggered by a tax policy change. In fact, they find that rent is even less responsive to a change in user cost than we do. They find that TRA increases user cost by four percentage points or, roughly, from 4 to 8 percent, which is a 100 percent increase. Rents only increase by 8 percent in response to this user cost change. We simulate the effect of a 10 percent increase in user cost, which is the estimate provided by both HFL and FHL in their analysis of TRA, and find that rents increase by 4 percent.

Conclusions

The primary purpose of this paper is to estimate a structural model of the rental housing market in which the distinction is made between housing units and housing services and in which it is possible to identify the extent and speed with which real rents adjust to shocks in the user cost of capital. The signs of the coefficients in the four equation model are all as expected and most of the elasticity estimates seem reasonable, especially the estimates of the elasticities of the services and units demand equations. The long-run rental price and income elasticities of housing services demand equal -1.02 and 0.66. The long-run elasticity of rental units demand is -0.19 for income and -0.02 for the relative rental to ownership price.

The impact of shocks to user cost on the level of rents is of primary interest. A 10 percent increase in user cost raises the level of real rents by about 4 to 5 percent, so only half of the user cost increase is passed along as higher rents. About half of this net impact is realized within the first decade after the increase in user cost. One surprising aspect of the results is the indirect path by which user cost has its impact. We expected to find most of the response reflected in the coefficient on rental user cost in the supply equation, but this coefficient is essentially zero and excess supply generates the larger effect on aggregate supply. Instead, rent adjustments are more sensitive to the ratio of real rent to user cost. These two effects combine to produce a positive linkage between rent and user cost, though a modest one. An increase in user cost causes rents to rise more rapidly. Higher rents reduce housing demand and increase excess supply, which then reduces the aggregate supply of rental housing.

Although the less than complete response of rents to user cost changes is a result also obtained by DiPasquale and Wheaton (1992), this result is inconsistent with the assumptions implicit in the simulation analysis of HFL, FHL and many others who assume a perfectly elastic supply of housing and a relatively rapid and complete adjustment of rents to changes in user cost. Three broad explanations of why we find rents so slow to adjust to user cost are possible. First, perhaps land prices adjust to the user cost shock along with rents. Implicit in the analysis of HFL and other proponents of the long-run equilibrium user cost model is the assumption that the long-run price of housing is fixed at the replacement cost of capital. Of course, rental properties also include a land component. If the value of this component is substantial and sensitive to changes in demand for rental housing, then the asset price of such housing would decline in response to a major shock like TRA.

Second, our measure of the user cost of capital may be flawed. However, since we use one commonly espoused in the literature, this casts doubt on a much broader set of measures than our own. At least two flaws seem possible. First, the use of a single discount rate may understate the importance of tax benefits and overstate the importance of expected capital gains. Second, tax policy may itself be endogenous, as FLH suggest. For example, builders believe that Congress will alter tax policy if the market is either too strong or too weak. If so, then user cost will not be as volatile as our measure implies. Future empirical research exploring these two issues may prove fruitful.

The last and most likely explanation for the slow adjustment relates to the data employed in this study. In a previous section we acknowledge several weaknesses in the data used to address these questions, including the absence of an asset price index and, most importantly, the small sample size. Perhaps these weaknesses are simply too severe to permit identification of the link between real rent and user cost at this time using national aggregate data. A better understanding of the linkage may only be possible with more and better data and by using data for smaller market areas like the metropolitan housing market. But even this approach is unlikely to settle the issue definitively owing to the complexity of the effects being examined and the severe data requirements. Nonetheless, efforts in this direction ought to be continued. Without additional empirical evidence, simulation models which assume a strong linkage will remain subject to serious criticisms.

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