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THE ECONOMICS OF MORTGAGE TERMINATIONS: IMPLICATIONS FOR MORTGAGE LENDERS AND MORTGAGE TERMS

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Abstract

The paper begins with the development of models explaining the mortgage refinancing and assumption decisions of households. Having identified the economic variables influencing these decisions, we then simulate the models for different values to determine under what conditions households will refinance or assume. Finally, we draw some implications of these results for: (1) the impact of a decline in mortgage rates on the asset portfolio yields of mortgage lending institutions and (2) the effect of the observed rise in interest rate volatility, including the optimal terminations response of mortgage borrowers, on the terms of the mortgage contract and the returns to mortgage lenders on recently issued mortgage loans.

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The Economics of Mortgage Terminations: Implications for Mortgage Lenders and Mortgage Terms

For the past 50 years, mortgage debt has been repaid in a relatively predictable manner. Amortization occurred according to a prespecified schedule, and prepayments took the form of either a lump sum upon the sale of the house collateralizing the mortgage or occasional double monthly payments as households saved via accumulation of housing equity. Households moved more frequently in some parts of the country than others but, in general, the determinants of household mobility were quite stable and predictable. Prepayment for wealth accumulation was attractive because alternative investments--savings accounts--paid low interest rates. On average, 30-year mortgages terminated in the twelfth year.

History is unlikely to be a reasonable guide to future mortgage terminations because mortgage rates have both risen sharply and become generally more volatile since 1979. We might anticipate numerous complete prepayments (refinancings) without the sale of the underlying house if mortgage rates decline sufficiently from their recent heights. On the other hand, in the 1970s and especially recently, we have observed a sharp increase in assumptions of existing mortgages when the underlying houses were sold and a related rapid growth in owner-financing. Moreover, gradual prepayment of mortgages (double payments) is improbable because yields on alternative household investments have become far more attractive.

The present paper is divided into three sections. We begin with the development of models explaining the economics of the refinancing and assumption decisions. Having identified the variables influencing these decisions, we then simulate the models for different parameter values to determine under what specific conditions households will refinance or assume. Finally, we draw some implications of these results for: (1) the impact of a decline in mortgage rates on the asset portfolio yields of mortgage lending institutions and (2) the simulated effect of the observed rise in interest rate volatility, including the optimal terminations response of mortgage borrowers, on the terms of the mortgage contract and the returns to mortgage lenders on recently issued mortgage loans.

I. Models of the Mortgage Termination Decision

The *ex post* termination of a mortgage reflects the exercise of the borrower's option which is often related to the observed course of interest rates in a way that reduces the *ex post* yield to investors.[1] If rates on newly-issued mortgages decline below the coupon rates on existing mortgages sufficiently to outweigh the costs of refinancing (including closing costs, repayment penalties and additional points charged the borrower), then most homeowners will terminate mortgages and refinance at the new lower rates. This eliminates the capital gain that otherwise would accrue to mortgage lenders. On the other hand, if mortgage rates on new issues rose above the coupon rates on existing mortgages, then homeowners who would normally terminate their mortgages upon the sale of their houses will instead be encouraged by the new buyers to allow assumption of the old mortgages, lengthening the mortgage life and increasing the capital loss accruing to lenders. This section develops explicit models of the refinancing and assumption decisions. The analysis assumes level-payment, fixed-rate financing.

A. Refinancings

Just like corporations, households may be expected to repay (call) existing debt and refinance if it is financially advantageous to do so. The following model predicts that a mortgage will be called when the present

[1] For evidence on this point, see Curley and Guttentag (1974).

value of expected benefits exceed the costs. The model considers only financially motivated refinancings.

The payment on a level payment mortgage of amount X and maturity M carrying a fixed rate i_o, where o denotes the period the mortgage was originated, is

$$PAY(i_o,X,M) = i_o X \left[\frac{(1+i_o)^M}{(1+i_o)^M - 1} \right] .$$

The factor in brackets captures the amortization of the mortgage. The principal outstanding on this mortgage in period k is

$$PRIN(i_o,X,M,k) = X \left[\frac{(1+i_o)^M - (1+i_o)^k}{(1+i_o)^M - 1} \right] .$$

Finally, the payment on the mortgage if it is refinanced at rate i_k for the remaining maturity M-k is[2]

$$PAY\left[i_k,\ PRIN(i_o,X,M,k),\ M-k \right] = i_k PRIN(i_o,X,M,k) \left[\frac{(1+i_k)^{M-k}}{(1+i_k)^{M-k} - 1} \right] .$$

If the borrower expects to maintain the mortgage for L additional periods ($1 \leq M-k$) and i_k represents the appropriate discount rate for all future periods, then the present value of the expected benefits of refinancing in period k are:

[2] If the initial loan had a maturity of 30 years and is refinanced after 5 years, then the new loan is assumed to equal the outstanding loan and to have a maturity of 25 years. Note that the new payment is identical to the original payment if $i_k = i_o$.

$$br_k = \sum_{t=k+1}^{L} \frac{PAY(i_o,X,M) - PAY[i_k,\ PRIN(i_o,X,M,k),\ M-k]}{(1+i_k)^{t-k}} + \frac{PRIN(i_o,\ldots) - PRIN(i_k,\ldots)}{(1+i_k)^{L-k}} .$$

The last term, which is zero if L = M, reflects the difference in amortization rates of the two mortgages. The benefits are obviously greater the larger is the decline in i, the greater was the amount of original mortgage (X), the larger is the remaining principal (the lower is k), and the longer the borrower expects to maintain the mortgage (the larger is L).

The cost in period k of refinancing the remaining balance of the mortgage is

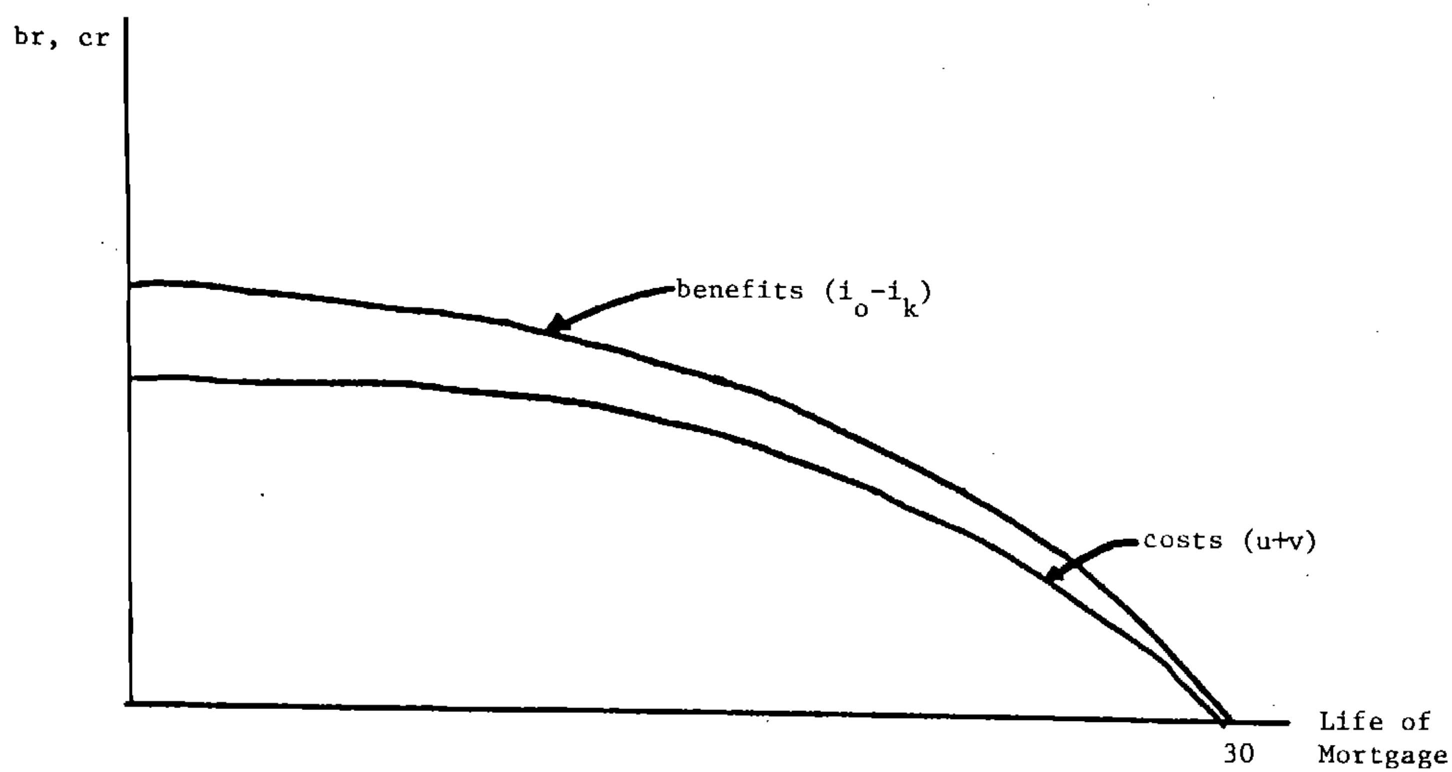
$$cr_k = (u+v)PRIN(i_o,X,M,k) ,$$

where the term in parentheses reflects normal closing costs and repayment penalties (u) plus any additional points that may be charged the borrower (v) to provide a "below market" coupon rate. The v term includes points paid by the buyer and points paid by the seller but built into the price of the house, and both u and v are expressed as a percentage of principal. Refinancing will be profitable in period k if $br_k - cr_k > 0$.[3]

The benefits and costs of refinancing are plotted in Figure 1 as a function of k. The height of cr_k depends solely on the initial principal and the cost parameters, u+v. The cr_k schedule declines monotonically, although quite slowly at first, as the mortgage amortizes. The height of the br_k schedule depends on the expected holding period L and the decline in i $(i_o - i_k)$, as well as the initial principal. The br_k schedule also declines monotonically

[3] If a call appears only marginally beneficial to a borrower at time k, but there is a significant probability that a call will be substantially more beneficial at some future period, even after discounting the interim cost, refinancing will be postponed.

Figure 1: Benefits and Costs of Refinancings



with the amortization of the existing mortgage. Because the shapes of the schedules are so similar, the refinancing decision is quite insensitive to k. Either the decline in the mortgage rate is sufficient to trigger refinancing, given L and u+v, or the decline is not. The schedules are drawn such that the household will refinance.

B. Assumptions

Just as large declines in interest rates tend to shorten the average life of outstanding mortgages, increases in interest rates can lengthen the life of these mortgages dramatically. All FHA/VA mortgages contain assumability clauses. While most conventional loans written since 1970 contain "due-on-sale" clauses, an explicit prohibition of the assumability provision, these clauses have proven somewhat difficult to enforce.[4] Moreover, due-on-sale and assumability clauses only apply on the transfer of title; homeowners can choose not to move precisely to avoid terminating the mortgage contract. This may be thought of as an "implicit assumption" by the existing owner. It is identical from the investor's perspective to an assumption by a new buyer.

The benefits to the assumption, explicit or implicit, of an existing loan are exactly analogous to the benefits of refinancing; the present value of the expected benefits of an assumption is the discounted savings from making payments on the outstanding principal at the lower old rate rather than at the higher current rate. In fact, we can simply write

$$ba_k = -br_k .$$

[4]See Sanders (1981) for a state by state analysis of the enforcability of due on sale. Its legality is currently being considered by the Supreme Court.

The cost of an explicit assumption is the discounted extra outlays made on the financing of the remainder of the house purchase that would otherwise be financed at the current mortgage rate, i_k. If the house (and thus the "normal" loan) has risen in value at rate π (inflation net of depreciation) and the financing rate for the "loan" in excess of the assumption is i_k^s, then the payments are

$$PAY(i_k^s,\pi,X,M,k) = i_k^s\left[(1+\pi)^k X - PRIN(i_o,X,M,k)\right]\left[\frac{(1+i_k^s)^{M-k}}{(1+i_k^s)^{M-k}-1}\right].$$

The expression for the payment on this loan if it were financed at i_k, $PAY(i_k,\pi,X,M,k)$, has an identical form but with i_k replacing i_k^s. The costs of assumption, then, are

$$ca_k = \sum_{t=k+1}^{L} \frac{PAY(i_k^s,\pi,X,M,k) - PAY(i_k,\pi,X,M,k)}{(1+i_k)^{t-k}} + \frac{PRIN(i_k^s,\ \ldots) - PRIN(i_k,\ \ldots)}{(1+i_k)^{L-k}}.$$

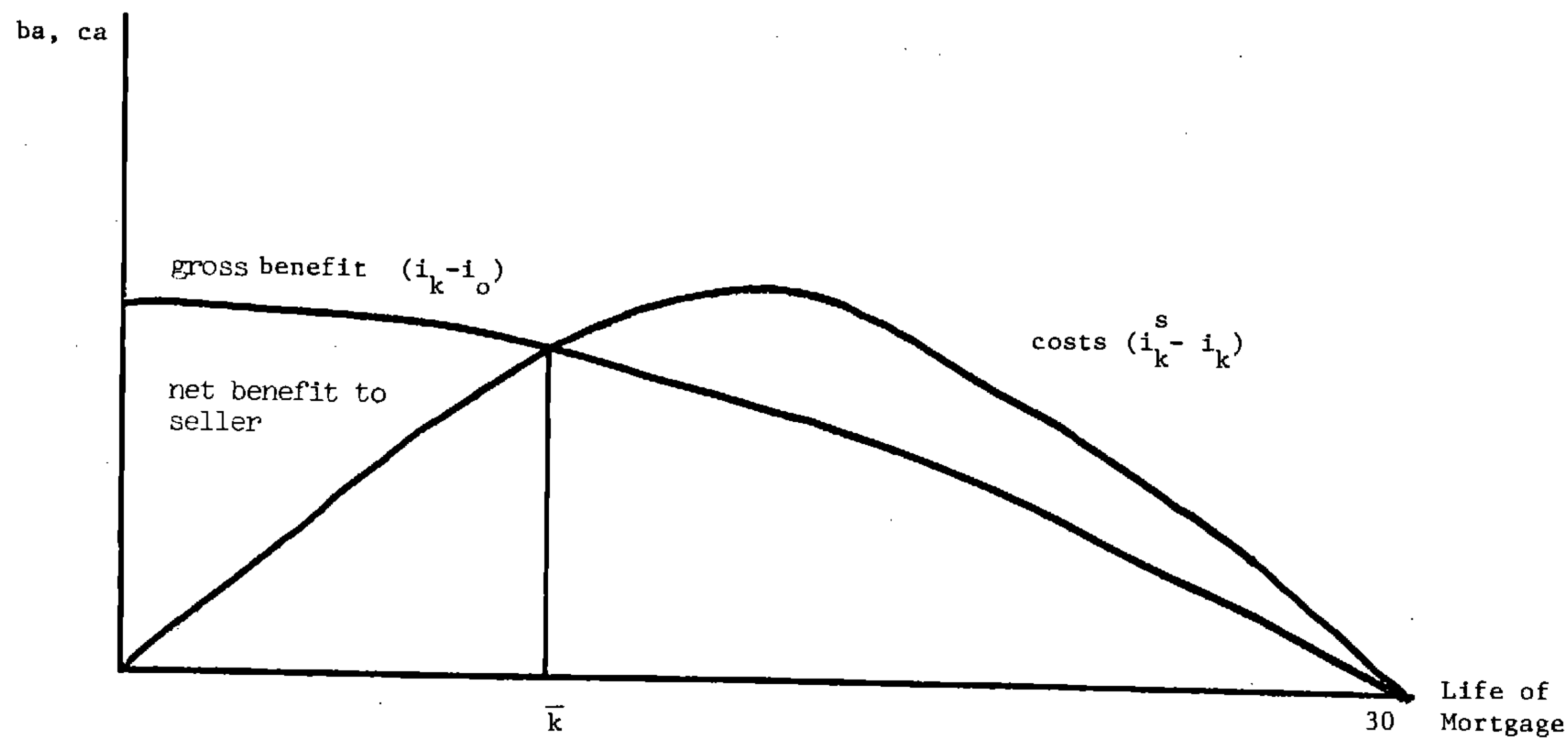
Of course, if $i_k^s = i_k$ —if the household is sufficiently wealthy that it can borrow the incremental funds (effectively use its own resources) at the rate on first mortgages, then there are no costs to assumptions, and all assumable mortgages will be assumed if mortgage rates rise at all. On the other hand, i_k^s could exceed the secondary mortgage rate to the extent that the combined monthly mortgage payment on the assumed and second mortgages exceeds that on a first mortgage and that the household faces a significant cash-flow constraint. The combined payment could be higher, even though the average interest rate on the assumed and second mortgages is less than that on the first mortgage, owing to the shorter remaining term of the assumed mortgage and the typical short term of second mortgages. Thus $i_k^s - i_k$ likely varies over time, depending on the cash flow position of the marginal borrower that must be induced to purchase a house with an assumable mortgage.

The cost of an implicit assumption is the loss of real income and/or the misallocation of consumption between housing and other goods owing to not moving. That is, one might forego a more lucrative job, if it requires relocation, or one might not "downsize" or "trade up" in response to changes in real income and/or the real price of housing services. These costs are discussed and modeled in Hendershott and Hu (1982) and (Hendershott (1982). In the present paper, we consider the costs of explicit assumptions only.

The costs and benefits of assumption at a given point in time are plotted in Figure 2 as functions of k. The ca_k schedule rises (from zero) initially as the amount of the second mortgage rises owing to $\pi > 0$ and amortization of the first mortgage. However, at some point (roughly $k = M/2$) the costs decline, owing to the shorter period (remaining expected loan life) over which the costs will be paid. The height of the ca_k schedule is largely determined by $i_k^s - i_k$. The ba_k schedule declines monotonically as the period over which the benefits are cummulated becomes progressively shorter. Its height depends primarily on how far interest rates have risen since the original mortgage was obtained $(i_k - i_o)$. The schedules are drawn so that the mortgage will be assumed if the underlying house is sold prior to period $\bar{k}$. Prior to this period, $ba_k > ca_k$; later, $ba_k < ca_k$.

The difference between ba_k and ca_k is the net value of the old

Figure 2: Benefits and Costs of Assumptions

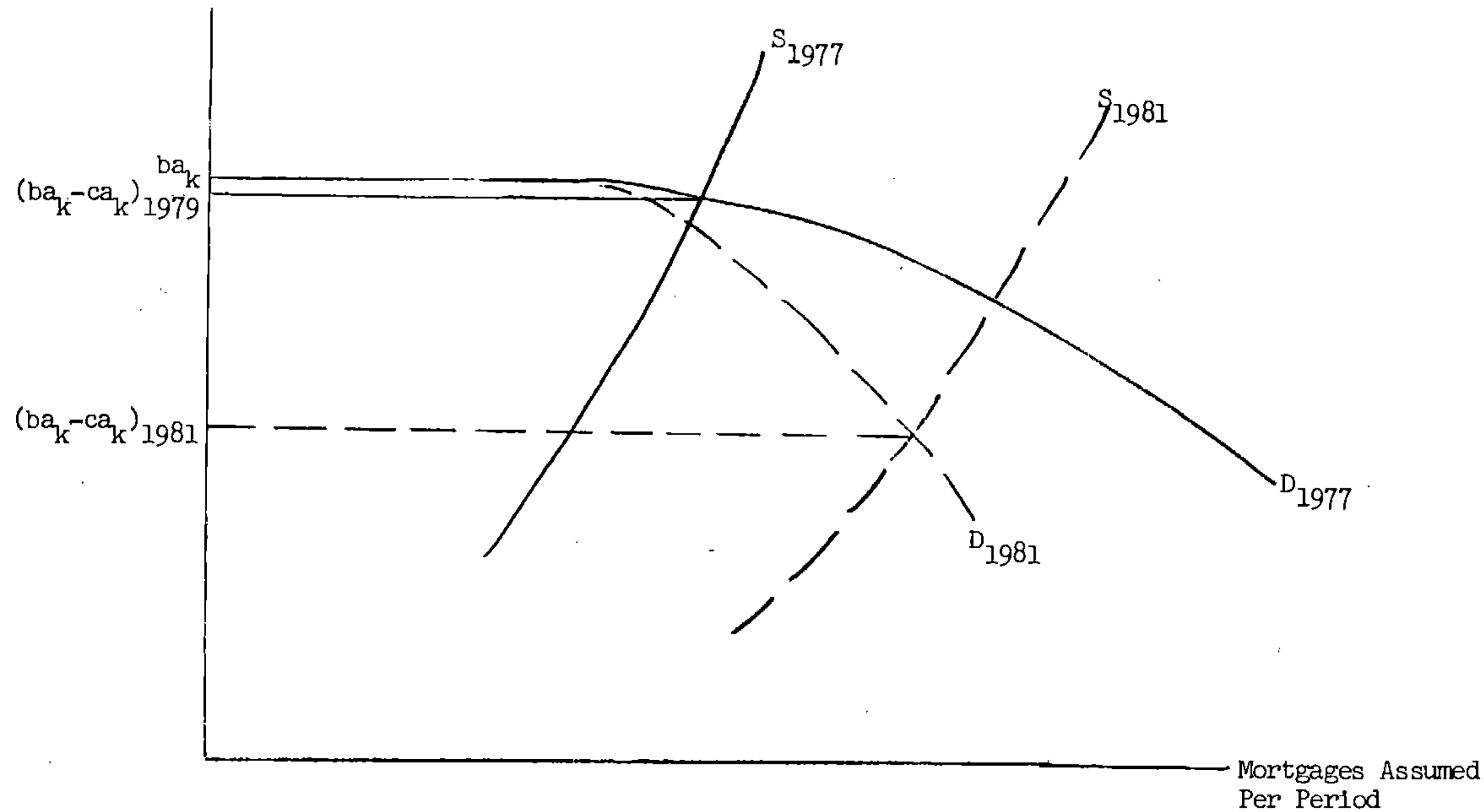


mortgage that is received by the seller. This value obviously depends upon $i_k^s - i_k$, a spread that is determined in the relevant local market for assumed mortgages. This determination is illustrated by the supply and demand schedules for a standard unit of significantly (say 2%) "below-market" assumable mortgages drawn in Figure 3. The standard unit is defined as a combination of principal, maturity and below-market coupon rate such that the present value of the stream of interest savings is a thousand dollars. Thus, ba_k equals $1000 for the unit. The supply curve in Figure 3 is the number of these units made available to the market by sellers in a given period. The higher the price paid for each unit, the greater the number offered. The demand depends on the liquidity or cash-flow constraints of households that desire to purchase houses. For households with no constraint (they can easily supply own equity for the entire difference between the sales price and the amount of an assumable mortgage), the demand is horizontal at ba_k. At a sufficient supply, households facing constraints must be drawn into the market by lower prices; thus the demand curve eventually falls off. The higher the level of interest rates, the more binding are cash-flow constraints, and the greater is the fall off in demand.

The solid schedules in Figure 3 might refer to the situation at the end of 1977. The supply is limited because virtually no mortgages were issued in the 1969-1977 period at a rate significantly below the late 1977 rate of 9 percent. As a result, $i_k^s - i_k$ was low for the marginal investor, as was ca_k. Thus, the net benefit of assumptions was close to the gross benefit.

The sharp jump in mortgage rates in the last four years has had an enormous impact on the net benefit. First, the supply of units of

Figure 3: Determination of the Net Benefit of Assumption of a Standard Below-Market Mortgage



below-market, assumable mortgages grew enormously. Second, many potential homebuying households have become severely cash-flow constrained. This twists the demand schedule clockwise. The net result is a sharp drop in the net benefit ($ba_k - ca_k$) relative to the gross benefit (ba_k).

C. The Addition of Taxes

Taxes alter the above expressions in a fairly straight-forward manner. Let interest payments of the relevant household be deductible at rate Θ. Equations (1) and (3) are then changed in two ways. First, the discount rate becomes an after tax rate, $i_{ka} = (1 - \Theta)i_k$. Second, the difference in the streams of tax savings on interest payments must be subtracted. For br_k, this difference is:

$$- \sum_{t=k+1}^{L} \frac{\Theta\left[i_o PRIN(i_o,t-1) - i_k PRIN(i_k,t-1)\right]}{(1+i_{ka})^{t-k}} .$$

For ca_k, i_k^s replaces i_o.

We also must change the expression for the cost of refinancing. If points charged the borrower to provide a below-market rate are the only deductible costs, then the correct expression is:

$$cr_k = [u+(1-\Theta)v]PRIN(i_o,X,M,k).$$

II. Some Simulation Results

In the following pages we compute the net gains (benefits less costs) from refinancings and assumptions for various values of the key parameters. These values are selected to enable us to deduce (in Section III A below) how far interest rates will have to fall from recent levels in order (1) to trigger massive refinancings and (2) to deter the continued assumption of old mortgages (those carrying 8 and 9 percent coupons) upon the sale of the underlying houses.

A. Refinancings

The parameters key to the refinancing decision are the difference between the original and current mortgage rates, $i_0 - i_k$, and the upfront fees and points, u + v. The higher are the points, the more the mortgage rate must decline in order to make refinancing profitable. In fact the relationship is virtually a linear one. With a holding period of 12 years, a mortgage life of 30 years and an initial mortgage rate of 15 percent, the issuer will gain from refinancing if

$$i_0 - i_k \geq \frac{1}{4} [u + (1 - \theta)v]$$

within the first twenty years of the mortgage life. For example, if u were 0.02 and v zero, then the mortgage rate need only decline to 14½ percent. In contrast, if v = 0.08, a decline to 12½ percent is required. This approximation is roughly correct for tax rates of zero and 0.3.

While the calculation is most heavily influenced by the decline in the mortgage rate and the upfront charges, the calculation is also sensitive to the effective remaining holding period of the owner if it is short. The impact of variations in M and L are illustrated by the data in Table 1. In the first three rows, the remaining effective holding period is assumed to be the remaining life of the mortgage ($L = M - k$). As is shown, a 1½ percent decline in the mortgage rate (from 15 percent and assuming upfront fees equal to 6 percent of the mortgage) will produce profitable refinancing if the decline occurs before the remaining maturity falls below 10 years, regardless of the original maturity of the mortgage. This result holds for household tax rates of 0.0 and 0.3.

Rows 4-6 illustrate that the refinancing decision is sensitive to the expected holding period and that the household tax rate matters if the expected holding period is not long and the mortgage rate declines by a particular amount. In these calculations, the original maturity of the mortgage is 30 years, and the effective holding period is 8 years. With this short a holding period, the 1½ percentage point decline in the mortgage rate (from 15 percent) will trigger refinancing for households who take the standard deduction ($\theta = 0.0$) only if the decline occurs before the fourth year after origination. For households in the 30 percent tax bracket, even an instantaneous decline of this magnitude will not induce refinancing. Rows 5 and 6 suggest that 2 or 2½ percentage point declines will induce refinancing even as late as the 24th year of the mortgage. The sharper decline is needed for households in higher tax brackets.

Table 1

The Refinancing Decision: Initial Mortgage Rate (i_o) of 0.15 and Up Front Fees (u+v) of 0.06

New Mortgage Rate (i_k)	Original Maturity of the Mortgage	Effective Holding Period Remaining	Refinancing Will Occur Prior to This Year of Mortgage Life	
			$\theta = 0.0$	$\theta = 0.3$
.135	20	20 - k	10	10
.135	25	25 - k	15	15
.135	30	30 - k	20	20
.135	30	8	4	0
.130	30	8	24	11
.125	30	8	24	24

B. Assumptions

Recall that the trade off driving the assumption decision is the lower costs on the existing mortgage vis a vis the extraordinary costs (second mortgage rate greater than first mortgage rate) of the second mortgage. The greater has been the increase in mortgage rates since the mortgage was issued, $i_k - i_o$, the more profitable is assumption. On the other hand, the greater is the excess of the second over the first mortgage rate $i_k^s - i_k$, and the larger is the portion of the total financing taking the form of the second (the greater is the net inflation rate, π, and the time since the original mortgage was issued, k), the less profitable is assumption.

In the calculations presented below, the rate on second mortgages has been set two percentage points above the rate on first mortgages. This constant difference reflects two offsetting factors. On one hand, we would expect the difference to rise as the maturity of the second rises because lenders tend to charge higher rates on longer term second mortgages. On the other hand, the longer is the maturity of the second, the less likely is the cash flow on the assumed and second mortgages to pose a problem for the borrower. The original mortgage is assumed to carry a 9 percent coupon and have a life of 30 years.

The data in Table 2 indicate how increases in new-issue mortgage rates raise the desirability of assumption. In the upper half of the table, the gross benefit of assumption is reported for households in zero and 30 percent tax brackets assuming a 7 percent net inflation rate, roughly the rate in the U.S. between 1972 and 1981. The percentage capital gains 4, 8, and 16 years after origination on a 9 percent coupon, 30 year mortgage are listed for different values of the new issue mortgage rate. As can be seen, with new issue yields in the 15 to 17½ percent range, the capital gains are enormous. For mortgage issued in 1978 (four years ago), the gain is 30 to 40 percent of the original value; for mortgages issued in 1974 (eight years ago), the gains are only 4 percent less. Eight years from now the gains would still be in the 20 to 25 percent range. In general, the gains are 3 percent less for those in the 30 percent tax bracket than for those not paying taxes.

The data in the lower half of Table 2 refer to the net benefit of assumption.[5] The last year in which the mortgage will be assumed is reported, as are the percentage net gains on the old mortgage that will exist after the fourth and eighth years. The results are reported for two net (of depreciation) inflation rates. Of course, the higher is the inflation rate, the smaller are the net gains from assumption upon sale of the underlying house because a larger portion of the sale price is financed at the higher second mortgage rate.

Consider first the results for a 7 percent net inflation rate. A one percentage point increase in the mortgage rate to 10 percent will induce an assumption only if the house sale occurs within 4 years after the mortgage was first originated. An increase from 9 to 15 percent, in contrast, will lead to an assumption if the sale occurs within the first 15 years of a 30-year mortgage (12 years of a 20-year mortgage). If the sale occurs at the end of the fourth year (1982 for a mortgage originated in 1978), the gain to the seller is 29 percent of the face value of the mortgage. At the end of the eighth year, the gain is still 21 percent.

[5]The reported results are households taking the standard deduction and are little different for households in the 30 percent tax bracket. The last year in which the mortgage will be assumed is, at most, one year less, and the percentage capital gain is never reduced by as much as one-tenth.

TABLE 2

The Assumption Decision: Initial Mortgage Rate (i_0) of 0.09 and

Original Maturity (M) of 30 Years

A. Gross Benefit: inflation rate (π) = 0.07

New Issue Mortgage Rate (i_k)	tax rate (θ) = 0.0			tax rate (θ) = 0.3		
	% Gain After 4 Years	% Gain After 8 Years	% Gain After 16 Years	% Gain After 4 Years	% Gain After 8 Years	% Gain After 16 Years
.10	8	7	4	6	6	3
.125	23	20	13	20	17	11
.15	34	30	20	31	27	17
.175	42	38	26	39	34	22

B. Net Benefit: tax rate (θ) = 0.0

New Mortgage Rate (i_k)	NET INFLATION RATE (π) = 0.07			NET INFLATION RATE (π) = 0.12		
	Last Year Mortgage Will Be Assumed	% Gain After 4 Years	% Gain After 8 Years	Last Year Mortgage Will Be Assumed	% Gain After 4 Years	% Gain After 8 Years
.10	5	2	0	3	0	0
.125	12	18	9	7	14	0
.15	15	29	21	10	26	11
.175	18	38	30	12	35	21

With a net inflation rate of 12 percent, assumption is less attractive; assumption will occur only about two-thirds as far into the life of the mortgage as was the case for a 7 percent net inflation rate. To illustrate, with a current market mortgage rate of 15 percent, assumption would occur through the tenth year; with a 17½ percent rate, the net gain after 8 years is 11 percent.

The above calculations explain both the passions generated by the "due-on-sale" controversy and the growth in owner financing. There are enormous gains at stake. Sellers with low rate mortgages surely would like to avoid giving up the gains (to the lenders from whom the gains were received). If owner financing is required, so be it. Moreover, there are other interested parties such as realtors. In a depressed housing market owing largely to high real and nominal interest rates, house sales are down and so are real house prices. The incorporation of special financing terms (based on the favorable terms on the existing mortgage) into a sales contract both increases the volume of sales and maintains the list house price upon which fees are earned. If due-on-sale clauses were rigidly enforced, then many households who would otherwise move would maintain their existing homes.[6]

III. Implications of the Calculations

The above analysis has at least two interesting implications. The first is the likely impact of a decline in mortgage interest rates from their current high level on the return mortgage lenders are earning on their existing portfolios of mortgage loans. That is, at what interest rate level will old mortgages earning 9 percent and less cease being assumed (will the rate of repayments at thrifts return to normal) and

[6] See Hendershott and Hu (1982).

at what level will recent issues of mortgages earning 15½ to 18 percent be refinanced? The second implication is for the value of the terminations call option in recent mortgage contracts. Our calculations suggest that movements in mortgage rates within the range observed in the past four years can have an enormous impact on the life of a mortgage because most issuers terminate their mortgages to their economic advantage and to the disadvantage of lenders (call the mortgage if rates fall and put it if rates rise). As a result, the expected return to mortgage lenders could be significantly less than the promised return. To compensate, lenders will charge an up front "origination fee" or a higher mortgage coupon rate than they otherwise would. Hypothetical values of this compensation are computed.

A. Declining Interest Rates and The Return on Thrift Asset Portfolios

Declining interest rates might be expected to restore thrift profitability through two channels. First, and most obvious, the cost of funds would fall. This is not of concern to us in this paper. Second, some of the low-coupon mortgages made in the 1970s might be terminated sooner than otherwise with the funds reinvested at higher rates. That is, the profitability of assumptions would decline, and the incentive to "stay put" with an existing loan would be diminished. This would, of course, augment earnings only gradually over time as the underlying houses were sold.

The above analysis suggests that the decline in new mortgage rates would have to be substantial for the profitability of assumptions to be reduced sufficiently to eliminate the assumption phenomenon in the near term, except possibly in very high inflation areas like California. Mortgage rates in 1981 fluctuated between 15½ and 18 percent. The data in Table 2 implied that with $\pi = 0.07$ a decline to 12½ percent will not deter assumptions on the 9 percent mortgages issued as early as 1973 until at least 1987.

Mortgages issued prior to 1973 are less likely to be assumed because of their shorter remaining lives but more likely to be assumed because they carry lower coupon rates (between 7½ and 8½ percent for the mid 1969-mid 1973 period and down to 6 percent for the early 1960s). Our analysis suggests that the new mortgage rate must decline below 13 percent for there to be <u>any</u> significant reduction in the near term in assumptions of 30 year mortgages issued after 1965.[7] In higher inflation areas, a reduction in the new mortgage rate to 13 percent would virtually end the assumption phenomenon.

Rather than ending the assumption phenomenon, declines in mortgage rates in the near term are likely to trigger substantial refinancings, and these would occur instantly (they do not depend on the sale of the underlying house). If new mortgage rates should fall to 13 percent, then probably half of all the mortgages issued since the beginning of 1980 could profitably be refinanced. This would, of course, offset some of the benefits of the decline in the cost of funds of thrifts.

B. Mortgage Values and Coupon Rates

The value of a mortgage is the discounted present value of the total cash flow it generates. If we are certain that the mortgage payments will

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[7]The assumption of mortgages originated in the first half of the 1960s will be stifled, and the principal of these 30-year mortgages still exceeds half of its original value. However, the size of these mortgages was quite low owing to the low price of houses (and relatively low loan-to-value ratios) at that time.

be made and that the mortgage principal will be prepaid at the end of the k^{th} year, then

$$V^{c} = \sum_{t=1}^{k} \frac{PAY(i_0,X,M)}{\prod_{j=1}^{t} (1+y_j)} + \frac{PRIN(i_0,X,M,k)}{\prod_{j=1}^{k} (1+y_j)},$$

where y_t is the yield on a pure discount bond of maturity t.

There is, of course, a large array of termination patterns that might occur with significant probability, at least one for every future interest-rate scenario. Moreover, each scenario implies a different set of discount rates (y's). For simplicity, assume that there are three possible interest rate patterns: rates can rise, fall, or remain the same. We denote these patterns by y(U), y(D) and y(C), where U denotes up, D down, and C constant. If the probability of rates rising is p and of rates falling is also p, then the probability of rates being constant is 1-2p. The value of the mortgage is then

$$V^{u} = pVU + (1-2p)VC + pVD,$$

where

$$VX = \sum_{t=1}^{X} \frac{PAY+\theta i\ PRIN_{t-1}}{\prod_{k=1}^{t} [1+(1-\theta)y(X)_j]} + \frac{PRIN(X)}{\prod_{k=1}^{X} [1+(1-\theta)y(X)_j]} \qquad \text{for } X = Y, C, D.$$

The arguments in the PAY and PRIN functions are dropped, except for the prepayment date, because they are the same as above. Note that interest payments are deductible at the lender's tax rate θ and that after-tax discount rates are employed.

Consider the case where the prepayment (termination) of a 30-year mortgage is assumed (by the lender) to be independent of future interest rates and is expected to occur at the end of the twelfth year. Assume further that the mortgage and discount rates are 15 percent and that interest rates are expected with probability p to average 15½, 16½ and 17½ percent in the next three periods and to average 18 percent thereafter. Assume further that rates are expected, again with probability p, to average 14½, 13½, and 13 in the next three periods and y percent thereafter. If $p = 0.2$ and $y = 12.64$, then a mortgage loan of X will be valued at X by tax-exempt investors. The data in the exogenous row of Table 3 indicate how the changes in interest rates affect the value of the given mortgage payment stream. The value when interest rates are constant at 15 percent is set at unity. When rates rise, the payment stream based on a 15 percent coupon falls in value to 0.89 or by 11 percent. The decline in interest rates is specified such that the increase in the value of the payment stream is also 11 percent.

Now let the prepayment decision be endogenous. More specifically, assume that the mortgage will be prepaid (refinanced) at the end of the third year when interest rates decline but at the end of the twenty-first year (assumed until then) when interest rates rise. These responses are consistent with the refinancing and assumption calculations made above. The data in the second row of Table 3 demonstrate the impact of endogenous terminations on mortgage value. When the mortgage life shortens to 3 years with the decline in interest rates (refinancing occurs), the increase in mortgage value is only 3 percent. That is, the terminations response wipes out 70 percent of the capital gain that occurred when the mortgage life was fixed at

Table 3: Interest Rate Changes and Mortgage Value for Mortgages with a 15 Percent Coupon

	Prepayment Year and Value of Payment Stream						Total Value
	Rate = 12.64%		Rate = 15%		Rate = 18%		(p = 0.2)
Terminations	Year	Value	Year	Value	Year	Value	
Exogenous	12	1.11	12	1.0	12	0.89	1.0
Endogenous	3	1.03	12	1.0	21	0.87	0.980

Table 4: Interest Rate Uncertainty and the Premium in Mortgage Coupon Rates

	Tax Rate = 0.0			Tax Rate = 0.3		
p	y (%)	Total Value (Par = 1.0)	Mortgage Premium (basis points)	y (%)	Total Value (Par = 1.0)	Mortgage Coupon (basis points)
0.1	12.94	0.990	19	12.80	0.990	24
0.2	12.79	0.980	41	12.65	0.980	50
0.3	12.74	0.969	66	12.60	0.969	80

12 years. Moreover, the capital loss in response to an increase in interest rates is exaggerated by the lengthening of mortgage life to 21 years (assumptions occur). Here, however, the impact is not large; the loss is increased by about 15 percent.

The last column in Table 3 indicates that the value of the mortgage falls by 2.0 percent. This is the cost to the lender of giving the borrower the option of terminating the mortgage at his discretion. An upfront fee of 2 points (or percent of par mortgage value) would offset the decline in mortgage value--would equate the expected yield on the mortgage to that on a "mortgage" which terminates with certainty at the end of the twelfth period.

The total-value columns of Table 4 show how changes in the probability of significant increases or decreases in interest rates (in p) affect mortgage value for lenders in 0.0 and 0.3 tax brackets. As can be seen, the relationship between p and value is negative and approximately linear. Mortgage lenders can charge borrowers for the terminations option over time via a higher mortgage coupon rate and thus greater monthly payments rather than by a single upfront payment. The results of converting the single payments into higher coupon equivalents are listed in the mortgage-premium columns of Table 4. In these calculations, we determine how high the mortgage coupon rate would have to be to maintain mortgage value at par even when adverse terminations were expected. The results indicate, for example, that a 41 basis point premium in the mortgage rate (a rate of 0.1541) would be appropriate when p = 0.2 for tax-exempt investors. As can be seen, the premium is approximately a linear function of p, and the premium is about 20 percent greater for investors in the 30 percent tax bracket.

In the period after October 6, 1979, when the Federal Reserve appeared to deemphasize substantially the importance it attached to interest rate stability, interest rates have been far more volatile than in preceding years. To illustrate, the standard deviation of expost one-month returns on 20-year Treasury bonds over a one year period has roughly quadrupled from 1¼ percent to 5 percent. In terms of our analysis, this should have lead mortgage lenders to raise their estimate of p substantially. As a result, calculations of effective mortgage yields that incorporate the cost of the terminations option should have risen relative to yields on, say, 10-year Treasury securities. If the increase in p were from 0.1 to 0.3, then about a half percentage point relative increase in mortgage coupon rates should have occurred or lenders should have charged an additional two points upfront. A similar experiment was performed with larger possible changes in interest rates, namely increases to 16, 18, 20 and 21 percent thereafter and declines to 14, 13, 12 and z percent, thereafter, where z is such that mortgage value is unity for the relevant p when the year of termination is maintained at 12. In this case, an increase in p from 0.1 to 0.3 would raise the coupon rate by 100 basis points.[8]

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[8]Between 1978 and late 1981, the yield on pools of near-par GNMAs rose by over 100 basis points vis a vis the yield on a comparable maturity portfolio of Treasury securities. Hendershott and Villani (1982) have attributed this increase to an increase in the termination or call option in mortgage coupon rates.

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