Housing Market Bubbles and Mortgage Contract Design: Implications for Mortgage Lenders and Households

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Abstract: This paper explores the implications of a housing market bubble for three critical elements of mortgage contract design: difference between term to maturity and amortization period; prepayment options; and, lender recourse in the event of default. Using an extension of classical immunization theory, this paper provides equilibrium conditions demonstrating the risk reduction benefits of shorter term to contract maturity at origination for lenders of long amortization mortgage contracts. In addition, the risks of underpricing prepayment and no recourse default options in the mortgage contract when compared with full recourse mortgage contracts having yield maintenance prepayment penalties are explored by contrasting the ability of US and Canadian mortgage funding systems to withstand a housing market bubble collapse that might occur.

Keywords: classical fixed income immunization theory; mortgage contract design; systemic risk management; housing market bubbles

1. Introduction

There is accumulating empirical evidence that housing market bubbles, somehow defined and estimated, are appearing in numerous countries.[1] This raises obvious questions about global contagion of a housing market collapse like that which crippled the US economy a decade ago. More precisely, starting around mid-2005, the survival performance of single-family residential mortgages in the US began to deteriorate sharply (Mayer et al. 2009). This exposed weaknesses in methods for predicting mortgage defaults and estimating default loss severities used in the market valuation of collateralized mortgage products central to funding residential house purchases, e.g., Hayre et al. (2008). Difficulties of pricing and trading securities with cash flows impacted by US mortgage contract design features combined in a perverse fashion with originate-to-distribute underwriting

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[1] In addition to theoretical studies on the definition and measurement of 'housing market bubbles', there is rapidly accumulating evidence on bubbles emerging in various countries. Included in studies on defining and measuring bubbles are: Shi (2017); Bono et al. (2017); Giglio et al. (2016); Phillips et al. (2015) and Himmelberg et al. (2005). Recent empirical evidence for housing market bubbles in various countries includes: Gomez-Gonzalez et al. (2018); Vogiazas and Alexiou (2017) and Engsted et al. (2016) for OECD countries; Shi (2017) for certain regional markets in the US; Dermani et al. (2016) for Sweden; Shi et al. (2016) for Australia; Shi and Kabir (2018) for New Zealand; Kim and Lim (2016) for Korea; Glaeser et al. (2017) for China; Huang and Shen (2017) for Hong Kong; Boelhouwer (2017) for Netherlands; and, Yip et al. (2017) for Malaysia. In contrast, Giglio et al. (2016) found no evidence of the violation of the transversality condition in the UK and Singapore housing markets indicating no support for the presence of a bubble.

procedures used in the creation of collateralised mortgage obligations and related mortgage financing vehicles, e.g., Wilmarth (2009), to create the housing market bubble that subsequently collapsed in 2008–2009.

Prior to the housing market failure, criticism of the US mortgage system was muted and claims for innovation and superiority over mortgage financing methods used in other countries were common. In contrast, the Canadian mortgage funding system was criticized for "lack of access to mortgages with fixed rates, penalty-free prepayment and high loan-to-value ratios" (Green and Wachter 2005, p. 102). Yield maintenance penalties and relatively low levels of mortgage securitization were also singled out for criticism. Yet, despite considerable economic integration of the Canadian and US economies and financial markets, and considerable evidence that severe housing market bubbles have recently emerged in the important housing markets of Vancouver and Toronto, the Canadian mortgage funding system has been comparatively unscathed by the type of crises that emerged in the US and other countries. Specifically, the Canadian mortgage market is dominated by a small number of large opaque universal banks able to manage mortgage funding risks using full recourse mortgage contracts with term to maturity restrictions and yield maintenance prepayment penalties. The widespread recommendations for reform of the US mortgage market that involve improved valuation methodologies, significant enhancement of regulations (Government Accountability Office 2009), and strengthening of government oversight, generally ignore the implications of mortgage contract design. Two systemic mortgage funding collapses in a generation suggest that reforms in US mortgage contract design aimed at achieving actuarially sound mortgage origination should be carefully considered.

Extending results in Poitras and Zanotti (2016) on the implications of mortgage contract design, the primary objective of this paper is to assess the impacts of a housing bubble on residential mortgage funding lenders arising from interest rate and house price risks. The classical fixed income portfolio immunization model, e.g., Redington (1952); Reitano (1991), is adapted to demonstrate that shortening mortgage term to maturity and having a yield maintenance prepayment penalty reduces the risk of a housing bubble collapse to mortgage lenders. In addition to mitigating the difficulty of determining an actuarially sound fair market value at origination, mortgages with term to maturity significantly less than the amortization period strengthens adherence to underwriting standards by requiring mortgagors to periodically reaffirm both the equity value in the underlying housing asset and the source of household income available to service the mortgage. In addition, even if the mortgage contract has no prepayment penalty and includes a no recourse default option, reducing mortgage term to maturity still significantly reduces the fair value of the prepayment and default options when the mortgage is priced, thereby reducing the housing bubble collapse risk to lenders associated with the exercise of options that are underpriced at origination.[2]

2. US and Canadian Mortgage Contract Design

The history of the mortgage contract design stretches back to antiquity. Cuneiform tablets from second millennium BC Mesopotamia record debt-bondage contracts for consumption loans structured with landed property as security. Much of mortgage contract history is concerned with: Evolving legal interpretations of the contract, such as the remedies available to mortgagee and mortgagor in the event of default; and, how mortgage contract language can be structured to achieve a specific objective, such as including a power of sale clause to avoid the costs of foreclosure for the mortgagee. In the modern era, mortgage contract design varies substantively across countries and over time. These differences are the result of unique evolution of the mortgage contract in each country. Specifically, Campbell (2013) demonstrates that mortgage contract design in the US is

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[2] The "no recourse" provision refers to the lender having 'no recourse' in the event of default against any other assets (or income) of the household than the housing asset securing the mortgage. In other words, the household borrower can 'put' the house back to the lender in exchange for the unpaid balance on the mortgage. A 'full recourse' provision allows the lender in the event of default to make a claim against other household assets and future income for the difference between the unpaid balance on the mortgage and the market price received when the housing asset is sold by the lender following default.

anomalous compared to other countries in having a long amortization period with a fixed interest rate. This contract design feature is combined with other anomalous features: no prepayment penalties; and, in many state jurisdictions, limited or no recourse for deficiency claims. In contrast to the mortgage contract in Canada and other countries, the modern US mortgage contract is decidedly in favour of the mortgagor.

The current conventional US mortgage contract has roots in the collapse of the mortgage funding system brought on by the Great Depression, e.g., Rose (2011); VLR (1937). Recognizing considerable diversity across regions, a reasonable estimate of the residential house price collapse during the Depression in the US was around a 50% decline. This had drastic implications for the mortgage contract design in use at the time that involved short term to maturity mortgages, usually 3–10 years depending on the security of the borrower with loan-to-value ratios of 60% or less. Because the amortization period was usually much longer, 25 years being common, the unpaid principle due on maturity could not be refunded in many cases by taking another mortgage with the same lender. The combined collapse of house prices and personal incomes prevented refunding as the value decrease of the underlying housing assets was so severe that the bankers could not fund such roll-over loans, even at much higher loan-to-value ratios. This propelled a consolidation of mortgage loans starting in 1933 under the Home Owners ' Loan Corporation (part of the Federal Home Loan Bank System) combined with the introduction of home mortgage insurance under the National Housing Act (1934). The upshot was the introduction of the conventional 30-year term to maturity, fixed rate, no prepayment penalty US mortgage contract that, more or less, survives to the present (see Table 1).

Table 1. Comparison of US and Canadian Mortgage Contracts.

	Prepayment Penalty	**Default Recourse**	**Main Funding Source**
US Contract	No Penalty: Not Assumable	Depends on State Usually No Recourse	Government Sponsored Enterprises (GNMA, FNMA, Freddie Mac)
Canadian Contract	Loss of Interest: Assumable	Full Recourse	Depository Institutions
	Benchmark Term	**Benchmark Amortization**	**Floating Rate Benchmark**
US Contract	30 Year	30 Year	ARM: Fixed Reset Date
Canadian Contract	5 Year	25 Year	Variable Rate: Prime Rate Reset

In contrast to the conventional US mortgage contract, the Canadian mortgage funding system is based on full recourse mortgage contracts with term to maturity at origination significantly less than amortization period. Standard contracts have a loss of interest (yield maintenance) provision to dampen the impact of interest sensitive prepayment and a three times monthly payment penalty impacting other factors influencing the exercise decision.[3] Unlike the conventional due-on-sale US mortgage contract, in the case of a house sale prior to the end of term, mortgages are usually assumable with no prepayment penalty if the house purchaser elects and qualifies to assume the mortgage or the mortgage holder qualifies to transfer the mortgage to their next residence. At the end of mortgage term to maturity, the unpaid balance on the mortgage is due. At this time, the mortgage borrower may reset the terms of the mortgage if desired, this can include changing both the amortization period and unpaid balance. It is also possible to transfer the mortgage without penalty

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[3]   A typical Canadian mortgage contract offered by the chartered banks specifies a prepayment penalty that is loss of interest or 3 months payment, whichever is greater. However, the typical contract permits a once a year payment, without penalty, of 10% of the initial principal amount. Payments beyond 10% incur a penalty on the entire amount of the prepayment. The 10% penalty free prepayment amount cannot be carried forward to the next year. It is also possible to "double-up" on monthly payments, i.e., to make a payment that is twice the amount of a regular monthly payment with a corresponding reduction in remaining principle, subject to some restrictions, in addition to the 10% annual prepayment.

to another lender. Within this framework, mortgage interest rates vary by term to maturity with, typically, a much wider difference between floating and fixed rate mortgages than in the US.

Any examination of practical issues associated with mortgage contract design would be incomplete without considering the seemingly incongruent regulatory and legal framework governing US mortgage origination. From the National Housing Act (1934) to the American Dream Downpayment Act (2003) to the Helping Families Save Their Homes Act (2009), the US federal government has actively promoted home ownership and, when necessary, provided relief in the event of a housing market collapse. A plethora of similar schemes appear in state legislation and initiatives. While the originate-to-distribute, government sponsored enterprise (GSE)-based residential mortgage funding system has much earlier historical origins, passage of the FDICIA (1990) following the housing market collapse of the late 1980s represents transition from funding mortgages through the balance sheets of depository institutions to funding through capital markets, e.g., Benston and Kaufman (1997). This transition sustained the development and growth of a range of primarily OTC (over-the-counter) cash and derivative products designed to "slice up" the cash flows from the pools of conventional US mortgages underlying the GSE mortgage securities that were being traded, thereby mitigating risks and, supposedly, providing more efficient pricing and greater access to residential mortgage financing. These and other so-called innovative mortgage products were key contributors to the creation and subsequent collapse of the recent US housing bubble, e.g., Davidson et al. (2016).

A partial list of the innovative financial engineering products introduced in the US include: interest-only and payment-option ARM's (adjustable rate mortgages); sub-prime and Alt-A mortgage pools; credit default swaps and related synthetic derivatives; various exotic interest rate derivatives; and re-bundled mortgage pass-throughs producing tranche and Z-class CMO's (collaterized mortgage obligations). It is now recognized that dispersion of default risk and duration gap risk through securitization did not enhance financial stability in the US mortgage funding system as financial engineering advocates claimed in the lead-up to the housing bubble, e.g., Shin (2009). Instead, these products directly contributed to a system-wide increase in leverage fuelled by an expansion of mortgage lender balance sheets sustaining an overall reduction in mortgage origination standards and subsequent housing bubble collapse. In contrast, such innovative mortgage products have made limited progress in Canadian mortgage funding where the conventional Canadian mortgage contract facilitated accuracy of credit assessment essential to mortgage funding by chartered banks and other lenders. [4] Though there has been some progression of securitized mortgage products in Canada, the underlying mortgage pools are composed of loans subject to the same origination standards and contract design as mortgages funded by bank balance sheets (CMHC 2014; Crawford et al. 2013).

3. Immunizing Risk to Mortgage Lenders: Basic Results

Many of the confusions about mortgage funding and housing bubbles can be traced to inadequate attention to defining risk for mortgagors and mortgagees. Bullard et al. (2009, p. 403) hinted at the inadequate recognition of mortgage funding risk in the US in the runup to the housing bubble collapse: After several years of rapid growth and profitability, banks and other financial firms began to realize significant losses on their investments in home mortgages and related securities in the second half of 2007. Consistent with the conventional insurance perspective on risk measurement that only recognizes outcomes involving either loss or no loss, connection between the profitability

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[4] Though subject to less government regulation than in the US, there is regulation of mortgage lenders in Canada by the Office of the Superintendent of Financial Institutions (OSFI), an independent agency of the Government of Canada, created in 1987, reporting to the Minister of Finance. OSFI is responsible for supervising and regulating banks, insurers and some federally registered pension plans. In addition, the Canada Mortgage and Housing Corporation (CMHC) also plays a regulatory role as the provider of mortgage insurance and, since 2001, has been a conduit for Canada Mortgage Bonds issued through the CMHC-run entity the Canada Housing Trust. Through CMHC and OSFI, the federal government has authority over the maximum amortization period of mortgages qualifying for CMHC insurance.

generated in a period of rapid growth in house prices and the losses resulting from a housing market bubble is often ignored. Yet, risk in financial markets is two-sided. Actuarial prudence dictates that some portion of profits generated in a market upswing be retained as an equity (surplus) buffer against future losses in a downturn, especially where accurate pricing of long term to maturity securities with embedded contingencies is complicated. In an originate-to-distribute model of securitized mortgage origination, there is a compelling market incentive for originators and mortgage security issuers to underprice the contingencies at origination. The market discipline needed to prevent mortgagees, i.e., direct mortgage lenders and mortgage security investors, from directly or indirectly purchasing over-priced mortgages were undermined by credit assessment and mortgage market conventions that provided false confidence the embedded contingencies had been accurately priced. Significant reduction of funding risk to lenders can be achieved by using mortgage contracts that facilitate more accurate and efficient pricing of the embedded contingencies that reduces the negative impact of option exercise on lenders arising from interest rate and house price changes.

In the context of immunization theory, serious contagion risk in the mortgage funding system originates when the transfer of mortgage risks between households and mortgage lenders due to the collapse of a housing market bubble results in crushing equity losses that exceed the mortgage funding system equity available. To cover such losses, the mortgage funding system needs to draw capital from elsewhere in the financial system creating the risk that equity losses spill over into the greater financial system having potentially catastrophic macroeconomic consequences for incomes needed to service mortgage payments. The ongoing debate over the causes and remedies of the recent mortgage-driven US housing bubble collapse features the widespread, but false, perception that risks inherent in residential mortgage funding can be mitigated, if not eliminated, by transferring the risks to capital markets, e.g., Green and Wachter (2005). Such claims point to various potential gains from trade available from funding mortgages through capital markets instead of relying on depository institutions, such as: enhanced diversification; correcting mismatches in the maturity composition of assets and liabilities; increasing liquidity and pricing accuracy through speculative participation; and, improved alignment of asset and liability composition with risk preferences, expectations and time horizon of individual traders. The extent and severity of the recent US housing market bubble collapse suggests that such gains are illusory, e.g., Hancock and Passmore (2010).

To model the risks to mortgage lenders of a housing bubble forming and collapsing, the fixed income interest rate immunization model from Poitras and Zanotti (2016) will be adopted. In the actuarial science literature, the classical zero surplus fixed income portfolio immunization model uses a univariate Taylor series expansion to derive two rules for immunizing a depository institution, pension fund or insurance company against a change in the level of interest rates: (1) Match the duration of cash inflows (assets) and outflows (liabilities); and, (2) set the asset cash flows to have more dispersion (convexity) than the liability cash flows around that duration, e.g., Redington (1952), Shiu (1990); Reitano (1991); Poitras (2007). In the classical case, surplus immunization is structured around the balance sheet of an individual fund whereas the risk immunization framework used in Poitras and Zanotti (2016) involves aggregating the balance sheets of households and mortgage lenders. In classical immunization, the fund surplus is set equal to zero –- with the actual surplus being segmented and treated separately –- to obtain the well-known solutions to that optimization problem. In contrast, Poitras and Zanotti (2016) proceed by aggregating risk immunization conditions. Extending this model to assess the impact of a housing bubble needs to specifically identify connections between different balance sheets of mortgage lenders and household mortgage borrowers. This requires the implications of having positive aggregated balance sheet surplus to be recognized.

To develop the basic theoretical framework, default and prepayment options will initially be ignored to derive simplified interest rate immunization conditions for the aggregated balance sheets of households and mortgage lenders. In this case, interest rate risk immunization requires percentage changes in the market value of equity (surplus) supporting the residential mortgage funding system to be non-negative after interest rates change. If this does not occur, then the mortgage funding system will require net equity transfers from elsewhere in the financial system as the aggregate loss

exceeds the mortgage funding surplus available to service the loss. In the collapse of a housing market bubble this equity transfer is large enough that mortgage funding system risk spills over into the broader financial system producing systemic risk where one part of the financial system—the mortgage funding system—has a catastrophic negative impact on the greater financial system, somehow defined. The recent housing bubble collapse in the US revealed that the extent of the 'financial system' can be global. Financial institutions around the globe were significant players in providing the equity transfers required to cover US mortgage funding system losses generated by the sub-prime mortgage crisis, e.g., Harrington (2009, p. 797).

Immunization of the market value of mortgage funding system surplus involves explicit recognition of the aggregate household and mortgage lender balance sheet relationships:

$$A = L + S \Rightarrow S[y,h] = A[y,h] - L[y,h]$$

where: A, L and S are aggregate assets, liabilities and surplus (equity); y is the yield to maturity on the annuity component of the mortgage; h is the growth rate of residential house prices; and, indicates the next step in the derivation. For households: A_H is the market value of residential household assets associated with the mortgage; L_H is the market value of household mortgage liabilities; S_H is the household equity position. For lenders: A_L is the market value of the lender mortgage assets; L_L is the market value of mortgage lender liabilities used to fund mortgage assets; S_L is the lender equity position.

Upon aggregation, $L_H = A_L$ acts to transfer mortgage value changes between households and lenders. This balance sheet transfer is an essential avenue for mortgage funding risk transmission. Considering only interest rate risk and ignoring house price risk, a univariate Taylor series expansion is applied to the aggregate surplus value function $S = S_H + S_L = A_H - L_H + A_L - L_L$ (where $S[y]$) to give:

$$S[y] = S[y_0] + \frac{dS}{dy}(y - y_0) + \frac{1}{2}\frac{d^2S}{dy^2}(y - y_0)^2 + \dots H.O.T.$$

$$\frac{S[y] - S[y_0]}{S[y_0]} \cong -DUR_S(y - y_0) + \frac{1}{2}CON_S(y - y_0)^2$$

This equation is fundamental and must be understood to interpret the results that follow. To those unfamiliar with the actuarial science literature, surplus is the difference between the market value of assets less the market value of liabilities—what is also referred to as 'equity value'—recognizing that market values are typically estimates. As such, surplus is the buffer that protects the solvency of a fund, a business or, as in this paper, the stability of the mortgage funding system from changes in exogenous variables. In the simple case considered above, where the only exogenous variable affecting market values is changes in the interest rate, the instantaneous percentage change in the surplus ($\Delta S/S$) is approximated using a combination of two parameters (defined above), *DUR* (Duration) and *CON* (Convexity), which are determined by the types of fixed income securities that make up the assets and liabilities. Where S is a convex function—as would be the case where 'plain vanilla' fixed income assets exceed liabilities—*DUR* is the linear approximation to the percentage change in surplus and *CON* is the quadratic adjustment. Focusing on the zero duration of the surplus follows from the observation that, when interest changes are small, the *DUR* term explains much of the change in surplus.

Because the duration of mortgage funding system surplus is the value-weighted sum of the durations of surplus for the mortgage lender and household, it follows:

Definition 1. *Duration of Mortgage Funding System Surplus.*

$$DUR_S = (S_H / S) DUR_{SH} + (S_L / S) DUR_{SL}$$

$$= \left(\frac{S_H}{S}\right)\left(-\frac{1}{S_H}\frac{dS_H}{dy}\right) + \left(\frac{S_L}{S}\right)\left(-\frac{1}{S_L}\frac{dS_L}{dy}\right)$$

where subscripts indicate households (*SH*) and mortgage lenders (*SL*). Similarly, $CON_S = (S_H/S)$ $CON_{SH} + (S_L/S)$ CON_{SL} is the modified convexity of system surplus. The mortgage funding system interest rate immunization conditions follow: (1) Set the duration of aggregate surplus equal to zero; and (2) have a positive convexity of aggregate surplus.

Observing the subscripts *H* and *L* denote households and mortgage lenders and the superscripts *A* and *L* denote assets and liabilities, respectively, exploring the zero duration of mortgage funding system surplus condition –- $DUR_S = (S_H/S)$ $DUR_{SH} + (S_L/S)$ $DUR_{SL} = 0$ –- reveals that interest rate risk immunization for a mortgage funding system using mortgage contracts with term to maturity equal to the amortization period cannot be achieved unless interest-bearing assets are included on the household balance sheet. More precisely:

Proposition 1. *The zero duration of mortgage funding system surplus condition (T = N).*

$$DUR_S = ((S_H/S)\ DUR_{SH}) + ((S_L/S)\ DUR_{SL} = 0$$

It follows that this condition is equivalent to:

$$\left(\frac{A_H}{S} DUR_H{}^A - \frac{L_H}{S} DUR_H{}^L\right) + \left(\frac{A_L}{S} DUR_L{}^A - \frac{L_L}{S} DUR_L{}^L\right) = 0$$

Recalling $L_H = A_L$, the aggregate zero duration of mortgage funding system surplus requires:

$$DUR_H{}^A = \frac{L_L}{A_H} DUR_L{}^L$$

This condition applies because, if the mortgage liabilities of households (L_H) are identical to the mortgage assets held by mortgage lenders (A_L), it follows that $DUR_H{}^L = DUR_L{}^A$.

When this condition holds, the aggregate surplus of the mortgage funding system, combining the surplus of households and mortgage lenders, will be unchanged and the possibility of net equity drawn from the greater financial system will be zero when interest rates change. Recalling that house price changes are not incorporated into this solution, for a no recourse mortgage where the only household asset is the residential property, $DUR_H{}^A = 0$ and zero duration of mortgage funding system surplus cannot be achieved.[5] Of course, the level of interest rates, over time, will be capitalized into

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[5] This conclusion assumes that mortgage lender liabilities are not a completely floating rate where $DUR_L{}^L = 0$. Assuming for simplicity that $DUR_L{}^L = DUR_H{}^A = 0$, the mechanism of system surplus adjustment for the zero duration of surplus result in Proposition 1 follows: market value losses (gains) on mortgage lender assets due to interest rate increases (decreases) will be offset by gains (losses) on household liabilities, resulting in no change in the aggregate mortgage funding system equity from changes in mortgage market value. This result does not imply that the surpluses of households and lenders will both be unchanged. Rather, only that surplus gains for households (lenders) will be exactly equal to surplus losses for lenders (households) for an instantaneous increase (decrease) in interest rates. These gains and losses will offset over an interest rate cycle. If $-DUR_L{}^L > 0$ and $DUR_H{}^A = 0$, then lenders will have an offsetting gain (loss) of surplus from an interest rate increase (decrease) from the change in the market value of liabilities. This implies that for no recourse *T* = *N* mortgages without contingencies, interest rate decreases (increases) are riskier (less risky) from a system surplus perspective. This is because, when interest rates decrease, households are locked into long term mortgages with higher fixed rates with no offsetting gain from interest-bearing household assets. At the same time, the surplus gain to lenders having mortgage assets that pay higher rates is partially offset with a smaller increase in the value of liabilities. Aggregate mortgage funding surplus has fallen. When interest rates increase, households (lenders) have surplus gain (loss) from mortgage liabilities (assets) with lower fixed

house prices. However, this impact is gradual while the valuation impact of interest rate changes on mortgage lender liabilities used to fund mortgages will be comparatively rapid.

The zero duration of the mortgage funding system surplus condition implicitly assumes both households and mortgage lenders separately seek an interest rate risk immunizing solution. Given this, the following condition applies to mortgage lenders:

Proposition 2. *The zero duration of surplus condition for mortgage lenders (T = N).*

From the balance sheet for mortgage lenders, $S_L = A_L - L_L$ and the zero duration of surplus condition for lenders is: $\dfrac{1}{S_L}\dfrac{dS_L}{dy} = 0 = \dfrac{A_L}{S_L}DUR_L{}^A - \dfrac{L_L}{S_L}DUR_L{}^L$.

It follows that the immunization conditions for mortgage lenders are given as:

$$DUR_L^A = \frac{L_L}{A_L}DUR_L^L \; \rightarrow \; CON_L^A > \frac{L_L}{A_L}CON_L^A$$

While the classical zero surplus immunization conditions require setting the duration of assets equal to the duration of liabilities, immunization with a positive surplus requires the duration of assets to be equal to the duration of liabilities, multiplied by the loan-to-value ratio for the market values of the mortgage assets and the lender liabilities used to fund the mortgage. This reveals the usefulness of increasing capital requirements on financial institutions—the primary source of funding for mortgages—to alleviate mortgage funding system risk. In classical immunization presentations of this result, the inability to satisfy this condition in a mortgage funding system based on depository institutions is due to the duration gap confronting depository institutions: The duration of long term fixed rate mortgages is too high relative to the duration of demand and term deposits used to fund the mortgages.

The systemic implications of setting term to maturity equal to amortization period for long term mortgage contracts, such as the 30-year fixed rate US mortgage, can be contrasted with a mortgage contract where term to maturity is significantly less than the long term amortization period. In this case, the size of the annual mortgage payment, which is primarily determined by the amortization period of the mortgage, will reset when the unpaid balance on the shorter term to maturity mortgage is refinanced at the end of the term to maturity (prior to the end of the amortization period). This changes the formulation of the mortgage funding system immunization conditions because the value of the mortgages on the aggregate household balance sheet is now composed of a funded and an unfunded component. Only the funded component is transferred to the mortgage lender. In turn, changes in the value of the unfunded component due to interest rate changes will systemically act to offset changes in the value of the funded component. For example, while an interest rate decrease will increase the value of the household mortgage liability, households will benefit when the mortgage matures by having a lower payment required to finance the unpaid balance.

To see this, let $L_H = F_H + U_H$ be the funded and unfunded portions of L_H, respectively. Once the amortization period (N) and the interest rate are specified, the value of the annual fixed rate payment (M) on the mortgage can be determined. Given this, U_H is the unpaid balance on the mortgage that needs to be refinanced at time T^*, the maturity date of the short-term mortgage:

$$L_H = \sum_{t=1}^{N}\frac{M}{(1+y)^t} = \sum_{t=1}^{T^*}\frac{M}{(1+y)^t} + \sum_{t=T^*+1}^{N}\frac{M}{(1+y)^t} \; -> \; U_H = L_H - \sum_{t=1}^{T^*}\frac{M}{(1+y)^t}$$

Because U_H represents the unpaid balance due at time T^*, changes in interest rates will alter the intrinsic value of this future liability for households. However, because the unpaid balance will be financed at future market interest rates, from the perspective of mortgage lenders U_H is a floating rate contract where $DUR_H{}^U = 0$. The imposition of a yield maintenance prepayment penalty that is at least

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rates. Lenders have a smaller surplus gain from liabilities that are funded at lower rates with shorter term to maturity than the mortgage. Aggregate mortgage funding surplus has risen.

equal to loss of interest prevents $T^* < N$ households from capturing any significant gain by refinancing prior to the maturity of the mortgage.

The implications of this substantive difference in mortgages where term to maturity (T) is equal to the long term amortization period (N) versus mortgage contracts where term to maturity (T^*) is less than the long amortization period can be seen from the change required to the associated zero duration immunization condition for households with short term to maturity mortgages:

$$\frac{A_H}{S} DUR_H^A - \left(\frac{F_H}{S} DUR_H^F - \frac{U_H}{S} DUR_H^U \right) = 0$$

Taking $(A_H^\#/S)\, DUR_H^{A\#} \equiv (A_H/S)\, DUR_H^A + (U_H/S)\, DUR_H^U$ produces the following:

Proposition 3. *The zero duration of mortgage funding system surplus when households use mortgages with term to maturity (T^*) less than amortization period (N) is:*

$$\left(\frac{A_H^\#}{S} DUR_H^{A\#} - \frac{F_H}{S} DUR_H^F \right) + \left(\frac{A_L}{S} DUR_L^A - \frac{L_L}{S} DUR_L^L \right) = 0$$

Given that $F_H = A_L$ in the $T^* < N$ case, it follows that zero duration of system surplus requires:

$$DUR_H^{A\#} = \frac{L_L}{A_H^\#} DUR_L^L$$

In this case, the values on the left side of this equilibrium condition will be substantively different than in the $T = N$ case. Specifically, the unfunded portion of the household mortgage liability will now be part of $DUR_H^{A\#}$ introducing an element that facilitates achievement of the zero duration of mortgage funding system surplus condition. By mitigating the impact of interest changes on the mortgage funding system, this result demonstrates the benefits of $T^* < N$ mortgage contracts for preventing contagion from collapse of housing bubbles. This is apparent by comparing the results of Propositions 1 and 3.

These simplified comparisons illustrate various risk containment advantages of the $T^* < N$ mortgage contract term to maturity feature leading to:

Corollary 1. *Risk of contagion from a housing market bubble collapse to a mortgage funding system using long amortization period mortgages is substantively reduced by shortening mortgage term to maturity.*

More precisely, having mortgage term to maturity significantly less than the amortization period enables the mortgage funding system to more readily approach the zero duration of aggregate surplus required for interest rate immunization of long amortization period mortgages. The longer term to maturity (T) mortgages associated with the simplified (no contingency) mortgage contract have larger mortgage market value changes when interest rates change and a potentially significant duration gap problem. Consequently, the contagion risk created by drawing significant equity from the greater financial system following a collapse in a housing market bubble created by interest rate changes is greater with a mortgage funding system using simplified $T = N$ contracts compared to $T^* < N$ contracts. This result is not applicable in practice because of the prepayment and default contingencies that are excluded from the simplified mortgage contracts assumed in this section but are integral to the conventional contracts used in funding US mortgages (but not Canadian mortgages).[6]

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[6] To see the importance of the prepayment option in undermining the simplified case, consider the inability of mortgage lender surplus to adequately deal with the 'sub-prime' bubble collapse. In the simplified case, the surplus available would have been supplemented by surplus gains associated with falling interest rates. However, exercise of the prepayment option allowed households to reduce the fixed rate on mortgages as interest rates fell significantly following collapse of the 'dot.com' bubble (the 'Greenspan put'), eliminating much of the gain to mortgage lender surplus from falling rates. When interest rates rose significantly, this

4. House Prices, Prepayment and Mortgage Default

An important historical rationale for retaining long term to maturity fixed rate mortgages in the US can be traced to the Great Depression when collapse of both house prices and incomes caused severe problems for households with $T^* < N$ mortgages seeking to refinance maturing mortgage balances with depository institutions. However, the recent dramatic house price drop associated with the US housing market bubble collapse indicates that funding conventional $T = N$ mortgages through capital markets is also not immune from the devastating impacts of significant house price declines. Introduction of house price growth rates (h) in the lender and household surplus value functions requires determination of the partial duration (*PDUR*) and partial convexity (*PCON*) for residential house price growth (see below for definition). In practice, the complicated contingent claims in the US mortgage pricing function—the prepayment and default options –- obscure precise calculation for relevant elasticities, e.g., Brueckner and Lee (2017); Kau et al. (1995). Limited empirical knowledge about the partial elasticities for residential house price growth and interest rates is compounded by the likelihood that estimates of such elasticities will be conditional on a range of variables that are not included, such as the level and change in household income levels.

Extending the mortgage funding system surplus function to depend both on interest rates and house price growth rates, Poitras and Zanotti (2016, p. 325) expand the surplus function in a bivariate Taylor series giving:

$$S[y,h] = S[y_0, h_0] + \frac{\partial S}{\partial y}\,(y - y_0) + \frac{\partial S}{\partial h}\,(h - h_0)$$

$$+ \frac{1}{2}\left[\frac{\partial^2 S}{\partial y^2}(y - y_0)^2 + \frac{\partial^2 S}{\partial h^2}(h - h_0)^2\right] + \frac{\partial^2 S}{\partial y\,\partial h}(y - y_0)(h - h_0) + \ldots H.O.T.$$

$$\frac{S[y,h] - S[y_0, h_0]}{S_0} \cong \left[\,-PDUR_{Sy}\,(y - y_0) + PDUR_{Sh}\,(h - h_0)\,\right]$$

$$+\ \frac{1}{2}\left[\,PCON_{Sy}\,(y - y_0)^2 + PCON_{Sh}\,(h - h_0)^2\,\right] + \frac{1}{S_0}\frac{\partial^2 S}{\partial y\,\partial h}(y - y_0)(h - h_0)$$

where the subscripts *Sy* and *Sh* indicate the partial derivatives of system surplus for *h* and *y*, respectively; and, *PDUR* and *PCON* are the associated partial durations and convexities. Observing there are now two random variables in the surplus value function produces the following:

Definition 2. *Bivariate Duration of Mortgage Funding System Surplus.*

The bivariate duration of system surplus with house price change and interest rates is defined:

$$\frac{S_H}{S}\left(\,-PDUR_{Hy}\,(y - y_0) + PDUR_{Hh}\,(h - h_0)\,\right) + \frac{S_L}{S}\left(\,-PDUR_{Ly}\,(y - y_0) + PDUR_{Lh}\,(h - h_0)\,\right)$$

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surplus was unavailable. In contrast, the prepayment option played an insignificant roll in the duration gap problem created by increasing interest rates that was a central issue in the collapse of the S&L industry in the US during the 1980s. In this case, the regime of persistently lower interest rates permitted by Regulation Q undermined the ability of lenders to accumulate surplus during a period of falling interest rates and, due to the bias toward savings deposits as S&L liabilities, there was little surplus gain from the reduction in the value of lender liabilities.

where: $PDUR_{i,j} = \dfrac{1}{S_i}\dfrac{\partial S_i}{\partial j}$. Given this, the zero change of surplus conditions for households and mortgage lenders can be used to assess the relationship between variations in $T = N$ versus $T^* < N$ mortgage contract terms and the emergence and collapse of a housing market bubble.

In the following, the mortgage funding system surplus value function for households, $S_H[h,y]$, involves two stylized formulations of the household equity function associated with the $T^* < N$ and $T = N$ mortgage funding systems. Theoretically the less complex case is for mortgages with $T^* < N$, no prepayment and full recourse. In this case:

Definition 3. *The (bivariate) $T^* < N$ household surplus function.*

For a full recourse mortgage with a yield maintenance prepayment penalty, the $T^* < N$ household surplus function is:

$$S[h_0, y_0] = A_{H,0} - L_{H,0} = A_{H,0} - \left(\sum_{t=1}^{T^*} \frac{(M_0)}{(1+y_0)^t} + \sum_{t=T^*+1}^{N} \frac{(M_{T^*})}{(1+y)^t} \right)$$

$$\underline{\quad} \; S[h, y] = A_{H,0}(1+h) - \sum_{t=1}^{T^*} \frac{(M_0)}{(1+y)^t} - U_H = A_{H,0}(1+h) - F_H - U_H$$

where: $A_{H,0}$ is the market value of the residential house asset (other assets not included in this case) and $L_{H,0}$ the market value of the mortgage payment cash flows, both at time $t = 0$; and, M_i is the fixed rate mortgage payment determined at $t = i$. To avoid presentation of complicated and unrevealing equilibrium conditions, it is helpful to make simplifying assumptions. Poitras and Zanotti (2016, p. 326) proceed by assuming $PDUR_{Hh}{}^L = 0$, i.e., that an instantaneous change in the house price growth rate will not change the value of mortgage liabilities held by households. While clearly inapplicable in the long run, this is a valid assumption for small time intervals. Using this assumption, the first order term in the Taylor series provides:

Proposition 4. *The zero change in household surplus (S_H) condition:*

$$-PDUR_{Hy}(y - y_0) + PDUR_{Hh}^A(h - h_0) = 0$$

$$\rightarrow \frac{L_H}{S_H}\, PDUR_{Hy}^L\, (y - y_0) = \frac{A_{H,0}}{S_H}\, (h - h_0)$$

where $L_H = F_H + U_H$. This follows because:

$$\frac{\partial S_H}{\partial h} = \frac{\partial}{\partial h}[A_{H,0}(1 + h)] = A_{H,0} \;\rightarrow\; \frac{1}{\partial S}\frac{\partial S_H}{\partial h} = PDUR_{Hh}^A = \frac{A_{H,0}}{S_H}$$

Absent an identifiable functional relationship between house price changes and interest rate changes, the zero change of household surplus condition still cannot be obtained on the household balance sheet requiring the zero duration of surplus for lenders to be incorporated.

Assuming $PDUR_{Lh}{}^L = 0$, for much the same reason as the assumption $PDUR_{Hh}{}^L = 0$, Poitras and Zanotti (2016, p. 326) produce:

Proposition 5. *The zero duration of mortgage funding system surplus condition for the $T^* < N$ mortgage.*

$$\frac{S_H}{S}\left(\frac{A_H}{S_H}(h-h_0)-\frac{L_H}{S_H}PDUR_{Hy}{}^L\right)+\frac{S_L}{S}\left(\frac{A_L}{S_L}PDUR_{Ly}{}^A-\frac{L_L}{S_L}PDUR_{Ly}{}^L(y-y_0)\right)=0$$

$$\left(\frac{A_H}{S}(h-h_0)\right)=\left(\frac{L_L}{S}PDUR_{Ly}{}^L-\frac{U_H}{S}PDUR_{Hy}{}^U\right)(y-y_0)$$

Because the surplus transfer between households and lenders from interest rate changes is small with the $T^* < N$ mortgages, as demonstrated in Proposition 3, changes in the mortgage funding system surplus are largely driven by house price growth rates. These surplus changes, which can be negative or positive, will be mainly located on household balance sheets. This leads to the important result:

Corollary 2. *Mortgage funding system risk with $T^* < N$ mortgage contracts depends fundamentally on the size of the household surplus.*

In contrast to mortgage lenders, households face real restrictions accessing the greater financial system for funds to cover equity losses. A full recourse provision in the $T^* < N$ mortgage expands the assets available to protect household surplus against adverse changes in house prices. In the context of a housing market bubble collapse, having a sufficient household surplus is essential from a $T^* < N$ mortgage funding system perspective as $S = S_H + S_L$ with the contribution from mortgage lender surplus being relatively small due to the smaller exposure arising from the use of shorter term to maturity mortgages. The implication is that, in a mortgage funding system with $T^* < N$ mortgage contracts, lower mortgage loan to house price value ratios at mortgage origination, yield maintenance prepayment penalties and the full recourse provision supported by substantial household non-housing assets are critical mortgage contract features for preventing potentially drastic consequences from collapse in a housing market bubble.

In contrast to the $T^* < N$, full recourse, yield maintenance prepayment penalty mortgage contract applicable in the Canadian case, the $T = N$ conventional US mortgage contract seeks to insulate the household balance sheet and control the negative impact of the interest rate and house price decreases by including contingencies in the mortgage contract protecting the market value of the $T = N$ household surplus. These options are: For the mortgage liability (L_H), the borrower prepayment option (PPO); and, for the residential house asset, the borrower mortgage default option (DO). The S_H from the household balance sheet can now be decomposed as:

$$S_H = (A_H{}^* + DO) - (L_H{}^* - PPO) = A_H - L_H$$

where $A_H{}^*$ and $L_H{}^*$ are the market value of the residential house asset and the fixed rate annuity portion of the household mortgage liability, respectively. Even though DO is embedded in the mortgage contract ($L_H = L_H{}^* - PPO - DO$), the no recourse provision makes the value of this option dependent on house price changes. Calculating the partial durations and convexities of these option payoffs is decidedly less tractable, though there are some helpful studies that address related issues, e.g., Sharp et al. (2008). Given this, Poitras and Zanotti (2016, p. 326) use the following:

Definition 4. *The (bivariate) stylized $T = N$ household surplus function.*

For a no recourse mortgage with prepayment and default options the $T = N$ household equity function is: $S_H[h,y]=\left(A_{H,0}{}^*(1+h)+DO[h,T,\sigma_h/S_0]\right)-\left[\sum_{t=1}^{T}\frac{(M_0)}{(1+y)^t}-PPO[y,T,\sigma_y/y_0]\right].$

This formulation is "stylized" because the functional specification of the PPO and DO options does not capture all relevant variables impacting valuation and exercise.

The stylized $T = N$ household surplus (equity) function illustrates the intuition of the US mortgage funding system. The contingencies have: complicated payouts; and, difficult to determine exercise decisions. For example, while $\partial DO/\partial A_H{}^* \to 0$ (−1) as $h \to +\infty$ (−∞) with $0 < DO < L^*$, it is not possible to say that DO will be exercised when $S_H < 0$ or $L_H{}^* > A_H{}^*$. No recourse default is triggered

when mortgage payments cease prior to T and the residential property is surrendered for the unpaid balance on the mortgage, the payout from lenders to households at that date being: $L_H{}^* - A_H{}^*$. This value is undetermined at origination as the default decision date is determined strategically, depending on other factors, not limited to having $S_H < 0$ or $L_H{}^* > A_H{}^*$. Similarly, $\partial PPO/\partial L_H{}^* \to 1$ (0) as $y \to 0$ (+∞) with $0 < PPO < L_H{}^*$. However, transaction costs associated with PPO exercise could delay exercise if there is an expectation that rates will continue to fall. Upon exercise, the yield maintenance payout from lenders to households is equal to loss of interest calculated as the annuity value of the difference in mortgage payments over the remaining amortization period. Because $\partial DO/\partial T > 0$ and $\partial PPO/\partial T > 0$, it follows:

Corollary 3. *Reducing mortgage term to maturity will reduce the value of the prepayment and default options at origination.*

This follows from the distribution free property of options: An option with a longer time to expiration will always have a value that is greater than (or, equal to in trivial cases) the value of an option with a shorter time to expiration.

While mathematically intuitive, straight forward application of Taylor series to solve for the mortgage funding system risk immunizing solution is complicated by the contingencies in the stylized $T = N$ household equity function. Unknown *ex ante* default and prepayment probabilities are necessary to the pricing of DO and PPO. Given this, Poitras and Zanotti (2016, p. 327) solve for the relevant partial derivatives as:[7]

Proposition 6. *The partial durations and zero duration of household surplus (equity) function for the stylized $T = N$ mortgage.*

$$\frac{\partial S_H}{\partial h} = A_{H,0}^* + \frac{\partial DO}{\partial h} \ \to \ \frac{1}{S_H}\frac{\partial S_H}{\partial h} = \frac{A_{H,0}^*}{A_{H,0} - L_{H,0}}\left[1 + \frac{\partial DO}{\partial A_H^*}\right]$$

$$\frac{\partial S_H}{\partial y} = -L_{H,0}^*\left[\frac{1}{L^*}\frac{\partial L^*}{\partial y} - \frac{1}{L}\frac{\partial PPO}{\partial y}\right] \ \to \ \frac{1}{S_H}\frac{\partial S_H}{\partial y} = \frac{L_{H,0}^*}{A_{H,0} - L_{H,0}}\left[PDUR_{Hy}^*\left(1 - \frac{\partial PPO}{\partial L^*}\right)\right]$$

where: $A_{H,0}{}^*$ is the market value of the residential house asset (with default option value not included) and $L_{H,0}{}^*$ is the market value of the mortgage payment cash flows (with prepayment option not included), both at time $t = 0$. These partial derivatives are then used to determine the zero duration of household surplus for the stylized $T = N$ household equity function as:

$$\frac{A_{H,0}^*}{A_{H,0} - L_{H,0}}\left[1 + \frac{\partial DO}{\partial A_H^*}\right](h - h_0) = \frac{L_{H,0}^*}{A_{H,0} - L_{H,0}}\left[PDUR_{Hy}^*\left(1 - \frac{\partial PPO}{\partial L_H^*}\right)\right](y - y_0)$$

$$-\left[1 + \frac{\partial DO}{\partial A_H^*}\right](h - h_0) = \frac{L_{H,0}^*}{A_{H,0}^*}\left[PDUR_{Hy}^*\left(1 - \frac{\partial PPO}{\partial L_H^*}\right)\right](y - y_0)$$

In the absence of the DO and PPO options, household equity increases (decreases) when both h and y increase (decrease) with the surplus changes being transferred between mortgage borrowers and lenders. With contingencies, whether h increases or decreases, the possible household equity loss associated with a y decrease is protected by exercise of the prepayment option which transfers this loss to lenders. In turn, household surplus still captures the market value gain from y increases at the expense of lenders. When the h decrease is large enough that $(1 + h)A_{H,0} < L_H$ then exercise of the default option can prevent household surplus from going negative, again at the expense of mortgage

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7   This solution requires the following results: $\frac{\partial A_H}{\partial y} = 0 \quad \frac{\partial DO}{\partial h} = \frac{\partial DO}{\partial A_H}\frac{\partial A_H}{\partial h} = \frac{\partial DO}{\partial A_H^*}\frac{\partial A_{H,0}^*(1+h)}{\partial h} = \frac{\partial DO}{\partial A_H^*}A_{H,O}^*$.

lenders. No recourse and high mortgage loan to house price ratio at origination significantly increase the probability of default option exercise.

Casual inspection of the zero duration of the system surplus condition given in Proposition 6 reveals that for mortgage lender surplus to sufficiently absorb losses transferred from households:

Corollary 4. *Mortgage contract contingencies do not substantively impact mortgage funding system risk if correctly priced at origination. Under-pricing of contingencies is required if mortgage contingencies contribute to generating housing bubble collapse contagion.*

To avoid contributing to house price collapse contagion, the option premia embedded in the valuation of $L_H = A_L$ needs to be accurately priced. Such valuation is required to ensure S_L is sufficient to offset the loss when *PPO* or *DO* is exercised. Unfortunately, obtaining an accurate contingency price at $T = N$ mortgage contract origination is decidedly difficult, especially when viewed from the perspective of a future housing bubble forming and collapsing over the 30-year $T = N$ horizon of the conventional US mortgage contract. In practice, market incentives associated with an originate-to-distribute method of mortgage issuance has the potential for *PPO* and *DO* being unpriced or, at best, grossly underpriced. In contrast, instead of attempting to embed a difficult-to-price prepayment option premium into the mortgage price at origination, yield maintenance penalties involve payment of the option premium upon exercise, with the premium equal to loss of interest on the remaining term to maturity. This leads to the following:

Corollary 5. *By providing more accurate pricing for the value of the prepayment contingency, including a yield maintenance prepayment penalty in the mortgage contract reduces the risk of contagion from a housing market bubble collapse originating from interest rate changes.*

In effect, the catastrophic risk of macroeconomic contagion from the collapse of a housing market bubble arising from interest rate changes is reduced because the premium paid for the prepayment contingency is more accurately priced at exercise than at origination.

By insulating the household balance sheet, an important consequence of accurately-priced *PPO* and *DO* contingencies is that much of the aggregate mortgage funding system surplus available to absorb the impact of changes in interest rates and house prices has been shifted to mortgage lenders. This increases potential difficulties of inadequate risk management by mortgage lenders resulting in insufficient surplus being allocated to handle future option exercise. Over the interest rate cycle, in the absence of *PPO,* the loss (gain) for mortgage lender assets from an increase (decrease) in interest rates would be approximately offset by the gain (loss) when interest rates decreased (increased). Changes in household surplus combine to offset changes in mortgage lender surplus providing for $S = S_H + S_L$. Changes in mortgage lender surplus would be associated with duration gap exposure with house price changes impacting household surplus. In contrast, when the *PPO* contingency is included to insulate the household surplus, the burden of surplus changes associated with interest rate immunization falls on $S = S_L$. In this case, the zero change of mortgage lender surplus condition becomes the zero change of mortgage funding system surplus for the stylized $T = N$ mortgage contract.

Consequences of the inclusion of *PPO* and *DO* for mortgage funding system immunization are assessed in Poitras and Zanotti (2016, p. 327) by evaluating the zero duration of mortgage lender surplus condition: $\left(-PDUR_{Ly}(y - y_0) + PDUR_{Lh}(h - h_0) \right) = 0$. This produces:

Proposition 7. *Zero duration of mortgage lender surplus (equity) function for the stylized $T = N$ mortgage with contingencies.*

When there are default and prepayment contingencies in the mortgage contract that transfer losses to the mortgage lender balance sheet, the zero duration of mortgage lender surplus condition produces:

$$\left[PDUR_L{}^{A^*}\left(1 - \frac{\partial PPO}{\partial A_L{}^*}\right)\right](y - y_0) - \frac{A_H{}^*}{A_L{}^*}\frac{\partial DO}{\partial A_H{}^*}(h - h_0) = \frac{L_L}{A_L{}^*}\left[PDUR_L{}^{L}\right](y - y_0)$$

where $S_L = (A_L{}^* - DO - PPO) - L_L$. While the market value of mortgage lender liabilities increases when interest rates decrease, the associated gain in lender assets is strangled by exercise of the prepayment option and the gain is captured on household balance sheets. Conversely, when interest rates increase, the loss on lender assets will not be fully balanced by the reduction of lender liabilities if there is a duration gap. In addition, mortgage lenders are now exposed to downward movement in house prices that, if large enough, will trigger exercise of the *DO* default option. This potential future loss of lender surplus is not offset by gains from house price increases that are realized on the household balance sheet. Consequently, the avenue for sufficient surplus transfer from households to lenders is accurate mortgage pricing at origination to reflect the fair value of the embedded contingencies.

As illustrated in Proposition 7, mortgage contract contingencies transfer surplus losses due to house price and interest rate decreases from households to mortgage lenders. Consequently, contingencies insulating the household balance sheet require mortgage lender surplus to bear the full weight system adjustment. Under-pricing of mortgage contract contingencies at origination (or inadequate surplus management by mortgage lenders of accurately priced contingencies) deprives the mortgage funding system of essential surplus to prevent contagion in the event of a housing market bubble collapse. The following corollary captures the drastic implications:

Corollary 6. *By reducing the surplus of the mortgage funding system available for adjusting to changes in interest rates and house prices, mortgage contracts originated with underpriced prepayment and default options significantly increase the risk of contagion from the collapse of a housing market bubble.*

In the present context, when mortgage interest rates are historically low and house prices are rising in the US and various other regions around the globe, the probability of the embedded *PPO* option exercise is small and the *PPO* premia will be a relatively insignificant component of mortgage price at origination. However, a situation where *PPO* exercise is a remote possibility comes with a higher probability of mortgage lender asset losses, and a reduction in lender surplus from increasing interest rates.[8] Given this, the problem of pricing the embedded *DO* premium begs the question: Is it possible to accurately price the long run possibility of a housing bubble collapsing in an environment where low interest rates fuelling house price increases may, or may not, be creating a bubble, e.g., Dombret and Goldbach (2017)?

5. Conclusions: Housing Market Bubbles and Mortgage Contract Design

This paper evaluates the implications of a housing market bubble for $T = N$ and $T^* < N$ mortgage contracts. In addition to mortgage contracts with a long amortization period that is equal to the term to maturity of the mortgage, three key contract design features of the conventional U.S. mortgage contract that have persisted through the history of various US mortgage funding system changes are: low or no prepayment penalties; limited or no recourse in the event of default; and difficult-to-price embedded options in the mortgage contract. These features shift the risk of housing market collapse from households to mortgage lenders. In contrast, three key features of the conventional Canadian mortgage contract are: Term to maturity of the mortgage contract that is significantly less than the maximum amortization period; full recourse in the event of default; and yield maintenance prepayment penalties. These features shift the substantial risk of a housing market bubble collapse from mortgage lenders to households.

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[8] While Canadian mortgage lenders would also be impacted by an interest rate increase, the loss of interest from a 1% move in interest rates on a 30 year term to maturity mortgage is about 3.5 times the loss from a 5 year term to maturity.

It is more than apparent that, to address the future risk of a housing bubble collapse and subsequent macroeconomic contagion, a policy recommendation in the US to introduce full recourse mortgages with yield maintenance prepayment penalties; restrictions on maximum mortgage term to maturity to be significantly less than the amortization period or accurate pricing of mortgage contract contingencies would be more than politically unpopular, a perceived threat against the 'freedom to choose' mortgage contracts that are most advantageous. Altering the no recourse provision and prepayment option would also be illegal under laws in various states. US residential mortgage borrowers have demonstrated overwhelming preference for implicitly subsidized, long amortization and term to maturity, usually 30-year fixed rate mortgages. For the first decade of this century, between 70–90% of mortgages financed by the GSE's –- Ginnie Mae, Freddie Mac and Fannie Mae –- were long term fixed rate mortgages, e.g., FNMA (2009).[9] Formation of a housing bubble is a generational or multi-generational event. Profits to mortgage originators from underpricing mortgage contract contingencies as a housing market bubble forms are difficult to resist. The excessive increase in household equity creates a political myopia that is difficult to overcome.

Against this backdrop, it is not surprising that decisive policy action to address a housing market bubble, if any, appears too late to do little but mitigate dire consequences of a bubble collapse. Attempts to alter the conventional mortgage contract by the FHLBB to alleviate the duration gap problems of S&L's during the 1980s by issuance of adjustable rate mortgages (ARMs) were too little and too late. These attempts were not popular with either mortgage borrowers or lenders, though for different reasons (Benston 1986, chp. IV). The collapse of the US housing market bubble in 2008–2009 was addressed with bailouts and ex-post policy changes. Despite a variety of questionable mortgage contract designs that appeared in the expansion of the sub-prime mortgage market, e.g., Chomsisengphet and Pennington-Cross (2006), the US mortgage funding system risks associated with conventional mortgage contract design have not been substantively addressed. While the residential mortgage funding landscape has changed dramatically since long term, fixed rate mortgages were introduced with government backing in the 1930s, periodic disruptions and collapses in the mortgage funding system have been addressed by changing financing conduits rather than substantively altering the conventional mortgage contract.

In contrast to the experience in the US, the largely depository institution-funded Canadian mortgage funding system has avoided the history of crisis that has plagued the US system. Mortgage origination and funding is primarily through opaque multi-platform depository institutions with national scope, especially the five largest chartered banks. Due to a distinctly different constitutional framework in the US where states have considerably more jurisdiction over mortgage markets than Canadian provinces, mimicking such a market structure would be difficult in the US. The small number of major players permits the Canadian mortgage funding system to be more self-regulatory, with less layering of financial regulation and regulators in comparison with that in the US. As the full recourse and yield maintenance provisions demonstrate, mortgage lenders in Canada have decidedly more market power than lenders in the US. Instead of contract contingencies that shift losses from households to mortgage lenders, the yield maintenance prepayment penalty and full recourse provision in the Canadian mortgage contract isolates mortgage lenders from much of the interest rate and house price change impacts.

In the US, failure to originate residential mortgages at prices consistent with the immunization of mortgage funding system risk facilitates the process of contagion from housing market bubble collapse. Negative shocks to household balance sheets from extreme decreases in house prices or interest rate volatility are transferred to mortgage lenders with insufficient surplus to handle such severe shocks. Much public debate on the management of mortgage funding system risk continues to focus on the illusory goal of improved pricing through better estimates of parameters in pricing functions, default probabilities and the like. With some exceptions, e.g., Shiller et al. (2013), detailed

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[9] The Federal Home Loan Mortgage Corporation (2017, p. 98) reports that 78% of mortgage purchased were 30-year fixed rate compared to 75% in 2015 and 2014. In 2016 a further 16% were 15-year fixed rate and 4% were 20-year fixed rate. By comparison, in Canada less than 1% of fixed rate mortgages have terms to maturity greater than 10 years with about half of all mortgages having a 4–5-year term to maturity.

discussion of mortgage contract design change has been muted. The conventional US 30-year, fixed rate mortgage contract is the product of a funding system currently dominated by GSE's. From collapse of Regulation Q to the bankruptcy of the GSE's and associated mortgage lenders following the most recent collapse in a US housing market bubble, government policy has been unable to contain the risk associated with the conventional contingency laden 30-year fixed rate ($T = N$) mortgage contract.

This paper demonstrates the benefits of a mortgage funding system based on contingency-light $T^* < N$ mortgage contracts for averting potential macroeconomic contagion from collapse of a housing market bubble. In the absence of prepayment and default options, an increase in interest rates will reduce the market value of the mortgage but will increase the value of the mortgage needed to fund the unpaid balance at the end of the term to maturity (T^*). Compared to the difficult-to-price prepayment option in the conventional US mortgage contract, risk management benefits of yield maintenance prepayment penalties arise from the more accurate pricing of this contingency at exercise rather than at origination. Because the full recourse provision allows interest-sensitive and other non-housing assets on the household balance sheet to be part of mortgage funding system surplus available, this provision reduces the risk of mortgage default and dampens the effect of interest rate volatility and, especially, house price changes on the mortgage funding system. However, if the bulk of assets on the household balance sheet are residential real estate, as happens near the peak of a housing market bubble, then a full recourse provision could give unwarranted confidence to mortgage lenders, resulting in an increase in mortgage funding system risk due to a possible erosion of underwriting standards and an increase in loan-to-value ratios at origination.

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