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Housing and the Macroeconomy

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Housing and the Macroeconomy

DISSERTATION

A dissertation submitted in partial
fulfillment of the requirements for the
degree of Doctor of Philosophy in the
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By

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Lexington, Kentucky

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ABSTRACT OF DISSERTATION

Housing and the Macroeconomy

This dissertation studies the impact of several different housing market features on the macroeconomy.

Chapter 1 augments the New-Keynesian model with collateral constraints to incorporate long-term debt in order to examine the interaction between multi-period loans, leverage, and indeterminacy. Allowing firms to borrow heavily against commercial housing by increasing the loan-to-value ratio from 0.01 to 0.90 reduces the level of steady state output approximately 3.19% and decreases social welfare. In contrast, increasing the debt limit of households increases steady state output by 2.72%. Social welfare is maximized under a utilitiarian function when households can borrow at a loan-to-value ratio of about 0.49. An economy with long-term debt also makes stabilization much more difficult for monetary policymakers because determinacy is harder to attain. Instead of only having to satisfy the Taylor Principle (which implies that a more than one-to-one response to inflation), central bankers must either use a strict inflation target or aggressively respond to inflation and the output gap to ensure determinacy.

Chapter 2 examine a New-Keynesian model with housing where default occurs if housing prices are sufficiently low, resulting in a loss of access to credit and housing markets. Default decreases aggregate and patient household consumption, increases impatient household consumption, and amplifies the decline in housing prices due to a misallocation of housing. The effects on consumption often peak immediately before default occurs. Policies that prevent underwater borrowing or raise interest rates along with housing prices are generally desirable because they increase utilitarian social welfare. This paper shows that default is not simply a symptom of economic downturns, but a cause.

Chapter 3 explores the correlation between the home mortgage interest deduction (HMID) and state economic growth. The HMID was introduced to incentivize home purchases by distorting the after-tax price, resulting in an overinvestment in real estate. Previous empirical

work has shown that investment in physical capital increases economic growth more so than investment in structures. Theoretically, the anticipated effect of the HMID would be lower subsequent economic growth. However, this paper finds that residential housing is actually beneficial for economic growth.

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Date: August 6, 2015

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Housing and the Macroeconomy

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1 Introduction

This dissertation studies the impact of several different features of the housing market on the macroeconomy.

The first two chapters focus on the relationship between the real estate market and macroeconomic variables, and the third chapter examines the role of housing and tax policy in state level economic growth. Specifically, Chapter 1 discusses the effect of changing the loan-to-value (LTV) ratio on steady-state levels of output and welfare. Chapter 2 shows that default is not just a side effect of economic downturns, but mortgage insolvency can cause a recession. Finally, Chapter 3 explores the interactions between the home mortgage interest deduction (HMID), the housing stock, and economic growth.

Monetary Policy, Access to Credit, and Long-term Mortgages

In light of the recent economic downturn, it is important to develop a comprehensive understanding of how long-term mortgages and leverage impact the level of output, welfare, and central bank policy. The contribution of this paper is to include multi-period debt in a New-Keynesian model with credit constraints, more realistically modeling a fixed-rate mortgage structure. In order to examine the effects of changes in debt limits, the amount of recoverable collateral is allowed to vary. Changing the parameter that represents the LTV ratio for households has several effects on individual agents, as well as societal welfare. Increasing the leverage ratio for households from 0.01 to 0.79 increases steady state output by 2.72%. There is an asymmetric effect of changing the LTV ratio for firms on output and welfare. When the firms' LTV ratio increases from 0.01 to 0.90, the steady state level of output declines about 3.19%

The second part of this chapter studies the implications of long-term mortgages for mone-

tary policy. Traditionally, a more than one-to-one response to changes in inflation to ensure a determinate equilibrium is considered to be the first step to ensuring optimal monetary policy (Gali, 2008). Multi-period debt makes this task more difficult for policymakers. Instead of being able to respond to changes in the output gap, provided that the above condition is satisfied, central bankers utilizing a contemporaneous policy rule should consider strict inflation targeting or aggressive output gap targeting in order to reduce volatility.

Chapter 2: Housing and Endogenous Default

Chapter 2 examines credit market imperfections in a New-Keynesian model with housing. Unlike in the related literature, households may default on their debt if housing prices are sufficiently low, potentially resulting in a temporary loss of access to credit or housing markets. Default has three opposing effects on borrowers. First, the loss of access to housing markets provides borrowers with an incentive to substitute toward consumption. Second, default transfers wealth from lenders to borrowers. Third, the loss of access to credit markets prevents borrowers from smoothing their consumption, resulting in decreased consumption. This paper uses adaptive learning to solve the model and find that borrowers respond to default by increasing their consumption. However, both aggregate and lenders' consumption decrease in the default state. In addition, default distorts the housing market which causes a large amplification of the decline in housing prices that initially caused default. Thus, it is concluded that mortgage default is not simply an effect of economic downturns, but that it is a causal factor as well.

Chapter 3: The Home Mortgage Interest Deduction and Economic Growth

Chapter 3 concludes with an empirical analysis of the implications of the HMID for economic growth. Delong and Summers (1991) show that investing in structures results in lower subsequent economic growth than investment in machinery and equipment. Following this

logic, it is expected that incentivizing home purchases with the HMID would lead to lower growth rates. Using primarily a two-stage least squares model, this paper finds that investment in residential real estate actually promotes growth more so than other forms of physical capital.

2 Monetary Policy, Access to Credit, and Long-term Mortgages

2.1   Introduction

Two patterns arose simultaneously during the recent housing bubble that eventually led to rising foreclosures, defaults, and the sharp decline in housing prices starting in 2007. First, there was a large increase in the number of subprime and Alternative A-paper (Alt-A) mortgages issued.[1] From 2002 to 2005, subprime mortgage originations as a percentage of total mortgage initiations rose from 9% to 25%. At the climax of the bubble, subprime and Alt-A loans combined to equal 40% of the mortgage market. Second, there was a concurrent mortgage credit expansion, particularly for those in the subprime category (Mian and Sufi, 2009b). Figure 2.1 shows the increase in the average loan-to-price ratio for single family mortgages from the first quarter of 2003 to the second quarter of 2007.[2] Many subprime borrowers in particular felt this ease in access to credit. In 2007, the leverage ratio (defined as total debt to assets) for households in the bottom quintile of net worth reached 108.4%.[3]

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[1] Subprime loans are given to households with credit scores of 620 or below. Alt-A loans are granted to households with a mixed credit record or incomplete documentation of wealth and income.

[2] The data shown were collected from the Federal Housing Finance Agency Monthly Interest Rate Survey (MIRS), Table 17: Terms on Conventional Single Family Mortgages, Monthly National Averages, All Homes.

[3] The leverage ratio is taken from Table 12 in the Survey of Consumer Finances produced by the Board of Governors of the Federal Reserve System.

Figure 2.1: Loan-to-price (LTP) ratio
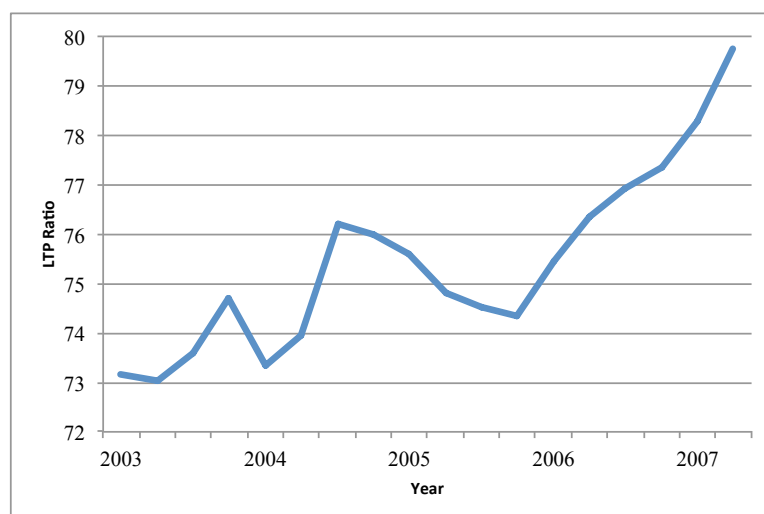
Previous literature, both empirical and theoretical, has shown that increased leverage contributed to the volatility of output during the Great Recession.[4] However, there has been no analysis of access to credit at the steady state. This paper examines the steady state effects of capital requirements for firms and loan-to-value (LTV) ratios for borrowers.[5] During the housing bubble, capital requirements and LTV ratios were the subject of many debates, and policymakers began to think about placing stricter limits on debt obligations after witnessing the severe effects of easy access to credit on the economy. Following the collapse, a consensus has yet to be reached on how, if at all, leverage should be regulated. In addition to analyzing steady-state effects, this paper evaluates the relationship among LTV ratios for firms and households, long-term debt, and indeterminacy.

This paper builds on the existing literature by incorporating long-term debt in the form of a fixed-rate mortgage into a New-Keynesian model with credit constraints. In the model, the

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[4]Mendicino (2012) shows that, typically, as the loan-to-value ratio increases, the amplification and propagation following a productivity shock is greater. In an empirical analysis, Mian and Sufi (2009a) conclude that a large proportion of the decline in output and housing prices during the recession of 2007 to 2009 can be attributed to credit expansion.

[5]Figure 2.1 above shows data on the loan-to-price ratio, which is the loan amount divided by the purchase price. The LTV ratio is the ratio of the loan amount to either the purchase price or the appraised value, whichever is lower. In this paper, access to credit, debt-to-capital ratio, leverage ratio, LTP ratio, and LTV ratio are synonymous. However, in data and empirical work, there are slight variations in the definitions of these variables.

patient households lend to impatient households and entrepreneurs, who each have a lower relative discount factor. As is standard in the literature, there is a limit on the debt obligations of households and firms. The parameter that changes the amount of recoverable collateral and thus the borrowing capacity of agents can be broadly interpreted as a LTV or leverage ratio (assuming that the borrowers possess mortgage debt but cannot take out loans in any other market). As shown in Figure 2.1, the data indicate that the loan-to-value ratio parameter can change drastically and frequently. The multi-period mortgage structure provides a more realistic framework to analyze credit and policy effects than one-period debt, which is standard in the literature. The alternative modeling assumption of multi-period debt drives the following results.

The current paper finds that increasing the entrepreneurs' leverage ratio from 0.01 to 0.90 decreases steady-state output by about 3.19%. In addition, a society with either utilitarian or Rawlsian preferences will maximize social welfare when firms face stricter borrowing limits. Interestingly, the same is not true when we change the borrowing capacity of households. When the LTV ratio for households increases from 0.01 to 0.79, steady-state output increases by approximately 2.72%. Household borrowing has a large and positive effect on steady-state output, despite the potential for increased amplification and persistence of shocks in the short run.

In the standard New-Keynesian general equilibrium model with cost-push shocks, a more than one-to-one response to inflation and no response to asset price changes is a necessary condition for optimal monetary policy (Gali, 2008). The first goal of rules-based monetary policy is to implement a policy rule that ensures a determinate equilibrium. Subsequently, the central bank optimizes by attempting to correct sticky price distortions that markets create and reduce volatility of the output gap and inflation. If policymakers fail to reach a determinate solution, stabilization is highly unlikely. In the traditional New-Keynesian model, a policy rule that responds with sufficient strength to changes in inflation will typically ensure determinacy.[6]

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[6]See Bullard and Mitra (2002) and Woodford (2003) for details.

In order to further understand the relationship between the housing market and monetary policy, a model is developed that includes long-term mortgage structure in the credit constraint. Long-term debt changes this relationship.

Iacoviello (2005) and Bernanke and Gertler (2001) analyze the impact of asset markets on volatility under various interest rate rules but only in terms of output and inflation stabilization. Xiao (2013) uses a New-Keynesian model with housing to evaluate determinacy under various policy rules. This paper extends the analysis to consider when agents must hold debt for two periods, which provides another source of indeterminacy and volatility. In the standard model with one-period debt, satisfying the Taylor Principle with a more than one-to-one response to changes in inflation is sufficient to ensure determinacy. In the model presented in this paper, with more realistic assumptions, the Taylor Principle is no longer enough to avoid indeterminacy. Under a contemporaneous interest rate rule that responds to changes in the current inflation rate and the current output gap, the central bank must either use a strict inflation target or a very strong response (more than one-to-one) to both, making it much more difficult for the policymaker to achieve stabilization. These results are different from Xiao (2013), which uses only one-period debt and shows that the determinacy region for the current data rule is large. Allowing multi-period debt and a more realistic mortgage structure makes it more challenging for central bankers to ensure determinacy and stabilization.

The takeaway for policymakers here is twofold. First, capital requirements and loan-to-value ratios significantly affect steady-state output and utility. A limit on borrowing, particularly for firms, may result in higher social welfare. Second, in a world with long-term mortgage debt, under a contemporaneous policy rule, strict inflation targeting or aggressive output gap targeting will reduce volatility.

The remainder of the paper proceeds as follows. Section 4.2 provides a brief literature review. Section 2.3 outlines the model. Section 2.4 displays the steady state results, and Section 2.5 shows the monetary policy results. Section 2.6 concludes.

2.2 Literature Review

Iacoviello (2005) augments a standard New-Keynesian model with a one-period credit constraint and concludes that the central bank responding to asset prices does not significantly reduce output or inflation volatility. The model includes patient and impatient households, entrepreneurs, retailers, and the monetary authority. *Impatient households* are characterized by a lower discount factor relative to patient households, indicating a smaller value placed on future consumption utility. *Patient households* lend to the impatient households. *Entrepreneurs* also borrow from the patient households to produce intermediate goods, which are sold to the *retailers* for transformation into final goods. Iacoviello (2005) finds that the presence of asset prices in the central bank policy rule does not significantly reduce inflation and output gap volatility.

Evidence from empirical studies confirms the presence of a financial accelerator effect. Hubbard (1998) provides a comprehensive overview of the empirical work supporting existence of a balance sheet channel transmission mechanism of monetary policy, in addition to the traditional interest rate channel. The effect of the interest rate channel on consumption and investment is not enough to explain the observed response of output to a change in monetary policy. The microeconomic literature studies informational imperfections between borrowers and lenders in financial markets. Costly external financing relative to internal financing is motivated by asymmetric information in credit markets. The balance sheet channel incorporates the unfavorable effect of contractionary monetary policy on net worth of firms and tightening of the credit constraint. The cost of external financing to firms increases, which decreases investment activities and production, resulting in magnification of the initial shock.

In addition to credit effects on firms, there is also a plethora of empirical documentation of borrowing constraints on households. Campbell and Mankiw (1989) estimate that approximately half of all consumers are forward-looking, directly supporting the permanent income hypothesis/life cycle (PIH-LC) model, while the other half consume their current income. One possible explanation for this result is that individuals cannot borrow indefinitely to substitute

between consumption now and future consumption, or that they are credit constrained. Japelli and Pagano (1989), in a cross-country study, find evidence against the PIH-LC and for liquidity constraints on households contributing to excess sensitivity of consumption in response to changes in disposable income. Zeldes (1989) explicitly tests the null hypothesis that consumers behave according to the PIH-LC against the alternative that the consumer behavior is subject to liquidity constraints. This study also concludes that consumption decisions of about half the population are based on a credit constrained optimization problem.

The model presented in this paper builds off of the empirical evidence for credit constraints and the theoretical models previously developed by augmenting the standard model with two-period mortgage debt. To the best of my knowledge, the only other paper to move beyond one-period debt considers the effects of fixed rate versus variable rate mortgages on the transmission of monetary policy shocks (Calza et al., 2009). The goal of the current paper is markedly different. The present analysis focuses on both firm and household debt (Calza et al. (2009) do not consider firm debt) and varying loan-to-value ratios in the steady state, as well as implications of long-term debt for indeterminacy.

The literature that examines indeterminacy largely does so in the standard New-Keynesian model without credit constraints. One exception is Xiao (2013), who examines a model that includes housing and borrowing limits; however, the conclusion regarding indeterminacy is, for the most part, unchanged. The general consensus is that following the Taylor principle is sufficient for ensuring determinacy.[7] Incorporating multi-period debt changes the condition for determinacy. In a world with long-term mortgage debt, the central bank must impose a strict inflation target or pursue an aggressive response to changes in output and inflation to avoid the instability of indeterminacy.

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[7]See Bullard and Mitra (2002) and Woodford (2003) for details.

2.3 The Model

The model consists of patient households, impatient households, entrepreneurs, retailers, and the central bank. Entrepreneurs, patient households, and impatient households are infinitely lived and on a continuum on the unit interval. This paper differs from others in the literature by altering the credit constraint to incorporate two-period debt. Debt is set in nominal terms, reflecting the standard loan in most low-inflation countries.[8] The purpose of incorporating long-term debt and a parameter that measures access to credit is to determine whether or not these features of the housing market contributed to the severity of the 2007 to 2009 recession. Multi-period debt provides a more realistic framework to evaluate the effects of the real estate market on macroeconomic variables and volatility. Over the last 25 years, the average term to maturity on conventional single-family mortgages is about 27 years (Federal Housing Finance Agency, 2012). Therefore, it is far more reasonable to assume that debt is paid off over two periods in the model as opposed to a single period. The length of time represented by a period in the model is ambiguous; however, the longer maturity on the typical mortgage is better approximated by multiple periods. The decisions of households will likely be different when about half of their debt is paid off and the two-period debt model captures these dynamics. Incorporating long-term debt with various mortgage structures implies that agents are constrained by their debt choices in previous periods and the effect of unanticipated shocks is larger.

In the model, households pay off approximately half of the debt in each period, whereas with the traditional credit constraint the entire debt is paid off in the subsequent period. Under the FRM structure, the interest rate is constant in both periods. Borrowers pay back debt over two periods and face the same interest rate in both periods.

Consider an example. Suppose in time t, an agent borrows \$1 at an interest rate of 1%, or $R_t^F = 1.01$. The interest rate on a FRM does not change throughout the life of the loan, thus

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[8]Iacoviello (2005) also sets the debt contract in nominal terms and provides an alternative, indexed debt, which does not significantly increase expected utility for any of the risk-averse agents.

the agent will pay $R_t^F = 1.01$ in both periods. The total amount owed plus interest is equal to $B_t R_t^F$, which is equal to \$1.01. The agent can pay back this amount over two periods. In the next period, $t + 1$, the payment on the loan he took out in time t is:

$$\frac{(R_t^F)^2}{1 + R_t^F} B_t \approx \$0.5075$$

Note, contemporaneously in time $t + 1$ he is paying off the second half of the loan he took out in time $t - 1$; however, this example only considers payments on B_t. At the end of $t + 1$, the agent owes:

$$B_t R_t^F - \frac{(R_t^F)^2 B_t}{1 + R_t^F} \approx \$0.5025$$

on the amount borrowed in time t. In period $t + 2$, he must pay interest on the amount he still owes and pay off the remainder of the loan. The payment on the loan initiated in time t will be

$$\frac{(R_t^F)^2}{1 + R_t^F} B_t \approx \$0.5075$$

such that after this payment is made, the loan is fully amortized. Following the $t + 2$ payment, the agent has no obligations from time t. After being charged interest on the remaining balance in period $t + 1$, the amount owed in time $t + 2$ is:

$$B_t (R_t^F)^2 - \frac{(R_t^F)^3 B_t}{1 + R_t^F} \approx \$0.5075$$

The loan is fully amortized at the end of period $t + 2$:

$$B_t(R_t^F)^2 - \frac{(R_t^F)^3}{1 + R_t^F}B_t - \frac{(R_t^F)^2}{1 + R_t^F}B_t$$

$$= \$1 * (1.01)^2 - \$1 * \frac{1.01^3}{1 + 1.01} - \$1 * \frac{1.01^2}{1 + 1.01}$$

$$= \$1.0201 - \$0.5126 - \$0.5075$$

$$= \$0$$

The following section outlines the model.

Long-term Debt in a New-Keynesian Model

Patient Households:

Households work, consume, demand real estate, and demand money. *Patient households*, represented by the prime symbol, are savers and lend to the impatient households and entrepreneurs. Patient households also have the option of trading one-period bonds amongst each other as an alternative to two-period lending. They maximize expected lifetime utility, which is a function of consumption ($c_t^{'}$), housing ($h_t^{'}$), hours worked for the entrepreneurs ($L_t^{'}$), and real money balances $\left(\frac{M_t^{'}}{P_t}\right)$ subject to a budget constraint.

$$\underset{c_t^{'} L_t^{'} h_t^{'} \frac{M_t^{'}}{P_t}}{\text{Max}} \quad E_0 \sum_{t=0}^{\infty} \beta^{'t}(lnc_t^{'} + jlnh_t^{'} - \frac{L_t^{'\eta}}{\eta} + xln\frac{M_t^{'}}{P_t}) \tag{2.3.1}$$

where the expectation operator is E_0 and the discount factor is $\beta^{'}$, assumed to be relatively high at 0.99. The real flow of funds constraint is given by:

$$c_t^{'} + D_t + q_t(h_t^{'} - h_{t-1}^{'}) + \frac{(R_{t-1}^F)^2}{(1 + R_{t-1}^F)} \frac{b_{t-1}^{'}}{\pi_t} + \frac{(R_{t-2}^F)^2}{(1 + R_{t-2}^F)} \frac{b_{t-2}^{'}}{\pi_t \pi_{t-1}} \leq$$
$$b_t^{'} + w_t^{'} L_t^{'} + R_{t-1} D_{t-1}^{'} + T_t^{'} - \frac{(M_t^{'} - M_{t-1}^{'})}{P_t} \tag{2.3.2}$$

where $\pi_t = P_t/P_{t-1}$. In time t, the patient households lend in real terms an amount $B_t/P_t = b_t$ to the impatient households or entrepreneurs. Also in time t, patient households are repaid for about half of the loan value taken out in $t-1$ and the second period payment on the loan taken out in $t-2$ plus interest, where R_t^F is the nominal interest rate on loans in time t.

The first order conditions for the patient households are

$$\frac{w_t'}{c_t'} = L_t'^{\eta-1} \tag{2.3.3}$$

$$\frac{q_t}{c_t'} = \frac{j}{h_t'} + \beta' E_t \left[\frac{q_{t+1}}{c_{t+1}'} \right] \tag{2.3.4}$$

$$\frac{1}{c_t'} = \beta' E_t \left[\frac{R_t}{\pi_{t+1} c_{t+1}'} \right] \tag{2.3.5}$$

$$\frac{1}{c_t'} = \frac{\beta' (R_t^F)^2}{1 + R_t^F} E_t \left[\frac{1}{c_{t+1}' \pi_{t+1}} + \frac{\beta'}{c_{t+2}' \pi_{t+1} \pi_{t+2}} \right] \tag{2.3.6}$$

where (2.3.3) is patient household labor supply, (2.3.4) is patient household housing demand, (2.3.5) is the patient household Euler equation with respect to one-period debt, and (2.3.6) is the patient household Euler equation with respect to two-period debt.[9] Combining (2.3.5) and (2.3.6), the two log linearized Euler equations, yields the interest rate arbitrage condition:

$$\beta' \hat{R}_{t+1}^e + \hat{R}_t(\beta' + 1) = \frac{(1 + \beta')(2 + \beta'^{-1})}{(1 + \beta'^{-1})} \hat{R}F_t \tag{2.3.7}$$

which implies that the patient households must be indifferent between lending to each other in the one-period bond market and lending to the impatient households and entrepreneurs in the two-period mortgage market.

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[9]The money demand equation is standard and falls out of the first order condition with respect to money. In what follows, I impose that the central bank sets the interest rate according to a Taylor rule and, consequently, money balances have no impact on the model and are thus disregarded.

Impatient Households:

Impatient households, indicated by the double prime symbol, are borrowers and have a lower discount factor than the patient households, $\beta'' < \beta'$, which implies that in equilibrium the borrowing constraint of the impatient household is binding.[10] In the model, the impatient households are borrowers and are typically poorer than the patient households. In the context of the recent financial crisis, these agents can be thought of as the poorer, including sub-prime, borrowers. Impatient households finance their current consumption and housing, both of which affect their utility, with borrowed funds. Housing purchases can be thought of as residential real estate, as the impatient households are wage workers and not producers. Impatient households maximize lifetime expected utility subject to a flow of funds constraint and a credit constraint.

$$\underset{c_t'' \, L_t'' \, h_t'' \, \frac{M_t''}{P_t}}{\text{Max}} \quad E_0 \sum_{t=0}^{\infty} \beta''^t (lnc_t'' + jlnh_t'' - \frac{L_t''^{\eta}}{\eta} + xln\frac{M_t''}{P_t}) \tag{2.3.8}$$

subject to the real budget constraint:

$$c_t'' + q_t(h_t'' - h_{t-1}'') + \frac{(R_{t-1}^F)^2}{(1 + R_{t-1}^F)\pi_t} b_{t-1}'' + \frac{(R_{t-2}^F)^2}{(1 + R_{t-2}^F)\pi_t\pi_{t-1}} b_{t-2}'' \leq b_t'' + w_t'' L_t'' + T_t'' - \frac{(M_t'' - M_{t-1}'')}{P_t}$$

and the real borrowing constraint:

$$\frac{b_t'' RF_t^2}{1 + RF_t} + \frac{b_{t-1}'' RF_{t-1}^2}{(1 + RF_{t-1})\pi_t} \leq m'' E_t[q_{t+1}\pi_{t+1}h_t''] \tag{2.3.9}$$

In each period, the borrower will pay back, in nominal terms:

$$\chi_t = \frac{(R_t^F)^2 B_t}{1 + R_t^F}$$

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[10]Note that if $\beta'' = \beta'$ (or the entrepreneur discount factor, γ, equals β') then there is no borrowing or lending in financial markets and the Lagrange multiplier on the credit constraint is equal to zero.

In time t, the borrower is paying back the periodic payment χ on loans taken out in time $t-1$ and $t-2$ with a payment each period of χ_{t-1} and χ_{t-2}, respectively.

To further emphasize the contribution of this paper, the traditional nominal credit constraint as in Iacoviello (2005) is depicted below:

$$B_t R_t \leq m E_t[Q_{t+1} h_t]$$

The standard one-period nominal debt credit constraint ensures that the repayment of debt and interest received by the lender is less than or equal to the value the lender could collect if he seized the borrower's home in the case of default. The function $(1-m)E_t[Q_{t+1}h_t]$ represents the transaction costs associated with repossessing a home, such that the lender would claim a proportion m of the foreclosed property. When $m = 0$, the borrower has no recoverable collateral and consequently cannot borrow. As m increases, the lender possesses more collateral and can borrow more. Therefore, a higher value of m will necessarily result in larger debt obligations.

The parameters m and m'' can be interpreted more broadly than the literature typically allows. Traditionally, m and m'' are incorporated in the credit constraint to acknowledge that asset value is not completely recoverable. For instance, in the foreclosure process, when default on a mortgage occurs, the full value of the home loan is almost never fully recovered when the bank seizes the property. The parameters that represent proportion of recoverable capital can also be viewed as a loan-to-value ratio. Consider the steady-state credit constraint for impatient households. Solving for m'':

$$m'' = \frac{2\bar{b}''\overline{RF}^2}{\bar{q}\bar{h}''(1 + \overline{RF})}$$

which implies that m'' is equal to the total debt owed by impatient households (including

interest) divided by the total value of impatient household housing.[11] For poor households, the majority of their net worth is concentrated in their home. Figure 2.2 shows the percent of total holdings for households in the lowest quintile of net worth.[12]

Figure 2.2: Percent of Total Holdings—Households in the Lowest Quintile of Net Worth
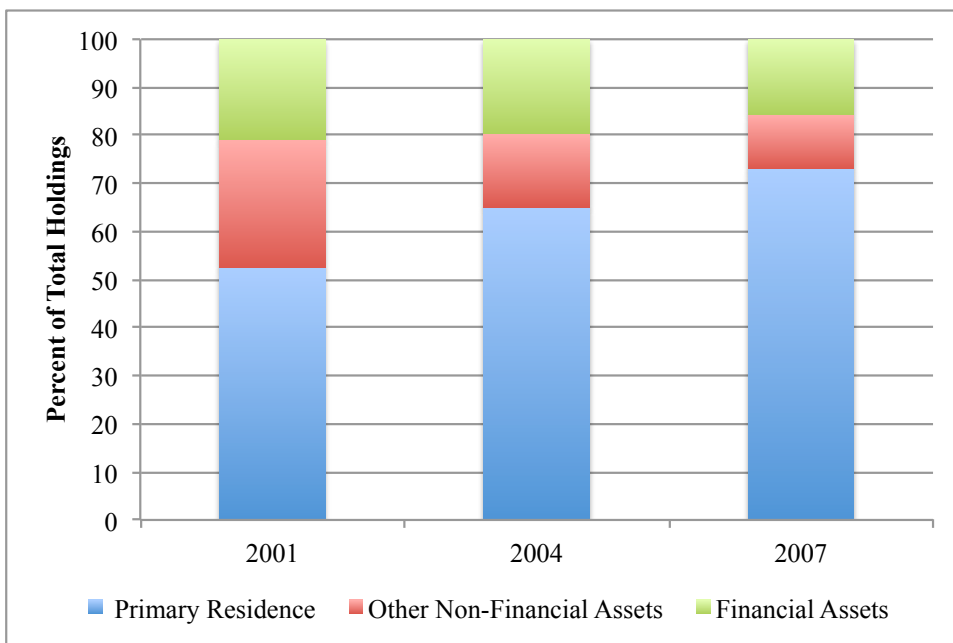
In the model, the impatient households are typically the poorer households. Based on the fact that the net worth of less wealthy households is derived from their homes, it is reasonable to begin to think about the parameter m'' as a debt-to-assets ratio. For the entrepreneurs, the parameter m represents a leverage ratio, equal to the amount of capital owned by the firm divided by the firm's total assets.

The proportion of recoverable capital, loan-to-value ratio, or leverage ratio can also be viewed as a policy parameter. It is feasible to have a federal limit placed on the amount of

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[11]Consider the case where $\overline{RF} = 1$, then $m'' = \frac{\bar{b}''}{\bar{q}\bar{h}''}$ or m'' is equal to the loan-to-value ratio exactly.

[12]The data for the chart above was collected from the Survey of Consumer Finances produced by the Federal Reserve System Board of Governors. Financial assets include transaction accounts, certificates of deposit, savings bonds, stocks, pooled investment funds, retirement accounts, and cash value in life insurance. Other non-financial assets include vehicles and business equity. For both, there is also a miscellaneous category that captures any other type of asset that was omitted.

borrowing as a fraction of asset value, especially if it is utility enhancing for the borrower.

The first order conditions for the impatient households are

$$\frac{w_t''}{c_t''} = L_t''^{\eta-1} \tag{2.3.10}$$

$$\frac{q_t}{c_t''} = \frac{j}{h_t''} + \beta'' E_t \left[\frac{q_{t+1}}{c_{t+1}''}\right] + \rho_t'' m'' E_t[q_{t+1}\pi_{t+1}] \tag{2.3.11}$$

$$\frac{1}{c_t''} = \frac{RF_t^2}{1+RF_t} E_t \left[\frac{\beta''}{c_{t+1}''\pi_{t+1}} + \frac{\beta''^2}{c_{t+2}''\pi_{t+1}\pi_{t+2}} + \rho_t'' + \frac{\beta''\rho_{t+1}''}{\pi_{t+1}}\right] \tag{2.3.12}$$

where (2.3.10) is impatient household labor supply, (A.4.15) is impatient household housing demand, and (2.3.12) is the impatient household Euler equation with respect to two-period debt.

Entrepreneurs:

Entrepreneurs produce a homogeneous intermediate good employing a Cobb-Douglas constant returns to scale production function with household labor and housing stock as inputs. The intermediate good cannot be consumed—it is sold to retailers, who costlessly transform it into the final good. Entrepreneurs maximize lifetime consumption subject to the production function, a budget constraint, and a borrowing constraint.[13] To ensure that in the steady state the credit constraint is binding, entrepreneurs discount the future more heavily than patient households, implying $\gamma < \beta'$.

$$\underset{c_t}{\text{Max}} \quad E_0 \sum_{t=0}^{\infty} \gamma^t ln c_t \tag{2.3.13}$$

subject to the production function:

$$Y_t = A_t h_{t-1}^v L_t'^{\alpha(1-v)} L_t''^{(1-\alpha)(1-v)} \tag{2.3.14}$$

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[13] Iacoviello (2005) imposes that the utility of entrepreneurs depends only on consumption.

where A_t is a stochastic technology process. It is important to note that housing and the two types of labor are inputs in the Cobb-Douglas production function, which implies that they are imperfect complements. The complementarity of impatient and patient household labor are an important part of the system dynamics. When patient household labor supply increases, this increases the marginal product of labor for the impatient households and vice versa. Entrepreneurs are also subject to a cash flow constraint:

$$\frac{Y_t}{X_t} + b_t \geq c_t + q_t(h_t - h_{t-1}) + w_t^{'}L_t^{'} + w_t^{''}L_t^{''} + \frac{(R_{t-1}^F)^2}{(1 + R_{t-1}^F)\pi_t}b_{t-1} + \frac{(R_{t-2}^F)^2}{(1 + R_{t-2}^F)\pi_t\pi_{t-1}}b_{t-2}$$

(2.3.15)

where X_t is the markup of the final good over the intermediate good, which is equal to P_t/P_t^w. As in Bernanke et al. (1999), the price P_t^w is the wholesale price which retailers pay to the entrepreneurs for the intermediate good, and the price P_t is the price at which the final good is sold to consumers. The amount entrepreneurs can borrow is limited based on the following credit constraint:

$$\frac{b_t RF_t^2}{1 + RF_t} + \frac{b_{t-1}RF_{t-1}^2}{(1 + RF_{t-1})\pi_t} \leq mE_t[q_{t+1}\pi_{t+1}h_t]$$

(2.3.16)

The first order conditions for the entrepreneurs are

$$w_t^{'} = \frac{(1 - v)\alpha Y_t}{X_t L_t^{'}}$$

(2.3.17)

$$w_t^{''} = \frac{(1 - v)(1 - \alpha)Y_t}{X_t L_t^{''}}$$

(2.3.18)

$$\frac{q_t}{c_t} = E_t\left[\frac{\gamma}{c_{t+1}}\left(\frac{vY_{t+1}}{X_{t+1}h_t} + q_{t+1}\right) + \rho_t m q_{t+1}\pi_{t+1}\right]$$

(2.3.19)

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$$\frac{1}{c_t} = \frac{(R_t^F)^2}{1 + R_t^F} E_t \left[\frac{\gamma}{c_{t+1}\pi_{t+1}} + \frac{\gamma^2}{c_{t+2}\pi_{t+1}\pi_{t+2}} + \rho_t + \frac{\gamma\rho_{t+1}}{\pi_{t+1}} \right] \tag{2.3.20}$$

where (2.3.17) is entrepreneur demand for patient households labor, (2.3.18) is entrepreneur demand for impatient household labor, (2.3.19) is entrepreneur housing demand, and (2.3.20) is the entrepreneur Euler equation.

Retailers:

The retailers' problem is identical to that of Bernanke et al. (1999) and Iacoviello (2005). The monopolistic competition distortion is introduced in the real estate sector with an implicit cost to adjusting prices. Retailers purchase the intermediate good from entrepreneurs at P_t^w and differentiate it into the consumption good. The final good is defined as

$$\int_0^1 Y_t(z)^{(\epsilon-1)/\epsilon}\, dx.$$

Central Bank:

The central bank makes lump-sum transfers to households to employ a simple policy rule. The Taylor rule the central bank responds to changes in lagged inflation and the output gap:[14]

$$\hat{R}_t = (1 + r_\pi)\hat{\pi}_{t-1} + r_Y \hat{x}_{t-1} + \hat{e}_{R,t}$$

Figure 2.3 describes the relationship between agents in the model outlined in Section 2.3.

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[14]A contemporaneous policy rule is also considered in Section 2.5.
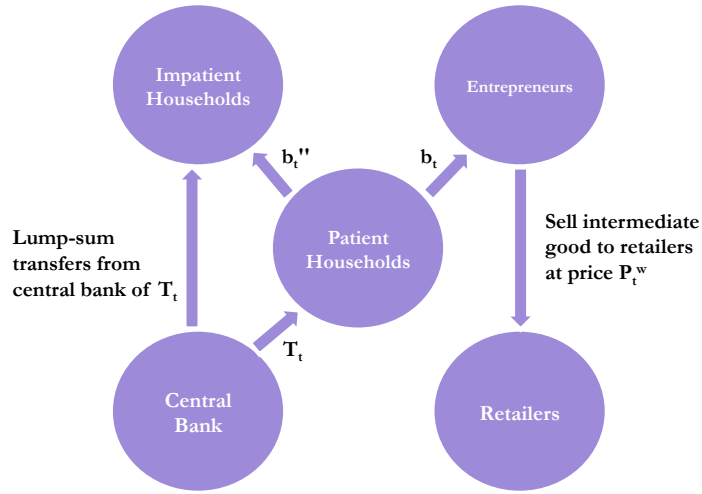
Figure 2.3: Model Structure

Three market clearing conditions and the New-Keynesian Phillips curve close the model:

$$Y_t = c_t + c_t^{'} + c_t^{''} \tag{2.3.21}$$

$$H = h_t + h_t^{'} + h_t^{''} \tag{2.3.22}$$

$$0 = b_t + b_t^{'} + b_t^{''} \tag{2.3.23}$$

$$\pi_t = \beta E_t[\pi_{t+1}] + \kappa x_t \tag{2.3.24}$$

The complete log-linearized model is presented in Appendix A.4.

2.4 The Steady State

The steady-state results are derived using standard calibrations shown in Table 2.1, following Iacoviello (2005).

Table 2.1: Calibrations

Parameter	Value
β'	0.99
β''	0.95
γ	0.98
X	1.05
j	0.10
υ	0.03
η	1.01
κ	0.024
r_R	0.73
r_π	0.27
r_Y	0.035
α	0.64
m	0.89
m''	0.55
ρ_A	0.95

In the steady state, patient households consume about twice as much as the impatient households and supply less labor than the impatient households. The patient households also own the majority of the housing stock and are the wealthiest agents in the model. In equilibrium, the entrepreneurs borrow far more than the impatient households. While housing does not directly increase the entrepreneur's utility, it does serve as an input to production, increasing profits and allowing them to consume more. The Lagrange multiplier on the credit constraint is larger for the entrepreneurs than the impatient households, which reflects the greater increase in lifetime utility from borrowing an additional dollar this period and decreasing consumption accordingly in the subsequent period. In other words, the entrepreneurs experience a greater loss in discounted utility from not borrowing. So, in the steady state, entrepreneurs borrow

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far more than the impatient households. Table 2.2 displays the steady-state values of select variables:

Table 2.2: The Steady State

Variable	Patient Households	Impatient Household	Entrepreneurs
Consumption	0.61	0.29	0.02
Housing	0.52	0.15	0.33
Debt	-4.36	0.97	3.38
Labor	0.89	1.05	–
Wage	0.61	0.29	–
Lagrange Multiplier	–	0.21	0.81

The steady-state level of output given the initial calibration is equal to 0.92, the mark-up is equal to 1.05, and lump-sum profits are equal to 0.04. In the steady state, housing prices are equal to 11.67. Also note, in equilibrium, the interest rate on two-period loans is equal to the interest rate on one-period loans, since there is no default.[15] Therefore, in the steady state, patient households are indifferent between lending to each other in the one-period bond market and lending to the impatient households or entrepreneurs in the two-period debt market. The no arbitrage condition is also driven by the absence of default in the two-period debt market. While the threat of default matters, borrowers cannot be insolvent in this model, a standard assumption in the credit constraints literature. See Appendix A.3 for a complete description of the steady state.

The Effects of Changes in Access to Credit

Next, I allow the recovery rate for the entrepreneurs, m, to vary and examine the steady-state dynamics holding constant the recovery rate for the impatient households at its calibrated value, $m'' = 0.55$. Lower values of m imply that the agent has less recoverable collateral and cannot borrow as much. Higher values of m increase the limit on debt obligations for the agent and allows him to borrow more. The positive relationship between the recovery rate and debt is

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[15]The interest rates $\bar{R}$ and $\bar{R}^F$ are equal to 1.01 in the steady state.

evident in Figure 2.4. The scales for debt and consumption are normalized such that the initial value for both variables is equal to one.[16]

Figure 2.4: Entrepreneur Debt and Consumption
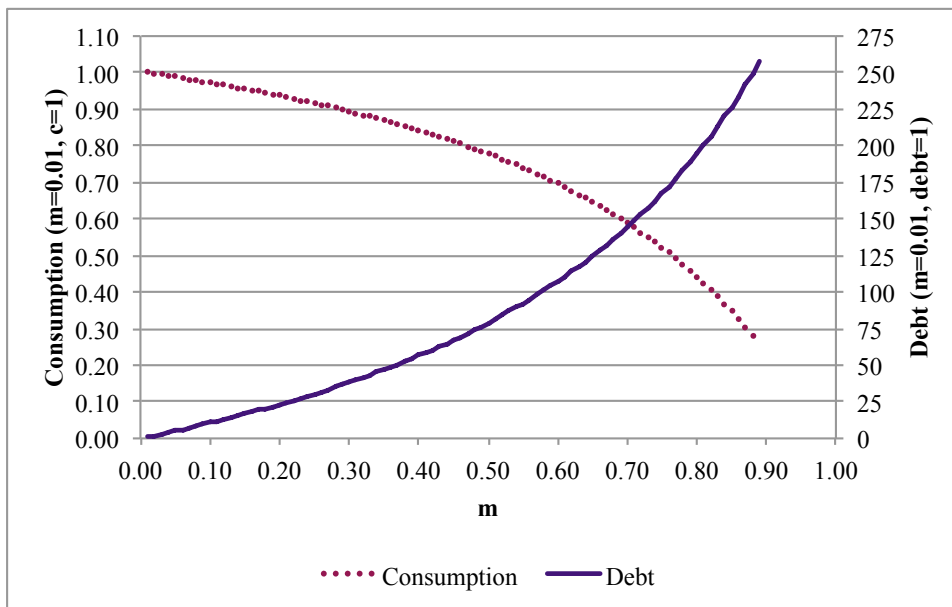
For the entrepreneurs, increased borrowing implies lower levels of consumption spending. Entrepreneurs, facing a binding borrowing constraint, purchase more housing and less of the consumption good when the recovery rate increases and the amount they are capable of borrowing increases.

Varying the recovery rate has consequences for the economy as a whole in equilibrium. As m increases from 0.01 to 0.90 and entrepreneurs are allowed to borrow more, the steady-state level of output declines significantly by approximately 3.19%.[17] This result suggests that allowing firms to be highly leveraged can be detrimental for economic activity. In addition, the wealthier agents in the economy are made better off and the poorer agents become poorer. It is more reasonable to consider a smaller change in m, one that policy may be able to implement. If m were to increase from its 2003 level of about 0.73 to 0.90, the steady-state level of output

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[16]Henceforth, all figures will normalize the initial values of the variables to one.

[17]Note, at values of m greater than 0.90 the steady state is no longer well-behaved.

would drop about 1.63%, which is still a very significant amount. Figure 2.5 depicts this phenomenon, holding m'' constant:[18]

Figure 2.5: Patient and Impatient Household Consumption
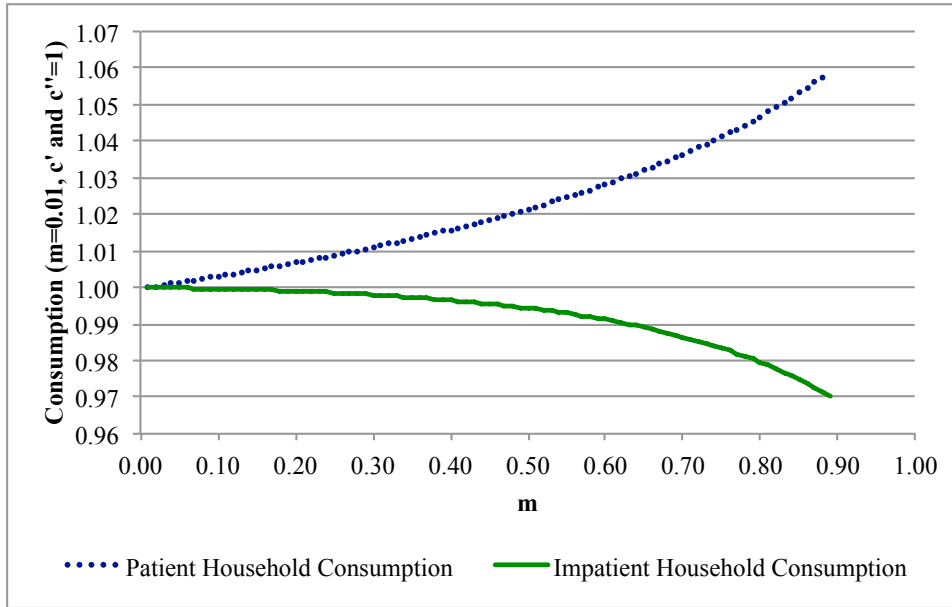
In the long run, firms borrowing to finance investment expenditures can decrease the steady-state level of output. Patient households increase the amount they lend to support the entrepreneurs' increased demand for debt. Anticipating future income from repayment of issued debt, patient households supply less labor, increasing their marginal product of labor, and driving up the wage for patient households. As patient household labor becomes more expensive, the firm's budget constraint tightens and the wage for impatient households falls. The return to borrowing for the impatient households decreases (represented by the Lagrange multiplier on the impatient household credit constraint) and the amount they borrow falls. With the reduction in labor income and loans, impatient household consumption and housing decreases. As entrepreneurs are able to borrow more with a higher proportion of recoverable collateral, they substitute away from consumption and towards housing. The change in lifetime utility as a result of borrowing an extra dollar today, spending it on housing or the consumption good, and

_____

[18]Again, starting values of consumption are normalized.

reducing consumption by the appropriate amount the following period increases dramatically for the entrepreneurs as they are able to borrow more. Entrepreneurs increase their housing by a factor of over 1.23, as m rises from 0.01 to 0.90. This dramatic increase in housing demand drives up housing prices.

Figure 2.6 shows the increase in entrepreneur housing and housing prices, about 33%.

Figure 2.6: Housing and Housing Prices
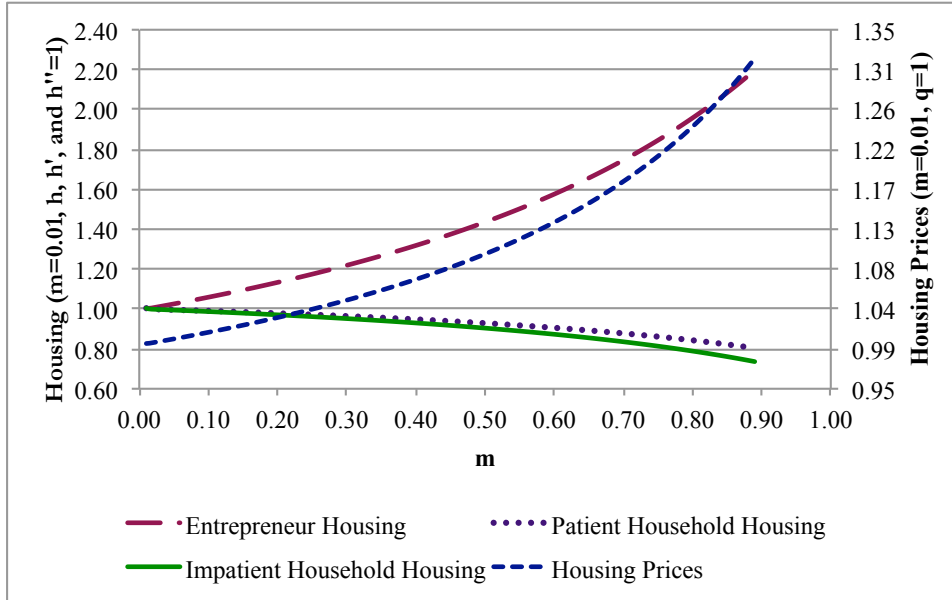
Since the housing stock is fixed, an increase in entrepreneur housing requires a decline in patient household and/or impatient household housing. As the amount of recoverable collateral for the entrepreneurs rises, impatient households and patient households decrease their housing stock. Impatient households lose approximately 27% of their housing and patient households find their housing stock depleted by about 20%.

Interestingly, when the equivalent parameter for impatient households is altered, the steady-state level of output rises approximately 2.72% over values of m'' from 0.01 to 0.79, holding m constant at its calibrated value 0.89. Again, consider a smaller change in m'' at an empirically plausible value. Suppose m'' increases from its 2003 value of approximately 0.73 to the maximum in this calibration 0.79. In this case, the steady-state level of output falls 2.56%, which

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would be detrimental to the economy. The same parameter implications as above apply in this situation to impatient households. As m'' rises, impatient households possess more recoverable collateral, allowing them to increase their debt. Borrowing more implies lower levels of consumption spending. Again, the link between m'', debt, and consumption can be seen in Figure 2.7 for the impatient household consumption.

Figure 2.7: Impatient Household Debt and Consumption
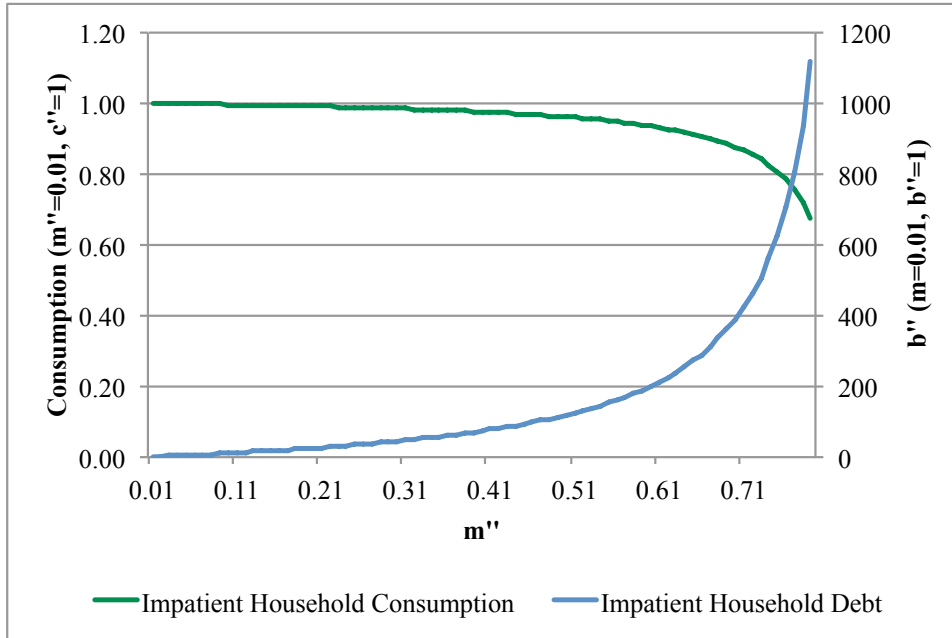
The effect on impatient household housing is analogous to the case where we vary m—the agent with increased recoverable collateral purchases more housing and accrues more debt. Impatient household housing rises by a factor of 6.42 as m'' varies from 0.01 to 0.79.[19] At higher values of m'', impatient household consumption spending declines. The impatient household first order conditions in the steady state imply a trade-off between housing and consumption. Allowing impatient households to borrow more increases the return to borrowing and housing purchases, decreasing consumption spending. Figure 2.8 shows the impact of changes in impatient household recoverable collateral on the housing market.

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[19]Again, at values of m'' greater than 0.79 the steady state is not defined.

Figure 2.8: Housing and Housing Prices
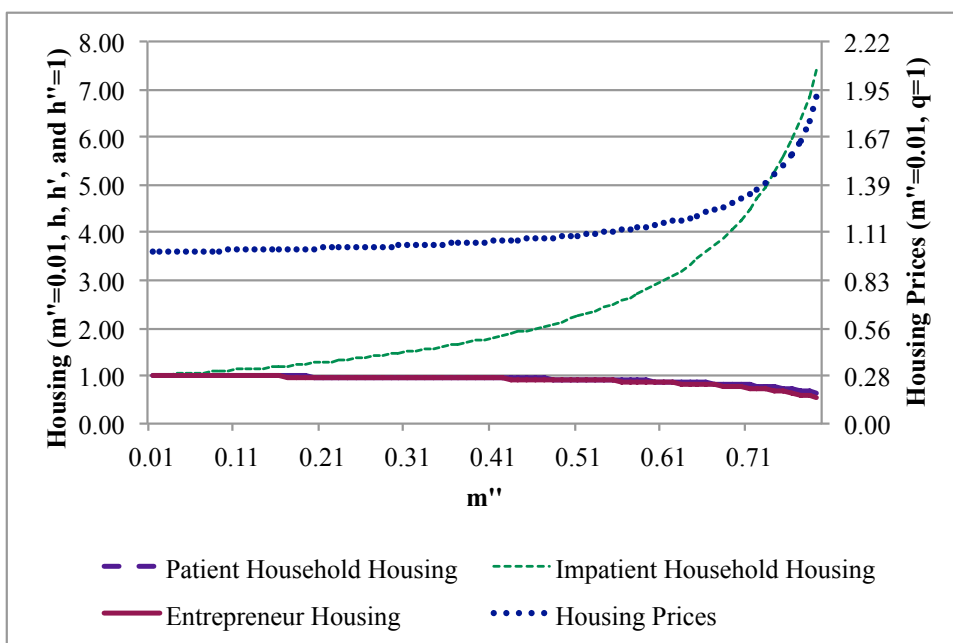
Recall that the housing stock is fixed in this model, so an increase in impatient household housing necessitates a decrease in at least one of the other housing types. In this case, the patient households and entrepreneurs both decrease the amount of housing they own. The demand effect of the impatient household housing increase dominates and housing prices increase. This is consistent with the empirical evidence and effects observed during the recent housing bubble. As households, particularly poor households, were allowed to borrow more, they purchased more housing and real estate prices rose. See Figure 2.9 below, which shows the leverage ratio by percentile of net worth from 2001 to 2010.[20]

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[20]The data used to create Figure 2.9 are from Table 12 in the Survey of Consumer Finances produced by the Board of Governors of the Federal Reserve System.

Figure 2.9: Leverage Ratio by Quintile of Net Worth
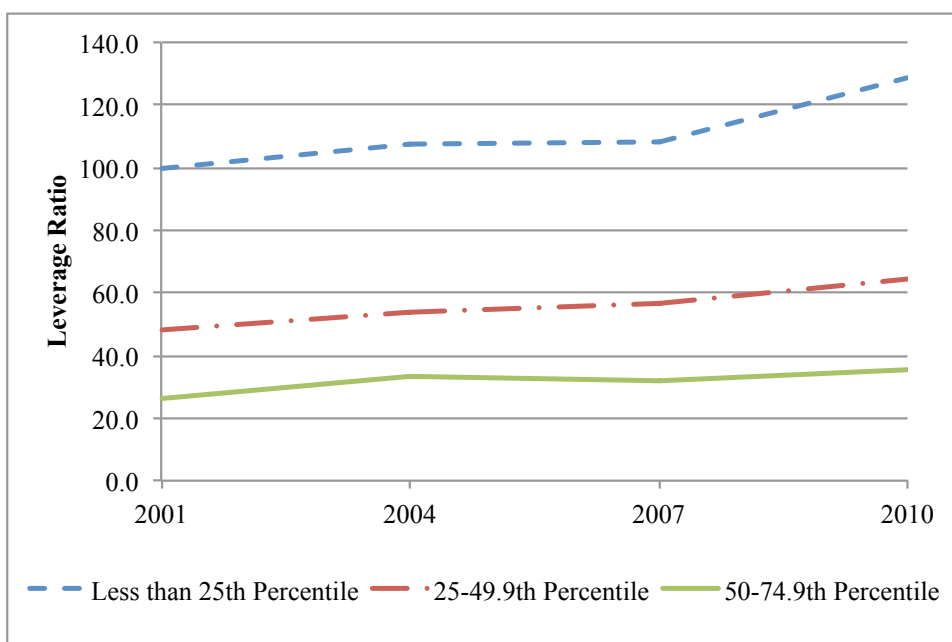
As impatient households can borrow more, their consumption decreases. Recall, the increase in m'' from 0.01 to 0.79 has increased the steady-state level of output 2.72%. As a result of aggregate demand increasing and impatient household consumption decreasing, consumption of the other two agents in the model increases over values of m''.

Figure 2.10: Patient Household and Entrepreneur Consumption
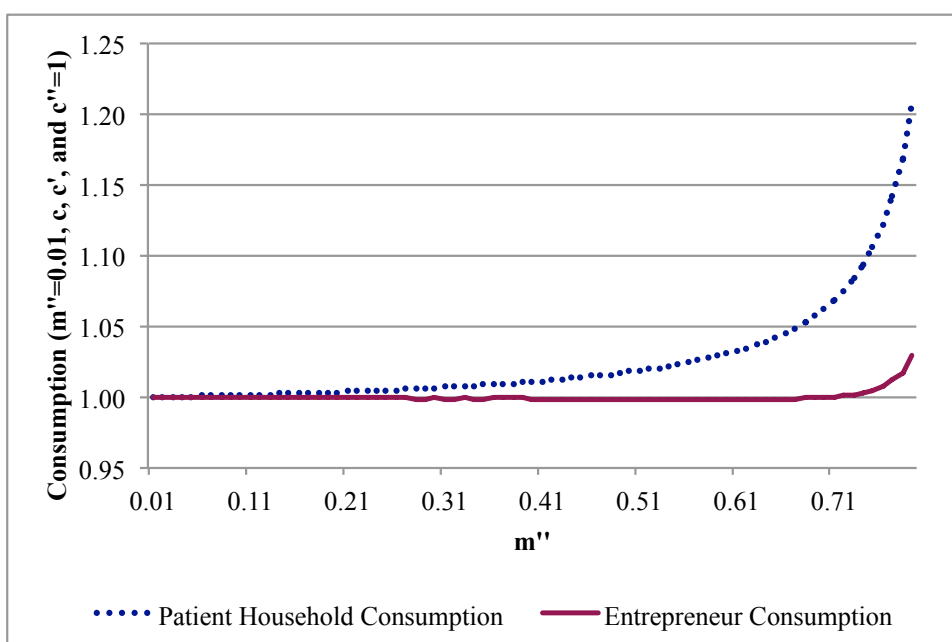
Changing the amount impatient households can borrow, unsurprisingly, has the largest effects on their own consumption and the lenders consumption. Steady-state consumption of the impatient households falls by 32.47% and steady-state consumption of the patient households rises by 20.79%. See Figure 2.10 for details on patient household and entrepreneur consumption.

It is clear from the above analysis that the loan-to-value ratio for firms and households has a significant impact on steady-state consumption, housing, housing prices, debt, and output; however, the impact on aggregate and individual well-being is not obvious. The following section discusses the welfare implications of changes in m and m''.

Welfare Analysis

In this section, in an effort to inform policy and the optimal value of m and m'' under different social planner preferences, a welfare analysis is conducted. Recall from Section 2.3 that these parameters can be interpreted as loan-to-value ratios for firms and households respectively.

Patient household steady state utility is maximized when either the firm loan-to-value ratio is at its maximum (0.90) or the impatient household loan-to-value ratio is at its highest value (0.79).[21] The utility behavior of the impatient households and entrepreneurs is slightly more complicated. Both impatient household utility and entrepreneur utility is maximized when m is equal to 0.01. In other words, both impatient households and entrepreneurs prefer the case where entrepreneurs can borrow the least amount possible. At first glance, it may appear counterintuitive that firms prefer to not be able to borrow; however, this could be a function of their utility only depending on consumption or this could be because they maximize expected lifetime utility, not steady-state utility. Of course, housing contributes to aggregate output and through this relationship affects consumption, but the entrepreneurs would prefer to spend directly on consumption.

For impatient households, the desire for a low m is obvious. If entrepreneurs can borrow more, they demand more housing which drives up real estate prices making it less affordable for impatient households to purchase, housing, which is a direct contributor to impatient household utility. Impatient household utility is maximized when the loan-to-value ratio for households, as opposed to firms, is equal to 0.33. This result implies that impatient households are better off when their borrowing is limited, despite the fact that housing contributes directly to impatient household utility. The utility of firms is highest when impatient households borrow large amounts ($m^{''}$ is maximized). Since entrepreneur utility does not depend directly on housing, even though their housing stock is declining, the utility of firms is increasing due to the positive effects on aggregate output and their consumption.

A society that cares about only one type of agent can inform policy using only individual agent utility. For the most part, we consider this an unreasonable assumption. Therefore, we

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[21]Recall that at values higher than these respective calibrations the steady state is not well-behaved. Determining the effects of loan-to-value ratios that approach or exceed 1 on the steady state and welfare is left for future research.

now consider a utilitarian regime in which the social planner seeks to maximize:

$$U^{'}(c_t^{'}, h_t^{'}, L_t^{'}) + U^{''}(c_t^{''}, h_t^{''}, L_t^{''}) + U(c_t)$$

The sum of individual utilities is maximized when m is equal to 0.01. A low value of m, minimizing the amount firms can borrow, is optimal if the social planner has utilitarian preferences. A Rawlsian social planner maximizes:

$$Min\{U^{'}(c_t^{'}, h_t^{'}, L_t^{'}), U^{''}(c_t^{''}, h_t^{''}, L_t^{''}), U(c_t)\}$$

Again, we find that the optimal value of m is 0.01. The implication for the parameter m is that unless a society cares strictly about maximizing patient household (or wealthier household) utility, then the policymaker should aim to keep borrowing of firms low. Policymakers could influence m through a variety of routes, most notably, setting a maximum debt-to-equity ratio for firms.

Holding constant the value of m at 0.89 and allowing the loan-to-value ratio for households to vary, utilitarian preferences imply that the optimal value of $m^{''}$ is 0.49. On the other hand, a Rawlsian social planner would choose $m^{''}$ equal to 0.79. The policy decision is less clear for household borrowing. Again, the patient households benefit when the impatient households borrow more, as do the entrepreneurs. However, impatient households prefer a loan to-value ratio of approximately 0.33. Societal preferences also impact the desired loan-to-value ratio of households. A case could be made for a lower loan-to-value ratio for households, 0.49, or increasing the debt obligations of households by raising $m^{''}$ to 0.79. Through regulation of mortgage markets, policymakers could set a minimum and/or maximum loan-to-value ratio to maximize welfare.

We can more concretely analyze the social welfare loss of various policies by transforming utilities into percentage of consumption lost. Consider a utilitarian social welfare function that only depends on consumption, holding constant labor and housing. For different values of m,

we can calculate the social welfare loss relative to the maximum value of social welfare loss. The social welfare function when consumption utility is maximized with utilitarian preferences is given by:

$$SW|_{m=0.01} = ln(c_t'|_{m=0.01}) + ln(c_t''|_{m=0.01}) + ln(c_t|_{m=0.01})$$

The social welfare loss for any value of m is equal to:

$$SW|_{m=0.01} - SW|_m = \Gamma$$

or

$$\begin{aligned}\Gamma = &ln(c_t'|_{m=0.01}) + ln(c_t''|_{m=0.01}) + ln(c_t|_{m=0.01})\\ &- [ln((1-x)c_t'|_{m=0.01}) + ln((1-x)c_t''|_{m=0.01}) + ln((1-x)c_t|_{m=0.01})]\end{aligned} \qquad (2.4.1)$$

where x represents the decrease in consumption associated with changing m. Solving for x:

$$x = 1 - \frac{1}{e^{\Gamma/3}}$$

The value of x is the constant fraction of steady-state consumption that is equivalent to the welfare loss that comes from changing m. Using the percentage lost of steady-state consumption as an evaluation criterion, we can examine changes in m from a different perspective. The same general conclusions are true; however, the impact of a change in m becomes much more concrete. When entrepreneurs are allowed to borrow more, they are hurt more than any other agent in the economy. Figure 2.11 shows the fraction of firm steady-state consumption lost when m increases from 0.01 to 0.90.

Figure 2.11: Entrepreneur Steady-State Consumption Loss
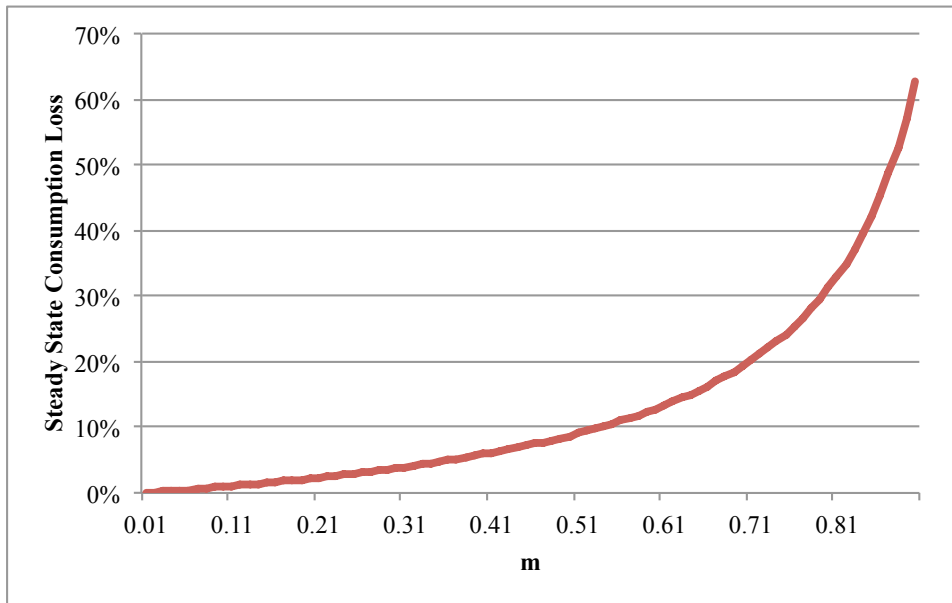
Firms lose approximately 63% of their steady-state consumption when m is equal to 0.90 versus 0.01. Both types of households are also impacted by changes in the borrowing rate of entrepreneurs, as shown in Figure 2.12.

Figure 2.12: Household Steady-State Consumption Loss

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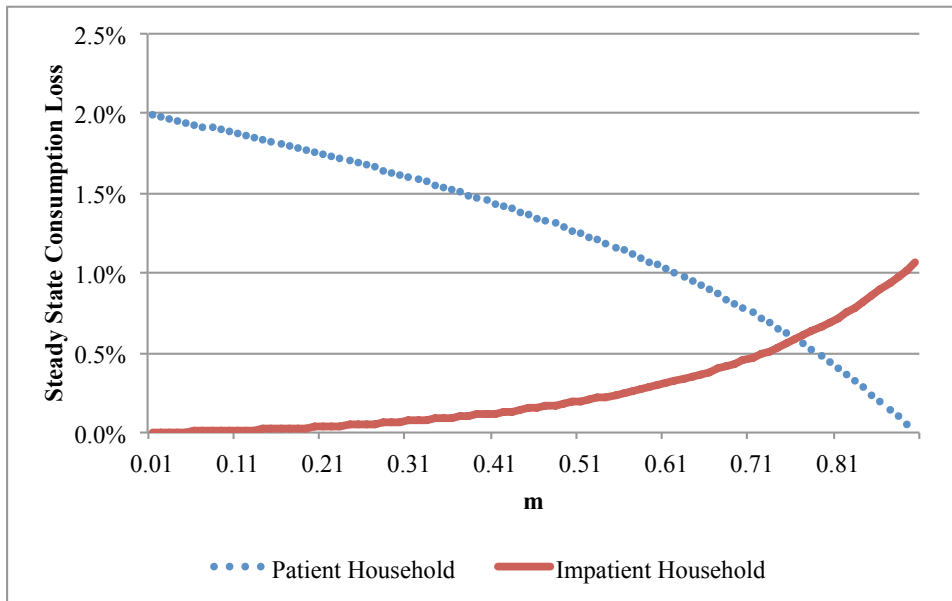
Patient household welfare is maximized when firms borrow heavily. Patient households lose approximately 2% of their steady-state consumption when entrepreneurs have little recoverable collateral. Changing m has the opposite effect on impatient households. When m is equal to 0.90, impatient households experience a decrease in steady-state consumption of about 1.1%.

We can use an analogous method to analyze the effects of a change in $m^{''}$ on steady-state consumption. Figure 2.13 shows these effects.

Figure 2.13: Steady-State Consumption Loss
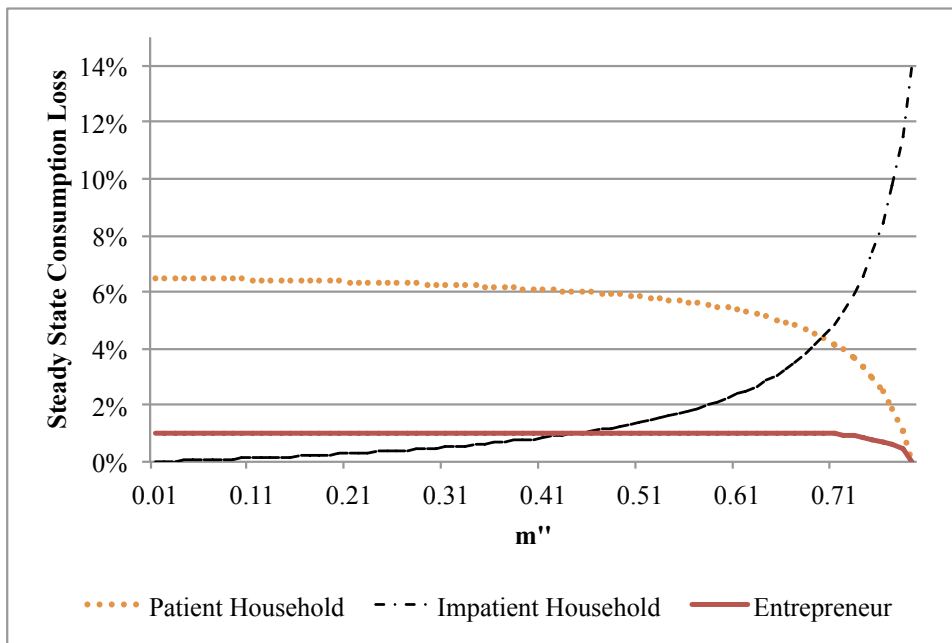
Patient households and entrepreneurs are better off at higher levels of $m^{''}$. The welfare loss associated with a low loan-to-value ratio for households is about a 6.5% loss in patient household steady-state consumption and a 1% decline in entrepreneur steady-state consumption. Impatient households are significantly better off at lower levels of $m^{''}$. As the loan-to-value ratio increases to 0.79, impatient households lose approximately 14% of their steady-state consumption. The policymaker should consider all of these competing effects in determining the social welfare function.

2.5 Monetary Policy

The current literature has evaluated the impact of credit constraints on monetary policy in a New-Keynesian framework.[22] These papers find negligible benefits in terms of inflation and output stabilization when asset prices are included in a simple monetary policy rule. However, they do not consider the effects of including asset markets and borrowing limits on determinacy of equilibrium. In addition to reducing output and inflation volatility, it is reasonable to assume a goal of the central bank is to ensure a unique, stable equilibrium. We can begin to talk about desired monetary policy more broadly when we consider that an indeterminate solution or no solution is not ideal. Indeterminacy can result in additional volatility if agents are not able to coordinate on one of the many equilibria, reducing welfare. There is also empirical support for monetary policy that results in indeterminacy contributing to volatile periods in history (particularly, the late 1960s and 1970s).[23]

For a contemporaneous interest rate rule, the response of monetary policy to inflation must be more than one-to-one in order to ensure determinacy. Considering a forward-looking interest rate, the central bank should neither be too aggressive nor too passive in response to changes in expected inflation and deviations of output from its target to avoid an indeterminate solution.[24] The majority of the New-Keynesian literature that incorporates a housing market largely abstracts from discussing determinacy. One notable exception is Xiao (2013), however, the conclusion has a similar sentiment to the remainder of the literature. He shows that responding to asset prices in a simple contemporaneous interest rate rule has little to no effect on the E-stability and determinacy regions. While Xiao (2013) does incorporate housing and credit constraints, he only examines household debt, not firm debt, and does not analyze the impact of long-term borrowing.

In order to examine the conditions for determinacy, the system can be reduced to 22 equa-

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[22]See, for example Iacoviello (2005) and Bernanke and Gertler (2001).

[23]See Clarida et al. (2000) and Lubik and Schorfheide (2004).

[24]For a more complete discussion of the indeterminacy region for the forward-looking interest rate rule, see Gali (2008).

tions (including the backward-looking policy rule) and 22 variables, written as:

$$X_t = JX_{t+1} + K\varepsilon_t$$

where X_t is a vector of variables remaining in the system and ε_t is a vector of shocks. Of the 22 variables in the system, there are 8 expectational variables ($\hat{\pi}_{t+2}$, $\hat{c}_{t+2}$, $\hat{c}'_{t+2}$, $\hat{c}''_{t+2}$, $\hat{x}_{t+2}$, $\hat{q}_{t+2}$, $\hat{\rho}^e_{t+1}$, $\hat{\rho}''^e_{t+1}$) that each require a saddle condition to ensure determinacy. Therefore, if there are 8 eigenvalues of J outside the unit circle, the solution will be determinate. If there are more than 8 eigenvalues of J outside the unit circle, this will correspond to indeterminacy and undesirable policy. In the case where there are less than 8 eigenvalues of J outside the unit circle, no unique solution exists.[25]

Figure 2.14 examines determinacy when the central bank uses a backward-looking interest rate rule that responds to inflation and the output gap:

$$\hat{R}_t = (1 + r_\pi)\hat{\pi}_{t-1} + r_Y\hat{x}_{t-1} + \hat{e}_{R,t}$$

in log-linearized form. The horizontal axis is the coefficient on lagged inflation $(1 + r_\pi)$, and the vertical axis is the coefficient on the output gap (r_Y), where the maximum value of each coefficient is 2. The region not filled in represents policy that results in a determinate equilibrium.

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[25]Note that when the contemporaneous policy rule is used to set the nominal interest rate instead of the backward-looking rule, the conditions for determinacy change. In this case, 7 eigenvalues outside of the unit circle corresponds to determinacy, less than 7 eigenvalues outside of the unit circle implies explosiveness, and more than 7 eigenvalues outside of the unit circle results in indeterminacy.

Figure 2.14: Backward-looking Interest Rate Rule
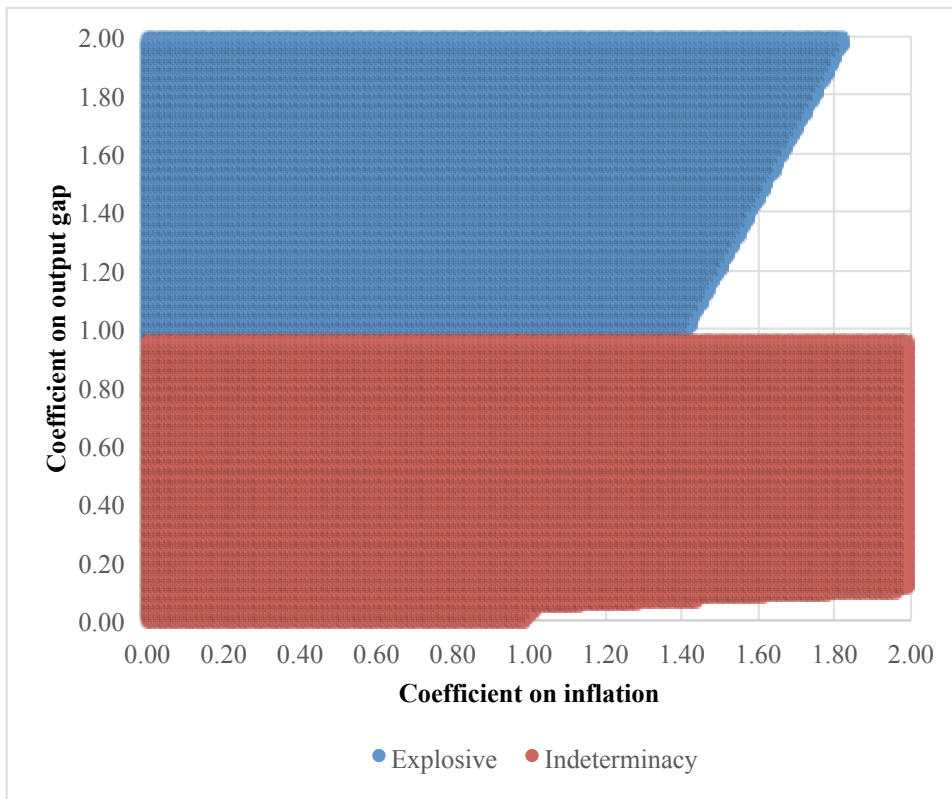
These results make it more difficult for monetary policy to ensure determinacy and reduce volatility compared to the traditional region of indeterminacy in the baseline New-Keynesian model. The responses must be very precise. There is no longer a determinate equilibrium corresponding to a small response to inflation and a response to the output gap between about 0.20 and 2.20. In an economy with long-term debt, the central bank must always respond to changes in inflation with a more than one-to-one response. Monetary policy must also be very precise, as a response to output that is larger than about 0.05 could result in indeterminacy. However, the central bank does have an alternate region of determinacy that can be reached with a large response to inflation and an aggressive response to changes in the output gap.

Figure 2.15 plots the determinacy region assuming that the central bank follows a contem-

poraneous policy rule:

$$\hat{R}_t = (1 + r_\pi)\hat{\pi}_t + r_Y \hat{x}_t + \hat{e}_{R,t}$$

responding to current inflation and the current output gap.

Figure 2.15: Contemporaneous Interest Rate Rule
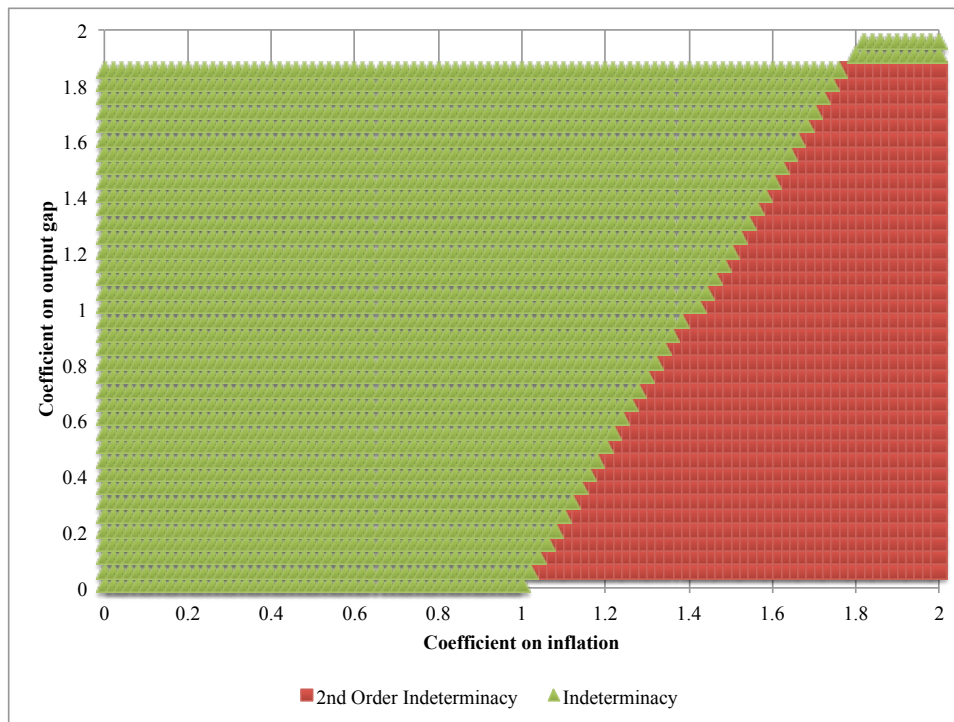
Under a contemporaneous interest rate rule, the region of determinacy shrinks tremendously. This makes is extremely difficult for the central bank to ensure stability. Either a strict inflation target or a large response to changes in the output gap will allow the monetary authority to avoid indeterminacy (and in some cases, double indeterminacy). Even slightly deviating from either of these policy rules could be detrimental to the economy as the determinacy space is extremely small. This result is dramatically different from what the current literature finds. Xiao (2013), in a model with one-period debt and a housing market, concludes that a more than one-to-one response to inflation and any empirically plausible response to changes in the

output gap will ensure determinacy. Long-term debt has significant implications for how to conduct monetary policy. Multi-period mortgage debt makes it much more difficult for the central bank to reach the determinacy region.[26]

2.6 Conclusion

This paper shows the implications of modeling multi-period debt for monetary policy. The central bank must pursue either a strict inflation target or a large response to changes in the output gap. Previous work that has only examined single-period debt largely misses this result. This paper also shows the significance of changes in the loan-to-value ratio on output and welfare. Steady-state output increases when the limits on household debt are increased, but steady-state output declines when firms are highly leveraged. Social welfare is maximized under utilitarian preferences at a household loan-to-value ratio of 0.49 and, under Rawlsian preferences, a household loan-to-value ratio of 0.79. Thus, policymakers must consider societal preferences before determining household leverage regulations. For firm borrowing, the policy implications are more concrete. Unless society cares only about wealth household utility, firms should maintain low loan-to-value ratios. The loan-to-value ratio for firms and households have large implications for economic performance.

Future work will consider loan-to-value ratios that approach or exceed 1, implying a broader interpretation of the leverage parameter. This would require households being able to violate the credit constraint and owe more in loans than the value of their collateral. Another possible extension would be to endogenize the housing stock. The majority of the collateral constrains

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[26]It is worthwhile to note that the region of indeterminacy might be reduced if the discount factors were recalibrated. For instance, suppose a period is approximated to be three years, yielding a two-period debt structure that mimics the typical life of a mortgage. In this case, a more reasonable calibration of β' is about 0.90 and a plausible calibration of β'' and γ is about 0.85. Typically, the indeterminacy region increases as agents are more forward-looking. Therefore, if the discount factor is lower, agents place less weight on the future, making indeterminacy less likely. In other words, recalibrating the discount factor could result in a larger determinacy region. However, since the regions of indeterminacy presented in this paper are so large, it would be unlikely to significantly alter the results.

and housing literature assumes a fixed housing stock. Allowing the housing stock to be variable could provide additional model dynamics.

3 Housing and Endogenous Default

3.1 Introduction

The recession of 2007 to 2009 has renewed interest in the detrimental effects of limited access to credit and mass foreclosures on business cycle fluctuations. This paper models mortgage default in an effort to determine if it is simply an effect of business cycles, or if mortgage default actively contributes to macroeconomic volatility. In a recent speech given by the former Federal Reserve Bank Chairman Ben Bernanke, he claims:[1]

> The multi-year boom and bust in housing prices of the past decade, together with the sharp increase in mortgage delinquencies and defaults that followed, were among the principal causes of the financial crisis and the ensuing deep recession— a recession that cost some 8 million jobs.

Bernanke suggests that mortgage default is not simply a result of economic downturns, but that default itself can precede and lead to a downturn. Despite this sentiment and empirical support (see Subsection 3.2), the recent macroeconomic literature largely ignores the effects of default, instead focusing on cases where the threat of default matters, but default never actually occurs. This papers fills this gap. We find that actual default does cause reductions in aggregate output and that it amplifies the decline in housing prices that initially caused default. The largest effect on consumption occurs in the period prior to default and the largest impact on housing prices occurs in the default period itself. As default risk builds, impatient households (who are relatively poor) increase their consumption and owner-occupied housing while patient households decrease their consumption. Impatient households cannot borrow in the default state, which causes a misallocation of housing where the patient households own all of the housing stock, lowering its marginal utility and price.

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[1] Taken from "Operation HOPE Global Financial Dignity Summit," Atlanta, Georgia, November 15, 2012.

This paper augments the New-Keynesian model with a housing market (that includes both owner occupied housing and rental housing). In this model, as well as the related literature, the economy is populated by impatient households and patient households. The patient households are the lenders and the impatient households are the borrowers, identified by a lower discount factor and typically lower wealth. Housing acts as both a durable good and collateral on secured loans made by the lenders to borrowers. In related settings, Bernanke and Gertler (2001) and Iacoviello (2005) examine New-Keynesian models with asset markets (stocks and housing respectively) and find evidence that credit constraints act to magnify and increase the persistence of demand shocks. However, these papers do not allow borrowers to take out loans greater than the discounted future asset value and consequently borrowers cannot default.[2]

We explicitly allow for default in order to analyze the effect of insolvency on the economy. In the case in which default is characterized by a temporary loss of access to housing and credit markets, there are three mechanisms through which default could potentially effect the economy. First, default represents a transfer of wealth from lenders to borrowers. This transfer occurs both because borrowers are unable to meet their loan obligations, and because the value of seized collateral (housing) declines as a result of default. Second, default creates a misallocation of housing, where lenders retain most or all of the economy's owner occupied housing stock. Third, by losing access to credit markets borrowers lose the ability to finance consumption.

We consider (in Section 3.5) the effects of default within a single period. Here, the economy enters the period with a predetermined default probability. We then compare pairs of shocks that result in default with those that do not. We find:

1. Sufficiently positive demand shocks increase the marginal utility of consumption and induce households to substitute away from housing to consumption. This lowers housing prices and results in default.

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[2]There is a partial equilibrium literature that allows agents to default but macroeconomic effects are not explored. See Gale and Hellwig (1985), for example.

2. Sufficiently small productivity shocks reduce the level of consumption and increase consumption's marginal product. Households again substitute away from housing, lowering its price and inducing default.

We also find several large and discrete effects of default on the model's endogenous variables:

3. Impatient household consumption increases. This is because their increased wealth and inability to buy housing dominates their inability to finance consumption.

4. Patient household consumption declines due to their reduced wealth. This effect is also large enough to cause aggregate consumption and output to decrease.[3]

5. Housing prices fall. This is because housing is misallocated by being fully owned by the patient households. This reduces its marginal utility and price.

We also look at the case where there is no loss of access to mortgage or credit markets.[4] We show that the effects of default are small in this case, suggesting that the loss of access to financial markets is the crucial, and previously unmodeled, aspect of mortgage default.

We then (in Section 3.6) examine the behavior of the model over time. In contrast to Section 3.5, the probability of default varies over time, and it tends to rise before default actually occurs. We observe a common pattern where impatient households tend to respond to higher default risk by increasing their consumption while patient households reduce theirs. The latter effect is larger so that aggregate consumption declines. As a result, changes in consumption tend to be most pronounced just prior to the default period. In contrast, the misallocation of housing that occurs during default causes decreased housing prices to be most pronounced during the default period itself instead of before it.

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[3]Because the model does not include capital and the housing stock is fixed, aggregate output and consumption are the same.

[4]The scenario where households lose access to credit but not housing markets is similar to the case where agents lose access to both markets and the effects of default are large.

Given the recent events in the U.S., we would expect the data to correspond with our results. Figure 3.1 shows personal consumption expenditures by income category from 2003 to 2009 from the Bureau of Labor Statistics with consumption normalized to 100 at its 2003 level. In our model, typically the patient households are wealthier and the impatient households are poorer. So, we can think of the income group less than $70,000 as representing the impatient households and the over $150,000 income group as representing the patient households. The delinquency rate is also depicted for low income households to indicate the increased likelihood of insolvency.[5]

Figure 3.1: Personal Consumption Expenditures by Income Level
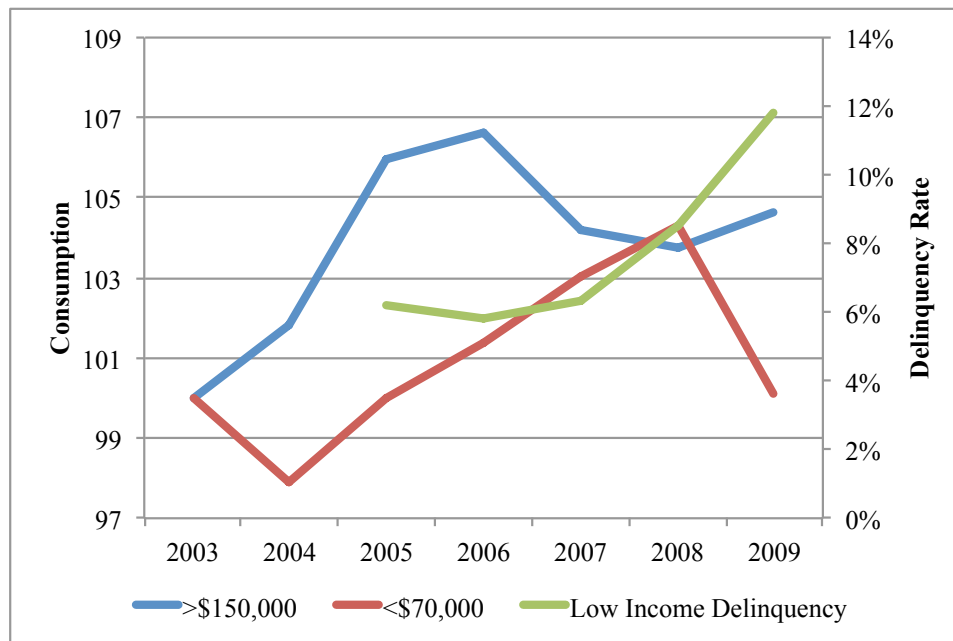
The patterns in Figure 3.1 generally align with our results. As the probability of default increases (depicted by the delinquency rate of low income households), the poorer households consume more as the likelihood of delinquency reaches its peak. We interpret this behavior as the poor households realizing that foreclosure is likely and increasing their consumption while

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[5]Low income is defined as households earning less than 50% of the median family income. These data are collected from the Federal Reserve Board of New York Consumer Credit Panel. We should also note that in the data, delinquency, insolvency, and default have slightly different measures; however, for our purposes in the theoretical model, they are used interchangeably.

they are still able. On the other hand, the wealthy households decrease their consumption as the probability of default increases, anticipating a reduction in wealth.

Several policy implications emerge from our findings. In Section 3.6, we modify the model to allow households to go underwater. Borrowers continue to make mortgage payments provided that they owe less than, for example, 130% of the value of their collateral. As the borrowers are able to go further underwater, impatient households have higher debt payments, their consumption decreases, and default becomes less common. At the same time, patient households are able to consume more. However, the decrease in impatient households' utility is greater than the increase in patient households' utility. If the policymaker places at least as much weight on the utility of the poor, it will be optimal to place restrictions on how far underwater borrowers are allowed to be. We find a similar result in the monetary policy analysis.

We allow the central bank to include asset prices in an interest rate rule. The response to housing prices tends to dampen the response to inflation, thus, a stronger response to asset prices increases impatient households' utility and decreases patient households' utility. The former effect is larger than the latter. Once again, this implies that any social welfare function that is indifferent to or dislikes inequality will be maximized when the central bank responds to deviations in asset prices from a target value.

The paper is organized as follows. Section 3.2 discusses the related literature including empirical evidence that supports our model's main conclusions. Section 3.3 develops the model. Section 3.4 develops the adaptive learning algorithm that describes how expectations are formed.[6] Section 3.5 illustrates the causes and effects of mortgage default in a single period. Section 3.6 reports simulation results that depict model dynamics. Finally, Section 3.7 concludes.

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[6]See Evans and Honkapohja (2009) for a more detailed discussion of adaptive learning.

3.2 Related Literature

Our paper contributes to the extensive literature, first developed by Kiyotaki and Moore (1997), on credit constraints. In this literature, an asset (housing, capital, land, etc.) acts both as an input to production and serves as collateral on secured loans by limiting borrowers' credit to an amount less than or equal to the value of their collateralized assets.[7] In this literature, credit constraints are a powerful transmission mechanism for the amplification and propagation of shocks. A shock that reduces the price of collateral also restricts access to credit, which reduces demand for the assets, further lowering its price, and the cyclical process continues. This financial accelerator effect helps to explain how relatively small shocks can result in large business cycle fluctuations.

Several papers extend the financial accelerator mechanism to a New-Keynesian framework. The closest paper to ours is Iacoviello (2005). He augments a New-Keynesian general equilibrium model with collateral constraints. Borrowers in the model secure debts with nominal housing wealth. Consistent with previous papers in the financial accelerator literature, Iacoviello (2005) finds that following a demand shock, the real economic effects are amplified and propagated due to inclusion of credit market frictions. A positive demand shock drives up consumer prices and asset prices, which relaxes the credit constraint, allowing agents to increase borrowing. With the additional loans, agents spend and consume more. Intensified demand raises prices, and inflation reduces the real value of debt obligations further increasing net worth.[8] Quantitatively, a one-standard deviation increase in the interest rate decreases output by 3.33 % in the absence of credit limits and 3.82 % when the credit channel is included. However, Iacoviello (2005) finds that the result is reversed when the economy experiences an adverse supply shock. The collateral constraint acts a "decelerator" of supply shocks in that an adverse supply shock increases housing prices and thus has a positive effect on borrowers net

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[7]Numerous empirical studies estimate that many households are credit constrained. See Zeldes (1989), Jappelli (1990), and Campbell and Mankiw (1989).

[8]The net effect on demand is positive since borrowers have a higher marginal propensity to consume than lenders.

worth.[9]

Each of these papers abstracts away from actual default. The potential for strategic default motivates the credit constraint, but default never actually occurs. Our paper allows for mortgage default in the New-Keynesian framework. In doing so, we show that default provides an additional source of amplification that has not previously been modeled.

Our paper is also related to a separate literature that does model actual default. Gale and Hellwig (1985) solve for the optimal debt contract in a framework where asymmetric information motivates costly verification in which the state is only observed if the firm is insolvent. In this setting, the optimal credit contract is the standard debt contract with bankruptcy. If the firm is insolvent, the lender can repossess as much of the firm's debt as possible in the form of assets; there is not, however, a credit constraint on the borrower. Thus, the lender recovers what they can of the loan, but there is no guarantee it will be equal to the full amount of the debt. We adopt this approach and apply it to our business cycle model with housing.

Other papers use this structure in very different general equilibrium models. Fiore and Tristani (2013) and Goodhart et al. (2009) model commercial default. Faia (2007) uses it to model default between countries in an open economy DSGE model. Our focus, however, is on mortgage default. To the best of our knowledge, ours is the first paper to model mortgage default in a New-Keynesian setting.

Our paper examines the performance of monetary policy that relies on a Taylor type rule. We are specifically interested in how a response to housing prices affects macroeconomic performance. We find that increasing interest rates as real housing prices increases the frequency of default. Such a policy benefits borrowers and harms lenders. Furthermore, such a policy is desirable for any non-convex social welfare function. This result is in contrast to the related literature, including Iacoviello (2005) and Bernanke and Gertler (2001), which finds negligible benefits to including asset prices in the monetary policy rule. Those papers, however, do not include actual default which we finds has substantial real effects on the model.

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[9]Other papers in this area include Bernanke et al. (1999). In this paper, stocks instead of housing act as collateral.

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Because we rely on adaptive learning to solve our general equilibrium model, our paper also contributes to the literature on learning and monetary policy. Orphanides and Williams (2008) compare optimal policy under learning and rational expectations and find that learning provides an additional incentive to manage inflationary expectations. Therefore, it is optimal for policymakers to more aggressively respond to inflation under learning. Xiao (2013) examines optimal policy in a New-Keynesian model with housing. He finds that the optimal response to housing prices is sensitive to the specific information set of agents. Evans and McGough (2005) examine learning in a standard New-Keynesian model. They find that the condition for determinacy of equilibrium is usually, but not always, the same as the condition for stability under learning.

Empirical Evidence

The following empirical evidence motivates our hypothesis and supports our findings that default directly contributes to economic downturns. Several studies investigate the relationship between housing prices and foreclosures. The majority of these papers use micro level data, and the general consensus is that there is a negative relationship between foreclosures and housing prices.[10] There is also a well-documented relationship between price and foreclosures in the reverse direction (a decrease in housing prices causes foreclosures).[11]

The direction of causality in the relationship between foreclosures and housing prices is unclear; in fact, most studies find evidence of dual causality. Foreclosure will occur if and only if the homeowner is underwater, inherently linking housing prices and foreclosures regardless

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[10] Gerardi et al. (2012) discover that the magnitude of this effect actually peaks before the foreclosure process is complete. We find a similar result, that the impact of default is most intense in the period prior to foreclosure. See Section 3.6 for more details. Lin et al. (2009) observe that the negative relationship between housing prices and foreclosures is larger during recessions. Leonard and Murdoch (2009) study the real estate market in Dallas and find that the impact of foreclosures on neighboring house prices is decreasing in distance from the foreclosed home. Harding et al. (2009) obtain a similar result using data from 37 MSAs in 13 states. Rogers and Winter (2009) use St. Louis county data and conclude that there is a non-linear effect of foreclosures on real estate prices. The marginal impact of an additional foreclosure decreases as the number of foreclosures increases.

[11] See Foster and Order (1984), Gerardi et al. (2008), Bajari et al. (2008), and Rana and Shea (2014).

of whether foreclosures have a direct impact on real estate prices. Mian et al. (2014) use a two-staged least squares analysis to correct for endogeneity employing whether states have judicial foreclosure laws or non-judicial foreclosure laws as an instrument. In addition, Mian et al. (2014) examine the real effects of foreclosures and housing price on real economic activity. Mian et al. (2014) find that from 2007 to 2009, foreclosures caused a 20% to 30% decline in housing prices, 15% to 25% decline in residential investment, and a 20% to 35% decline in auto sales.

Few papers use time series estimation techniques to examine the interaction between housing prices and foreclosures in both directions. Calomiris et al. (2013) use state level data in a panel vector autoregression (PVAR). They find that the effect housing prices have on foreclosures is larger than the effect foreclosures have on housing prices (quantitatively, 79% greater).

Rana and Shea (2014) take the analysis a step further and look at the relationship between foreclosures and unemployment in a PVAR that includes inflation and interest rates. They conclude that there is feedback between shocks to unemployment and foreclosures: a positive shock to unemployment increases foreclosures and a positive shock to foreclosures increases unemployment. Consistent with the previous literature, they conclude that housing prices are affected negatively by positive shocks to unemployment and foreclosures, and there is a negative relationship between shocks to housing prices and foreclosures. However, there is no significant effect of a shock to housing prices on unemployment indicating that the decline in real estate prices during the Great Recession was not the driving force of the subsequent high unemployment. The evidence in Rana and Shea (2014) suggests that the increase in foreclosures is the main cause for the decrease in housing prices and high levels of unemployment from 2007 to 2009.

These empirical results are consistent with the mechanism we model in this paper, implying that foreclosures have real effects on macroeconomic variables and directly contribute to business cycle fluctuations. We now build a formal model that captures the relationship be-

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tween foreclosures, housing prices, and real economic activity that is found in the empirical literature.

3.3 Model

We develop a discrete time, infinite horizon model, populated by impatient and patient households. Following Iacoviello (2005), we assume that a set of patient households have relatively high discount factors, γ, and thus typically lend to a separate set of impatient households who have lower discount factors, $\beta < \gamma$.[12] Our model has four notable differences from Iacoviello (2005). First, we allow for actual mortgage default instead of simply assuming that the threat of default (which never occurs in Iacoviello (2005)) imposes a credit constraint on borrowers.[13] Second, we add a rental housing market. This addition allows us to better examine the effects of impatient households potentially losing access to owner occupied housing and instead being forced into the rental market exclusively. Third, to solve the model (which contains several discontinuities) we rely on adaptive learning in the non-linear model instead of linearizing the model and using rational expectations. Finally, for simplicity, we assume that housing does not act as an input in the production function.

Households work, consume, supply and demand rental housing, and demand real estate.[14] Throughout this section, we denote variables that correspond to patient households with a prime symbol. We begin by assuming that patient households maximize expected lifetime

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[12]Rarely, impatient households lend to patient households in equilibrium. In this case, the model is unchanged except that default risk applies to the patient households. However, to remain consistent with the related literature, we use borrowers and impatient households interchangeably hereafter.

[13]Note, we assume that all cases of default result in foreclosure. In the data, these terms are not synonymous; however, in our model, we use them interchangeably.

[14]Note, money is not explicitly included in the utility function. Instead, we assume that the monetary authority can directly set the nominal interest rate. It would be trivial to add money in the utility function and derive the corresponding money demand equation. Household utility in Iacoviello (2005) depends on money balances; however, he only examines interest rate rules for which money supply will always equal money demanded in equilibrium. Given these conditions, the quantity of money does not affect the rest of the model and is disregarded.

utility:

$$\underset{c_t' L_t' h_t' \frac{M_t'}{P_t}}{\text{Max}} \quad E_0 \sum_{t=0}^{\infty} \beta'^t (ln(c_t') + jln(\left[(h_t' - x_t)^\epsilon + \omega(x_t')^\epsilon\right]^{\frac{1}{\epsilon}}) - \frac{(l_t')^2}{2}) \qquad (3.3.1)$$

where e_t is an exogenous demand shock. We assume that patient households may rent housing from impatient households (x_t') at the rental rate (v_t'). For computational reasons, we do not allow patient households to rent housing to each other.[15] The variable h_t' represents patient households' homeownership, which implies that $(h_t' - x_t)$ is their level of owner occupied housing. The parameter ϵ captures the degree of substitutability between owner occupied and rental housing, and the term $\omega \leq 1$ allows us to assume that households inherently prefer the former. Assuming for the moment that no default occurs, patient households maximize equation 3.3.1 subject to the following budget constraint:

$$\frac{A_t(l_t')^\alpha}{m_t} - b_t + k_t' + v_t x_t = c_t' + q_t(h_t' - h_{t-1}') + v_t' x_t' - R_{t-1}^m b_{t-1}/\pi_t + R_{t-1} k_{t-1}'/\pi_t + F_t \quad (3.3.2)$$

The exogenous variable A_t is a random, AR(1), productivity shock. The variable q_t represents the price of housing. We assume that patient households may borrow from each other (k_t') at the riskless rate R_{t-1}. As is standard, in equilibrium, $k_t' = 0$. The variable b_t represents impatient household debt to patient households, and the variable R_t^m represents the corresponding risky interest rate. By including π_t in (3.3.2), we are assuming that debt is not indexed to inflation.[16]

Finally, we assume that households produce intermediate goods, which are then costlessly transformed into final goods by a retail sector. The price of final goods is marked up at rate, m_t. We assume that the patient households own the retailers and receives profits $F_t = (1 - m_t^{-1})A_t \left[l_t^\sigma + l_t'^\sigma\right]^{\frac{1}{\sigma}}$.

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[15]We also assume that impatient households may not rent to each other, which results in two separate rental rates.
[16]As discussed in Iacoviello (2005), most U.S. debt is not indexed to inflation.

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Optimization yields the following first-order conditions:

$$\frac{\alpha A_t e_t (l'_t)^{\alpha-1}}{c'_t m_t} = l'_t \tag{3.3.3}$$

$$\frac{j\omega(x'_t)^{\epsilon-1}}{v'_t \left[(h'_t - x_t)^\epsilon + \omega(x'_t)^\epsilon \right]} = \frac{e_t}{c'_t} \tag{3.3.4}$$

$$\frac{e_t}{c'_t} = \gamma E_t \left[e_{t+1} \frac{R_t}{c'_{t+1} \pi_{t+1}} \right] \tag{3.3.5}$$

$$\frac{j(h'_t - x_t)^{\epsilon-1}}{q_t \left[(h'_t - x_t)^\epsilon + \omega(x'_t)^\epsilon \right]} + \gamma E_t \left[\frac{e_{t+1} q_{t+1}}{q_t c'_{t+1} \pi_{t+1}} \right] = \frac{e_t}{c'_t} \tag{3.3.6}$$

$$\frac{e_t v_t}{c'_t} = \frac{j(h'_t - x_t)^{\epsilon-1}}{\left[(h'_t - x_t)^\epsilon + \omega(x'_t)^\epsilon \right]} \tag{3.3.7}$$

Equation (3.3.3) is the labor supply rule. Equation (3.3.4) is the rental demand equation. Equation (3.3.5) is a standard consumption Euler equation. The housing demand equation is equation (3.3.6). Equation (3.3.7) is the rental supply equation and simply equates the consumption that results from renting out an additional unit of housing to the utility of using that housing as owner occupied housing.

In addition, the patient household must choose to distribute its lending between other patient households (k_t) and impatient households (b_t). The patient household does so taking the risky and risk free interest rates, and the probability of default, $p(def)$, as given. Optimization then yields an interest rate arbitrage condition:

$$E_t \left[\frac{e_{t+1} R_t}{c'_t} \right] = (1 - p(def)) E_t^* \left[\frac{e_{t+1} R_t^m}{c'_{t+1}} \right] + p(def) E_t^{**} \left[\frac{e_{t+1} R_t^m rec_{t+1}}{c'_{t+1}} \right] \tag{3.3.8}$$

where * indicates the conditional expectation in the case of no default and ** indicates the

conditional expectation in the case of default. The recovery rate rec_t is the perceived rate of recovery in the case of default.

We now consider the impatient households. Their optimization problem is similar to that of the patient households, except that they potentially default on their mortgage debt and thus borrow from the patient households at a risky interest rate. In addition to choosing consumption, various types of housing, debt, and labor, they also implicitly choose their probability of default. Impatient households maximize the following function:

$$\underset{c_t L_t h_t \frac{M_t}{P_t}}{\text{Max}} \quad E_0 \sum_{t=0}^{\infty} \beta^t \left(ln(c_t) + jln\left(\left[(h_t - x_t')^{\epsilon} + \omega x_t^{\epsilon}\right]^{\frac{1}{\epsilon}}\right) - \frac{l_t^2}{2} \right) \quad (3.3.9)$$

We assume that the demand shock affects both types of households identically. Again, ignoring the potential for default, the impatient household's maximize equation 3.3.9 subject to a budget constraint:

$$\frac{A_t l_t^{\alpha}}{m_t} + b_t = c_t + q_t(h_t - h_{t-1}) + v_t x_t - v_t' x_t' + R_{t-1}^m b_{t-1}/\pi_t \quad (3.3.10)$$

Optimization yields the first order conditions below:

$$\frac{j\omega x_t^{\epsilon-1}}{v_t \left[(h_t - x_t')^{\epsilon} + \omega x_t^{\epsilon}\right]} = \frac{e_t}{c_t} \quad (3.3.11)$$

$$\frac{\alpha A_t e_t l_t^{\alpha-1}}{c_t m_t} = l_t \quad (3.3.12)$$

$$\frac{e_t}{c_t} = \beta E_t^* \left[\frac{e_{t+1} R_t^m}{c_{t+1}\pi_{t+1}}(1 - p(def))\right] + \beta E_t^* \left[\frac{\partial p(def)}{\partial b_t}\right] \Gamma_t \quad (3.3.13)$$

$$\frac{j(h_t - x_t')^{\epsilon-1}}{q_t \left[(h_t - x_t')^{\epsilon} + \omega x_t^{\epsilon}\right]} + \beta E_t^* \left[\frac{e_{t+1} q_{t+1}}{q_t c_{t+1}\pi_{t+1}}(1 - p(def))\right] = \frac{e_t}{c_t} + \frac{\beta}{q_t} E_t^* \left[\frac{\partial p(def)}{\partial h_t}\right] \Gamma_t \quad (3.3.14)$$

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$$\frac{e_t v_t^{'}}{c_t} = \frac{j(h_t - x_t^{'})^{\epsilon-1}}{\left[(h_t - x_t^{'})^{\epsilon} + \omega x_t^{\epsilon}\right]} \tag{3.3.15}$$

Equation (3.3.11) is the rental demand equation, and (3.3.12) is the labor supply equation. Equation (3.3.13) is the Euler equation. Impatient households must consider both the probability of default as well as the utility loss resulting from a potential loss of access to markets, denoted Γ_t. Increased debt (b_t) increases the probability of a welfare reducing loss of access to financial markets following default. Due to this default risk, impatient households borrow at the risky rate $R_t^m - 1$ instead of the riskless rate $R_t - 1$.

Equation (3.3.14) is the housing demand equation. Once again, impatient households must factor in how their choice of housing affects default risk. Higher values of h_t increase collateral and make default less likely. The rental supply equation is (3.3.15).

We close the model with the following equations:

$$h_t + h_t^{'} = 1 \tag{3.3.16}$$

which assumes a fixed housing stock, normalized to one.

$$m_t = E_t \left[\frac{\pi_{t+1}^{\frac{\gamma}{\lambda}} \pi_t^{\frac{-1}{\lambda}}}{\sigma} \right] \tag{3.3.17}$$

which may be derived using the Calvo mechanism, where $\lambda = \frac{(1-\theta)(1-\beta\theta)(1-\alpha)}{\theta(1-\alpha(1-\frac{1}{1-\sigma}))}$, and θ represents the fraction of firms that do not re-optimize their price each period.[17]

$$R_t = \bar{\pi} \left(\frac{\pi_t}{\bar{\pi}} \right)^{\phi_\pi} \left(\frac{q_t}{\bar{q}} \right)^{\phi_q} \tag{3.3.18}$$

which is a monetary policy reaction function that potentially responds to asset prices through the parameter ϕ_q.

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[17]See Woodford (2003) for details.

The model includes the following 16 endogenous variables: $c_t, c'_t, x_t, x'_t, h_t, h'_t, l_t, l'_t, b_t, v'_t, v_t, q_t$ R_t, R^m_t, m_t, π_t. It consists of eleven first-order conditions, one budget constraint, (3.3.16) through (3.3.18) and a combined production function:

$$c_t + c'_t = A_t \left[l^\sigma_t + (l'_t)^\sigma \right]^{\frac{1}{\sigma}} \tag{3.3.19}$$

Default

We assume that credit markets work as follows. At the start of each period, the credit market clears, which requires that households sell off assets in order to fully pay off their debt. If $q_t h_{t-1} \pi_t \geq R^m_{t-1} b_{t-1}$, then it is able to do so and if not, default occurs.[18] Following credit market clearing, households then makes its labor supply, consumption, and savings choices. If $q_t h_{t-1} \pi_t < R^m_{t-1} b_{t-1}$, however, then default occurs.

When the default condition binds, we consider several cases:

1. *No access to housing or bond markets.*

   In this case, impatient households may not purchase housing or access credit markets. Here, $b_t = h_t = x'_t = 0$, and R^m_t and v'_t are undefined. Equations (3.3.2), (3.3.4), (3.3.13) through (3.3.15), and (3.3.8) no longer describe the model's equilibrium. The following condition, however, must hold:

$$\frac{A_t l_t}{m_t} = c_t + v_t x_t \tag{3.3.20}$$

   Equation (3.3.20) is simply the budget constraint for impatient households when they lack access to housing and credit.

2. *No access to bond markets.*

   Here, impatient households may purchase housing, but may not borrow using the credit

[18]In Section 3.6, we relax this condition and allow households to go underwater on their debt where they owe more than the value of their collateral.

market.[19] In this case, $b_t = 0$, (3.3.2) and (3.3.15) no longer bind, but the following budget constraint holds in equilibrium.

$$\frac{A_t l_t}{m_t} + v_t' x_t' = c_t + v_t x_t + q_t h_t \tag{3.3.21}$$

3. *Writedown.*

   Here, impatient households may access both housing markets and credit markets. We further assume that unpaid debt is written off, equivalent to imposing $h_{t-1} = b_{t-1} = 0$, and the model is otherwise unchanged. In cases 3 and 4, the utility loss from losing access to housing and credit markets, Γ, would be zero in equilibrium. The impatient households would want to borrow an infinite amount; however, when Γ equals zero, the model is undefined. For these simulations, we impose the Γ from the no access to housing or bond markets case. We interpret the writedown and no default scenarios as one-time unexpected deviations from the model's usual default behavior. Thus, it represents out of equilibrium behavior. In this case, households still optimize under the belief that default will result in a loss of access to both housing and credit markets and are surprised when this does not occur.[20]

4. *No default.*

   In this scenario, we ignore the default condition and continue the model unaffected.

3.4 Learning and Expectations Formation

The most common approach for modeling expectations is rational expectations. Under rational expectations, agents are assumed to use the model's reduced form solution to form mathematically optimal forecasts. Using rational expectations has been criticized for requiring

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[19]We do not consider the case where impatient households may access bond, but not housing markets, because such a scenario ensures that default will occur in the next period.

[20]If agents know that debt is simply written down, then $p(def) \to 1$ and $R_t^m \to \infty$ and the model's equilibrium is no longer well defined.

agents to possess implausibly high amounts of information. For example, they must know the exact model generating the data, despite the field's disagreement over which model is best and an innumerable list of candidates. In addition, they must also know the model's correct calibration and the true nature of its stochastic shocks.

The most prominent alternative to rational expectations is adaptive learning.[21] Adaptive learning is motivated by the principle of cognitive consistency, which suggests that agents in the model be neither much less intelligent nor much smarter than the people modeling them. Thus, adaptive learning assumes that agents use econometric algorithms (ordinary least squares, in this paper) to form expectations. Perhaps the most compelling argument for learning is that the reader, if asked to form forecasts of variables such as consumption and housing prices, is most likely to rely on econometrics rather than simply conjuring up a rational expectation based on minimal data (lagged productivity, housing prices and debt, along with current shocks, and whether the economy is in default). He would behave like an adaptive learner. Learning also provides an additional benefit, allowing us to work with the non-linear equations as opposed to taking linear approximations.

We assume a simple type of learning where agents fit most variables to one-lag autoregressive, AR(1), processes.[22] Furthermore, to simplify the analysis, we assume that agents do not consider whether or not the economy is in the default state when fitting the model. For $w_t = c_t, c_t', \pi_t, q_t$, we assume that agents form expectations using:

$$w_t = a_w + b_w(w_{t-1} - a_w) + u_t \tag{3.4.1}$$

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[21]For a detailed treatment of adaptive learning, see Evans and Honkapohja (2001).

[22]Experimental evidence suggests that agents do use simple autoregressive processes to form expectations. See, for example, Hommes et al. (2005).

where a_w and b_w are regression coefficients obtained through recursive least squares:

$$\begin{bmatrix} a'_{w_t} \\ b_{w_t} \end{bmatrix} = \begin{bmatrix} a'_{w_{t-1}} \\ b_{w_{t-1}} \end{bmatrix} + t^{-1} R_t^{-1} \begin{bmatrix} 1 \\ w_{t-1} \end{bmatrix} (w_t - a'_{w_{t-1}} - b_{w_{t-1}} w_{t-1}) \qquad (3.4.2)$$

$$R_t = R_{t-1} + t^{-1} \left(\begin{bmatrix} 1 \\ w_{t-1} \end{bmatrix}^2 - R_{t-1} \right) \qquad (3.4.3)$$

$$a_w = \frac{a'_w}{1 - b_w} \qquad (3.4.4)$$

It then follows that agents use (3.4.1) to form expectations according to:

$$E_t[w_{t+1}] = a_w + b_w(w_t - a_w) \qquad (3.4.5)$$

Agents also use this algorithm to estimate the default distribution. We assume that rely on point expectations so that:

$$E_t[q_{t+1}\pi_{t+1}] = E_t[q_{t+1}]E_t[\pi_{t+1}] \qquad (3.4.6)$$

Agents obtain an estimate of the expectational error from (3.4.6) using the following process:

$$\sigma_{q\pi,t} = \sigma_{q\pi,t-1} + t^{-1}|(E_{t-1}[q_t]E_{t-1}[\pi_t] - q_t\pi_t)| \qquad (3.4.7)$$

Agents then fit (3.4.7) to a truncated normal distribution so that:

$$E_t \left[\frac{\partial p(def)}{\partial b_t} \right] = \frac{R_t^m}{h_t} g \left(\frac{E_t[q_{t+1}\pi_{t+1}] - \frac{b_t R_t^m}{h_t}}{\sigma_{q\pi}} \right) \qquad (3.4.8)$$

$$E_t\left[\frac{\partial p(def)}{\partial h_t}\right] = -\frac{b_t R_t^m}{h_t^2}g\left(\frac{E_t[q_{t+1}\pi_{t+1}]-\frac{b_t R_t^m}{h_t}}{\sigma_{q\pi}}\right) \qquad (3.4.9)$$

where $\left(\frac{E_t[q_{t+1}\pi_{t+1}]-\frac{b_t m_t}{h_t}}{\sigma_{q\pi}}\right)$ is the truncated normal probability density function.[23]

Agents must obtain an estimate for Γ_t, the utility loss from losing access to housing and credit markets. We assume they do so by comparing equilibrium in the default state with the hypothetical equilibrium had they been allowed access to the relevant credit markets. The variable Γ is only updated in the default state:

$$\Gamma_t = (1-(t^*)^{-1})\Gamma_{t-1}$$
$$+ (t^*)^{-1}E_t\left[u(\hat{c}_t,\hat{h}_t,\hat{x}_t,\hat{l}_t) - u(c_t,h_t,x_t,l_t) + \frac{q_{t+1}\hat{h}_t - \hat{R}_t^m\hat{b}_t}{c_{t+1}}\right] \qquad (3.4.10)$$

where "hats" indicate the values of variables in a version of the model where impatient households maintain access to all markets and t^* is the sample size of default periods. Individual households solve this problem taking all prices as given.

Finally, agents also update their estimate of the recovery rate in the default state only. This is obtained by:

$$rec_t = rec_{t-1} + (t^*)^{-1}\left(\frac{q_t\pi_t h_{t-1}}{b_{t-1}R_{t-1}^m} - rec_{t-1}\right) \qquad (3.4.11)$$

Table 3.1 reports our calibration of exogenous parameters. Most of our values are taken from Iacoviello (2005). We set $\omega = 0.9$, so that there is a slight inherent preference for owner occupied housing and $\epsilon = 0.6$, implying an intermediate degree of substitutability between owner occupied and rental housing.

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[23] We truncate the normal distribution at two standard deviations. For values below -2 standard deviations, the distribution is then linear until $b_t = 0$ where $g(\cdot) = 0$. For values above 2 standard deviations, it is linear until 12 standard deviations where $g(\cdot) = 0$.

Table 3.1: Calibration

j	weight on housing	0.10
ϵ	substitutability of housing types	0.60
α	labor's share in production function	0.67
β	impatient households' discount factor	0.90
γ	patient households' discount factor	0.99
ω	weight on rental housing	0.90
ϕ_π	policy response to inflation	2.00
σ	substitutability of consumer goods	0.71
θ	degree of price stickiness	0.67
σ_a	st. dev. of innovations to productivity	0.01
σ_e	st. dev. of innovations to demand	0.02
ρ_a	AR(1) coefficient for productivity shocks	0.95
ρ_e	AR(1) coefficient for demand shocks	0.00

3.5 Causes and Effects of Default

To examine what causes default and how default affects equilibrium, we consider the model at a fixed point in time for $\phi_q = 0$. We impose the initial conditions, $h_{t-1} = 0.15$, $b_t = 0.81$, and $A_{t-1} = 1$, chosen so that the mean value of shocks ($A_t = e_t = 1$) is close to the default cutoff. The results that follow are representative of the model's systematic behavior. We begin by simulating this scenario for different values of the demand shock, e_t, holding A_t constant at 1.04. Figures 3.2 through 3.6 show the responses of different variables to various values of a demand shock (on the horizontal access). As the value of the demand shock increases, the marginal utility of consumption also increases. The default state is indicated by the shaded region. We report levels of the variables for different values of the demand shock under three of the four scenarios outlined in Section 3.3. We also simulated the case where households lose access to bond, but not housing markets. Without access to credit, impatient households purchased little housing and the results are thus similar to the case where access to both markets is lost. We thus exclude these results from all the figures in this section.

Figure 3.2 displays the results for housing prices.

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Figure 3.2: Behavior of q_t
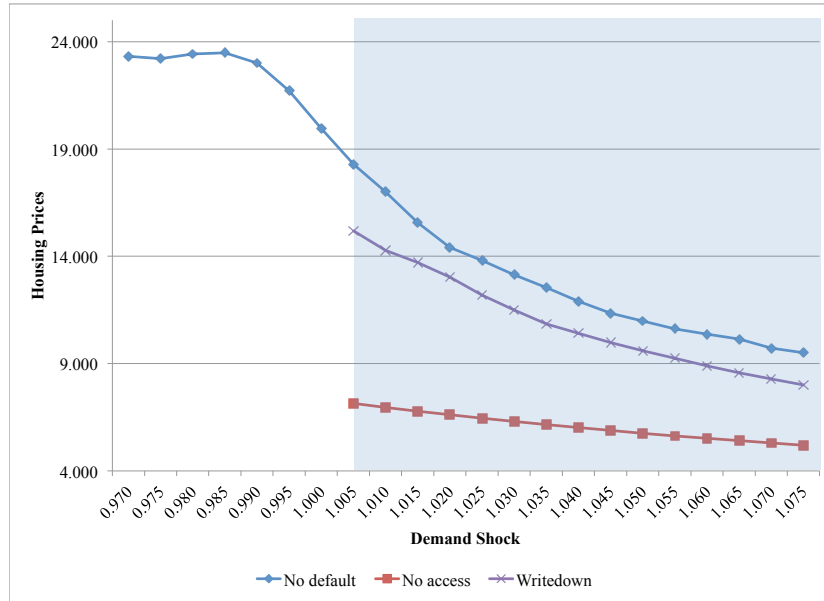
Higher values of the demand shock increase the marginal utility of consumption and induce agents to substitute away from housing and toward consumption, reducing q_t. In this simulation, default occurs when $e_t \geq 1.005$. The top line ignores the default constraint and continues the model unaffected, and the middle line shows the case where debt is written off. The bottom line shows the case where impatient households lose access to housing and credit markets. This causes a discrete amplification of the decline in q_t that caused default to occur. The further reduction of housing prices occurs because default causes a misallocation of housing. Patient households own all housing when default occurs, resulting in a decreased marginal utility of housing and lower housing prices.

Figure 3.3 illustrates the effects on impatient households' consumption.

Figure 3.3: Behavior of c_t
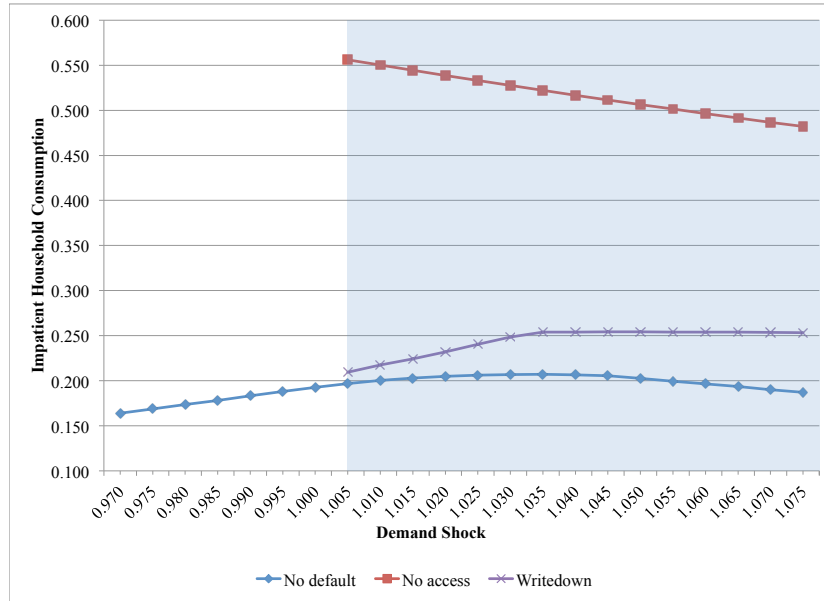
There are competing effects from default. The lack of access to credit markets reduces the ability of impatient households to borrow to finance consumption. Default also transfers wealth from patient to impatient households which increases consumption. The loss of access to housing also provides an incentive to substitute toward consumption. The latter effect dominates and c_t increases when default occurs.

Figure 3.4 illustrates the effects of default on patient households' consumption.

Figure 3.4: Behavior of c_t'
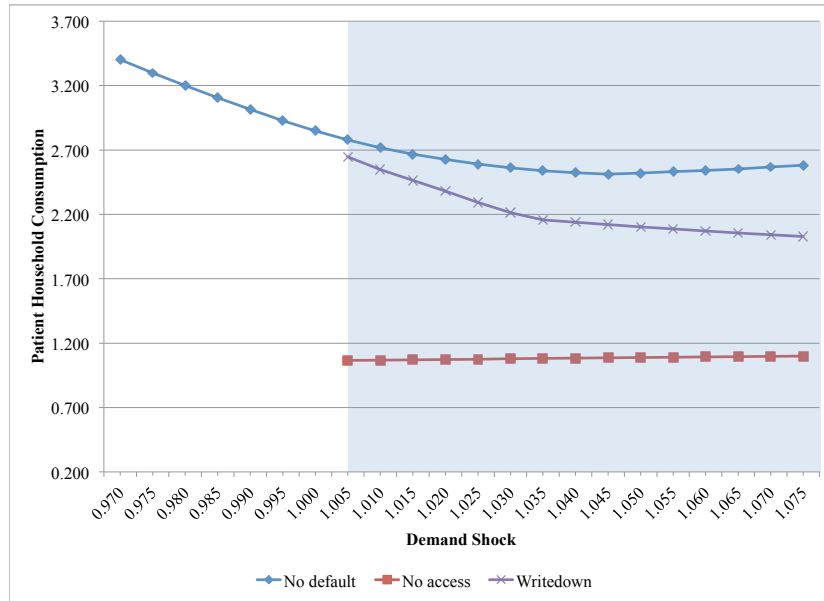
Default transfers wealth from patient households to impatient households. Because impatient households recover housing as collateral when default occurs, the severe decline in housing prices shown in Figure 3.2 amplifies the scope of this wealth effect. As a result, default causes a discrete decrease in patient households' consumption.

Comparing Figures 3.3 and 3.4, default causes a decrease in aggregate output (which equals aggregate consumption). Our theoretical model thus matches the empirical findings from Section 3.2—default is not simply a result of lower housing prices, it instead causes significant decreases to both aggregate output and housing prices.

Figures 3.5 and 3.6 show the effects on housing that is rented from patient households to impatient households.

Figure 3.5: Behavior of x_t
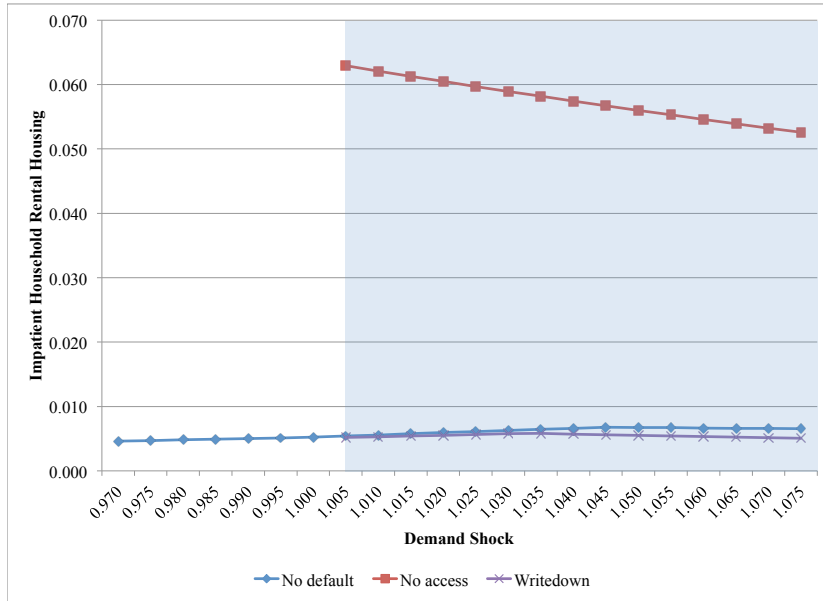
Figure 3.6: Behavior of v_t
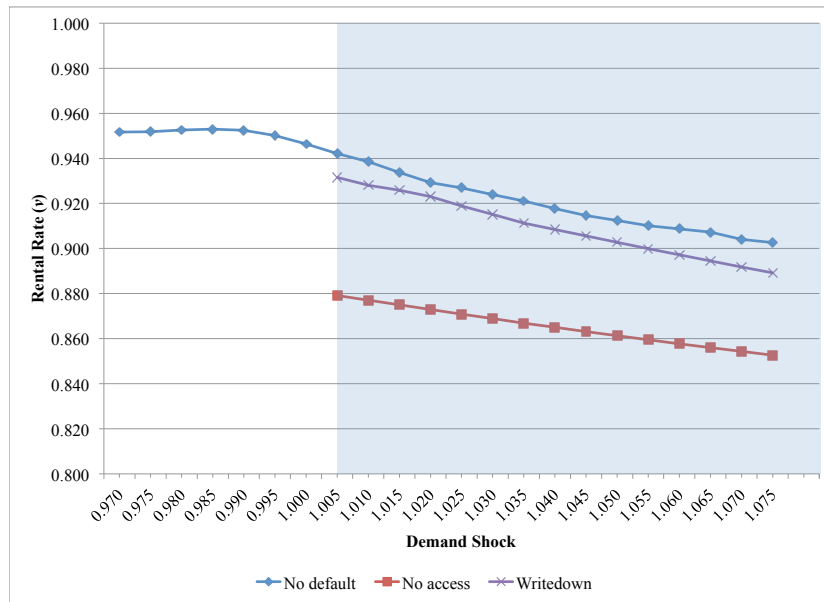
When impatient households lose access to owner occupied housing, they are forced into the rental housing market. As a result, x_t increases dramatically when default occurs. The effect on the rental rate is theoretically ambiguous because there is both increased supply and demand. In this simulation, the rental rate decreases further amplifying the adverse wealth effect that patient households experience.

Adverse productivity shocks may also induce default in the model. As the supply shock, A_t, falls, so does output. The marginal utility of consumption decreases as the value of A_t increases. In this simulation default occurs if $A_t \leq 1.03$, holding e_t constant at 1.

Figure 3.7 plots housing prices under each scenario:

Figure 3.7: Behavior of q_t in Response to Productivity Shocks
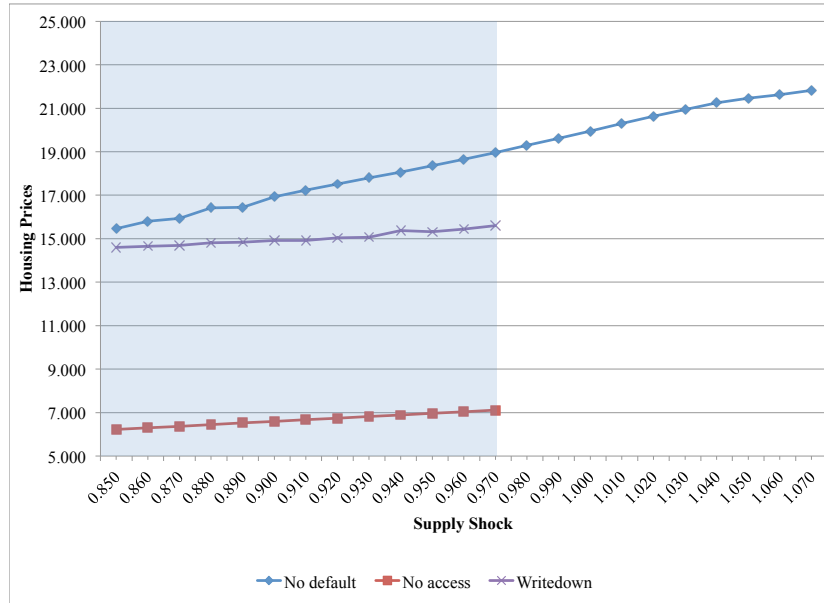
As before, default creates a misallocation of housing that results in an amplification of the decline in housing prices. As the marginal utility of consumption increases, households wish to substitute away from housing toward consumption which reduces both housing prices and rents. The remaining effects of default, including a decline in aggregate consumption, are similar to the case where default results from a demand shock.

3.6 Simulation Results

We now examine how some alternate parameterizations affect the model. We begin by altering the default condition so that default occurs if and only if $q_t h_{t-1} \pi_t < \chi R^m_{t-1} b_{t-1}$. The parameter χ represents how able households are to go underwater on their mortgage debt. $\chi = 1$ implies that they cannot go underwater while higher values suggest that they are able to carry more debt. All simulations are for 5000 periods where the first 2000 are a burn for the

learning process to converge. Learning coefficients are reported in Table 3.6.

Empirical evidence does not show a consistent relationship between underwaterness and default.[24] This evidence does, however, show that default does generally occur between χ equal to 1 and 1.5. We thus examine the model in this range.

Table 3.2: Equilibrium Dynamics for Different Values of χ.

	$\chi = 1$	$\chi = 1.1$	$\chi = 1.2$	$\chi = 1.3$	$\chi = 1.4$	$\chi = 1.5$
Mean(c_t)	0.645	0.643	0.631	0.623	0.594	0.527
St. Dev (c_t)	0.102	0.108	0.115	0.122	0.118	0.112
Mean(c_t')	1.052	1.080	1.115	1.097	1.178	1.302
St. Dev (c_t')	0.156	0.176	0.191	0.201	0.223	0.218
Mean(h_t)	0.253	0.242	0.233	0.252	0.203	0.166
St. Dev (h_t)	0.202	0.191	0.189	0.193	0.148	0.110
Mean(q_t)	8.437	8.347	8.516	9.088	8.669	10.794
St. Dev (q_t)	1.198	1.204	1.313	1.366	1.559	1.951
Mean(x_t)	0.019	0.019	0.019	0.015	0.013	0.013
St. Dev (x_t)	0.020	0.019	0.020	0.014	0.011	0.011
Mean(x_t')	0.084	0.078	0.074	0.085	0.058	0.050
St. Dev (x_t')	0.084	0.076	0.070	0.079	0.055	0.034
Mean(u_t)	-0.836	-0.856	-0.899	-0.914	-1.016	-1.239
Mean(u_t')	-0.050	-0.025	0.011	-0.008	0.077	0.206
p(def)	10.6%	8.6%	9.2%	3.0%	2.8%	3.1%

As χ increases, impatient households are able to borrow with less collateral. Doing so results in higher interest payments that cause their consumption to fall while patient households' consumption increases. With an increased marginal utility of consumption and less need for housing as collateral, impatient households' share of the housing stock generally declines. Higher values of χ cause competing effects to household utility, it increases for patient households while decreasing for impatient households. Simply adding their average utilities yields a maximum when $\chi = 1.1$ with a similar value to where $\chi = 1.0$. Because impatient household utility is declining in χ, any value of $\chi > 1.1$ performs worse for any social welfare function that is non-increasing in utility inequality. Therefore, as long as the policymaker

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[24]See Fuster and Willen (2013).

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cares at least as much about impatient household utility as patient household utility, limitations should be placed on how far underwater impatient households can be. We would expect that as χ increases, default would become less frequent. The results do illustrate a sharp fall in the frequency of the default state: for values of χ less than or equal to 1.2, default occurs about 10.0% of the time. Higher values, however, yield default rates nearer to 3%.

We now compare, for the baseline case where $\chi = 1$, the mean values of key variables in the default state versus the non-default state.

Table 3.3: Mean Values with and without Default

	No Default	Default
c_t	0.65	0.64
c_t'	1.05	1.05
h_t	0.28	0.00
q_t	8.46	8.19
x_t	0.013	0.072
x_t'	0.09	0.00

The most striking result is that the consumption variables exhibit about the same mean in each state. At first glance, this seems to contradict the results of Section 3.5. This result occurs because of a common pattern that occurs in the run-up to default. Most, but not all, defaults are preceded by increases in both the probability of default and the risky interest rate. For the calibrated model, the former effect is sufficient to induce both an increase in c_t and a decrease in c_t'. The expectation of default thus causes most of default's effects to be felt in the period prior to default. As a result, mean consumption is largely unaffected, and housing prices are less dramatically lower in the default state.

Tables 3.4 and 3.5 further illustrate this trend. The former redefines the default state as any period where default occurs either in that period, or the next period. The latter redefines the default state as one where default occurs only in the next period. Collectively, they show that as default nears, impatient households respond by increasing their consumption and housing. These effects are more dramatic than those that occur during the default period itself.

Table 3.4: Mean Values with and without Default (Current or Next Period)

	No Default	Default
c_t	0.63	0.68
c_t'	1.07	0.99
h_t	0.25	0.27
q_t	8.46	8.34
x_t	0.014	0.039
x_t'	0.08	0.09

Table 3.5: Mean Values with and without Default (Next Period)

	No Default	Default
c_t	0.64	0.73
c_t'	1.07	0.94
h_t	0.22	0.55
q_t	8.43	8.49
x_t	0.021	0.006
x_t'	0.07	0.17

Figure 3.8 illustrates a fairly common default. For the first 13 periods, default risk is relatively stable at about 2% and the behavior of the variables is, for the most part, uninteresting and not depicted in the chart. In period 14, however, impatient households become highly leveraged as default risk rises to about 80%. In period 15, default does in fact occur.

Figure 3.8: Sample Default
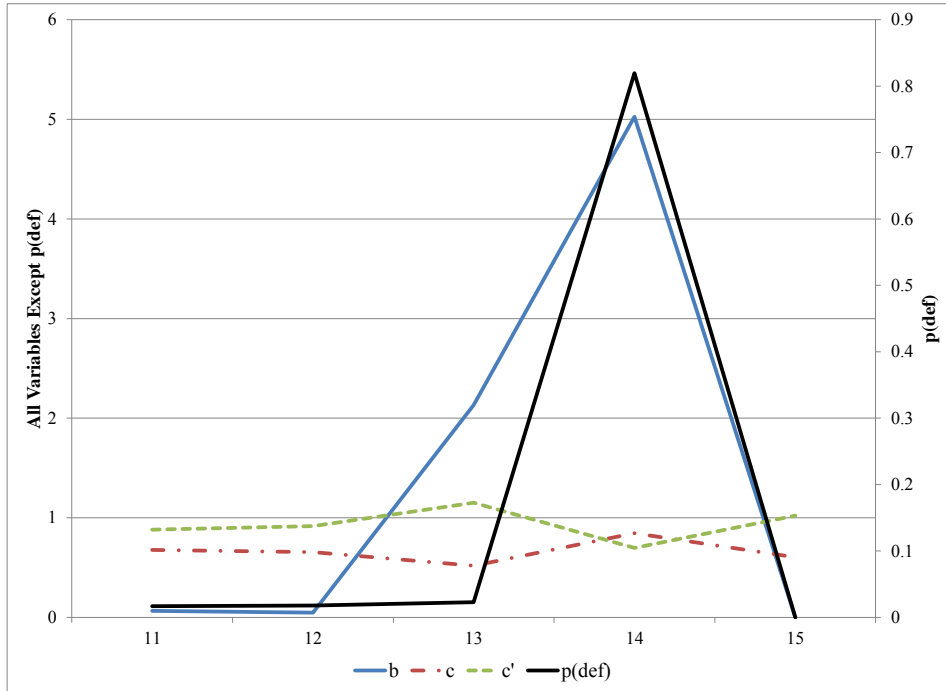
As the probability of default rises, patient household and impatient household consumption move in opposite directions. Increased debt is used to finance heightened consumption and housing for impatient households, while patient households, anticipating the decline in wealth as a result of default, decrease their consumption as default becomes more likely. These results are consistent with the evidence in Figure 3.1.

The model thus makes a pair of related predictions. Within a period, as seen in Section 3.5, default is more likely when demand shocks are high or productivity shocks are low. Default then causes discrete drops in aggregate consumption and housing prices relative to alternative values of the shocks that result in no default. Dynamically, however, these changes tend to be most observed just prior to entering the default state.

We now report the converged learning coefficients for each calibration in Table 3.6. Because agents employ a simple AR(1) specification, these coefficients also show the persistence of each variable:

Table 3.6: Learning Coefficients for Different Values of χ.

	$\chi = 1$	$\chi = 1.1$	$\chi = 1.2$	$\chi = 1.3$	$\chi = 1.4$	$\chi = 1.5$
a_c	0.65	0.64	0.64	0.65	0.59	0.57
b_c	0.84	0.84	0.82	0.82	0.80	0.80
$a_{c'}$	1.31	1.27	1.22	1.23	1.32	1.35
$b_{c'}$	0.91	0.90	0.88	0.89	0.87	0.89
a_π	0.97	0.98	0.98	0.97	0.98	0.99
b_π	0.98	0.98	0.98	0.98	0.98	0.98
a_q	9.75	9.22	8.90	9.85	9.28	10.73
b_q	0.89	0.88	0.87	0.88	0.86	0.89
rec_t	0.81	0.80	0.79	0.81	0.75	0.74
Γ_t	2.26	2.37	2.38	2.43	2.29	2.20

Monetary Policy

We now consider the impact of the monetary authority responding directly to housing prices by calibrating the model so that $\phi_q \neq 0$.[25] Since the bursting of the U.S. housing bubble around 2007, there has been considerable debate over whether the monetary authority should attempt to stabilize housing prices by imposing $\phi_q > 0$. The Federal Reserve has resisted such a policy and papers with credit constraints, such as Iacoviello (2005) and Bernanke and Gertler (2001), have generally found little benefit to doing so. The present paper, however, introduces a new mechanism by which asset prices affect monetary policy; thus, we re-examine this issue.

Table 3.7: Equilibrium Dynamics for Different Values of ϕ_q.

ϕ_q	Mean(c_t)	SD(c_t)	Mean(c_t')	SD(c_t')	Mean(h_t)	Mean(q_t)	Mean(u_t)	Mean(u_t')	p(def)
-0.20	0.61	0.12	1.12	0.18	0.22	8.54	-0.94	0.03	1.7%
-0.15	0.62	0.12	1.12	0.19	0.24	8.22	-0.91	0.03	2.2%
-0.10	0.63	0.13	1.12	0.19	0.25	8.74	-0.91	0.02	2.8%
-0.05	0.63	0.13	1.11	0.19	0.26	8.92	-0.90	0.01	2.7%
0.00	0.65	0.10	1.05	0.15	0.25	8.44	-0.84	-0.05	10.7%
0.05	0.68	0.15	1.08	0.21	0.25	9.67	-0.81	-0.05	7.9%
0.10	0.68	0.14	1.05	0.20	0.24	9.47	-0.79	-0.08	10.6%
0.15	0.69	0.13	1.03	0.18	0.25	8.56	-0.76	-0.11	12.8%
0.20	0.67	0.14	1.03	0.20	0.27	8.79	-0.79	-0.10	14.9%

Surprisingly, default occurs less often when the monetary authority lowers interest rates in

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[25]In addition to choosing ϕ_q, the monetary authority chooses $\bar{q}$, the real housing price target. In this section, we set this as the sample mean and discard the first 2000 periods.

response to higher housing prices. Note that because debt is not indexed in our model, inflation volatility contributes to default. Positive demand shocks and lower supply shocks both have the effect of simultaneously raising inflation and lowering housing prices. A negative value of ϕ_q thus has the effect of reinforcing the monetary authority's response to inflation, which results in more stable inflation and less default. A positive value of ϕ_q, however, undermines monetary policy's response to inflation and thus has the opposite effects.

As ϕ_q increases, impatient household utility increases while that of patient households decreases. The former effect is larger than the latter. Thus any social welfare function that has the ordinary property of being indifferent to or penalizing inequality will be maximized for higher values of ϕ_q, despite the higher rates of default.

3.7 Conclusion

This papers adds default to a New-Keynesian model with housing. The previous literature, for the most part, abstracts away from actual mortgage default. We find that allowing for default, as opposed to just the threat of default, has important implications for the model's behavior. Default creates a misallocation of housing that results in a discrete drop in housing prices that amplifies the initial decline that caused default to occur. Furthermore, borrowers increase their consumption due to a beneficial wealth effect and an incentive to substitute toward consumption due to their limited or non-existent ability to purchase housing. However, aggregate consumption, as well as lenders' consumption has the opposite effect.

We also show that the penalty of default matters. If unpaid debt is simply written off, without an accompanying loss of access to either housing or credit markets, then default does not have large discrete effects. It is the lack of borrower access to credit markets that makes default especially interesting. The current paper imposes a one-period penalty, but an interesting extension would be to consider a longer period of exclusion from financial markets. It would also be beneficial to consider other more realistic features of the housing market that

we have simplified. We conclude by briefly discussing three. First, it is obviously not the case that all borrowers in the economy either default or do not. It would thus be of interest to add an idiosyncratic shock to the model that allows for a default rate between 0 and 1. Second, many governments subsidize home ownership through the use of tax incentives. These could be added to the model to examine how they affect aggregate volatility. Finally, this paper treats the housing stock as constant. When default occurs, lower housing prices might incentivize producers to produce less new housing. Endogenizing the housing stock could thus yield larger effects on output than in the present paper.

4 The Home Mortgage Interest Deduction and Economic Growth

4.1 Introduction

The tax system in the United States (U.S.) incentivizes home purchases through three mechanisms: non-taxation of imputed rental income, special treatment of capital gains from home sales, and the home mortgage interest deduction (HMID). The focus of this paper will be determining whether or not certain features of the tax system in the U.S., in particular the HMID, result in inefficient over-investment in housing and consequently lower economic growth. Theoretically, the after-tax price of real estate investment is distorted by the HMID relative to other types of capital (interest on loans taken out to purchase other forms of capital ceased being tax-deductible in 1986). The impact of over-investment in housing is hypothesized to be lower subsequent economic growth.

The 16th Amendment was passed in 1913, allowing the government to implement an income tax.[1] Since then, the U.S. tax code has included a deduction for home mortgage interest. The federal HMID in its current state can be utilized on two owner-occupied homes on mortgages up to $1 million.[2] In order to benefit from the HMID, taxpayers must choose to itemize deductions. In 2009, two-thirds of households did not use itemized deductions.[3] Among taxpayers choosing to itemize deductions, the largest deduction is usually the HMID (Burman, 2003). Of households that earn over $125,000, 98 percent choose to itemize deductions. In contrast, only 23 percent of households with income below $40,000 choose to itemize (Poterba

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[1] The government tried to enact an income tax in 1894, but in 1895 Congress declared that it violated Article I, Section 9, of the constitution, which stated that "No capitation, or other direct, tax shall be laid, unless in proportion to the census or enumeration herein before directed to be taken." Pollock v. Farmers Loan and Trust Company, 158 U.S. 601 (1895) was the Supreme Court decision that declared the income tax sanctioned in 1894 to be unconstitutional.

[2] Henceforth, all mentions of the HMID refer to the Internal Revenue Code (IRC) of 1986 after amendment. A home is considered to be a house, condominium, cooperative, mobile home, house trailer, or boat.

[3] For more details, see the Internal Revenue Service (IRS) 2009 Statistics of Income (SOI) Table 2.1.

and Sinai, 2008).

The HMID was originally justified on the theoretical grounds that homeownership gener-ates positive externalities. For instance, individuals may be more likely to take care of a home that they own, as opposed to a home that they rent. Homeowners do not want to take the risk that their property will decrease in value upon resale; however, renters have no real incentive to update or upkeep homes since they will not reap the benefits upon selling. By maintaining and updating owner-occupied housing, the home price will likely increase, which has the potential to positively affect the value of other homes in the area. The "American Dream" and concept of familial stability are characterized by homeownership. Parents work late hours and difficult jobs in order to pay a mortgage so that their children can grow up in a safe neighborhood, surrounded by a caring community, and with access to good schools (Kiviat, 2010).

However, these positive associations have recently been scrutinized, as the negative ex-ternalities associated with homeownership were illuminated by the 2007 to 2009 recession. Households holding mortgage debt can be detrimental to the economy if they cannot make their loan payments. In addition, tying individuals to one location as a consequence of home-ownership decreases labor mobility and can raise unemployment costs, especially if people cannot find work in a given locale but are constrained from moving by an immobile asset such as a home.

Recently, economists have critically examined the HMID. In October 2012, National Public Radio brought together five economists from across the political spectrum and asked them to construct their dream political candidate. The economists unanimously agreed that their ideal political figure would eliminate the HMID and argue, primarily, that such a tax distorts the housing market (Smith, 2012).

In addition, residential housing stock has largely been ignored in the state-level economic growth literature. However, if we consider total private fixed assets (TPFA) in the economy, residential housing stock is more than half of the TPFA in the economy. Ignoring such a large

part of the capital stock could significantly bias estimates. Physical capital stock is almost always included in growth models, but from the estimates below, this is only about 47% of TPFA in the economy. Table 4.1 below shows capital stock statistics for the U.S. in 2009.[4]

Table 4.1: U.S. Private Fixed Assets 2009

Variable	Value	Percent of TPFA
Total Private Fixed Assets (TPFA)	31517.20	
Total Nonresidential Private Fixed Assets	14678.60	46.57
Equipment and Software	5382.70	17.08
Structures	9299.70	29.51
Residential Private Fixed Assets	16831.40	53.40

Source: Bureau of Economic Analysis, Survey of Current Business, August 2010

Units: Value in billions of chained 2005 dollars

This paper includes housing as an input in the production process and investment in housing as a determinant of economic growth, explicitly incorporating this significant portion of assets that was previously ignored.

The paper proceeds as follows. Section 4.2 outlines the related literature. Section 4.3 provides theoretical motivation. Section 4.4 and Section 4.5 describe the data and empirical methodology respectively. Section 4.6 presents the results, and Section 4.7 concludes.

4.2 Literature Review

The literature review is divided into three sections: the relationship between tax structure and the composition of investment (Section 4.2), investment and economic growth (Section 4.2), and determinants of state or regional income variation (Section 4.2).

Tax Structure and the Composition of Investment

Several studies have found that the composition of investment is affected by the tax system and inflation. It is estimated that eliminating the HMID would increase the user cost of hous-

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[4]While this table only shows values for 2009, the magnitudes are similar for the sample beginning with 2005.

ing by 7 percent, which is a substantial amount considering that the median home price was approximately \$173,300 in 2010 (Morris and Wang, 2012). This means that the user cost of housing would increase about \$12,131 if the HMID were eliminated (Poterba and Sinai, 2008). Increasing the user cost of housing could drive some individuals out of the housing market all together and encourage others to purchase smaller homes, freeing up funds for other types of investment activities.

In addition, Poterba and Sinai (2008) find that tax benefits from the HMID are ten times greater for households with adjusted gross income (AGI) of \$250,000 or more compared to those that earn between \$40,000 and \$75,000. In order to take advantage of the HMID, taxpayers must itemize. In 2004, 85 percent of citizens with AGI of \$75,000 or more chose to itemize, compared to 25 percent with AGI of less than \$75,000. Taxpayers earning over \$250,000 on average experience estimated tax reductions of \$5,459, whereas households with income between \$40,000 and \$75,000 only save on average \$523 (Poterba and Sinai, 2008). The importance of the HMID for those in higher income brackets is important because those individuals are also the most likely to be purchasing other forms of capital.

The HMID has recently been criticized as not achieving the initial goal of promoting home-ownership, particularly for those who may not otherwise been able to afford it. Glaeser and Shapiro (2002) find that the HMID "disproportionately favors the wealthy" and "is a particularly poor instrument for encouraging homeownership because it is targeted at the wealthy, who are almost always homeowners." For the purpose of this analysis, it is important to note that the HMID primarily benefits high-income taxpayers since they are more likely to purchase other types of capital than individuals with less disposable income. In other words, when examining how taxpayers allocate their disposable income, the choice of whether to purchase physical capital or a larger structure is most likely that of a household with a higher income.

Investment patterns have the potential to become distorted as a result of the HMID. The estimated average tax rate (EATR) on the return to corporate investment is 26.3 percent and 20.6

on the return to non-corporate business investment. In contrast, the EATR on owner-occupied housing is approximately 5.1 percent (Slemrod and Bakija, 2008). The HMID subsidizes real estate purchases and subsequently provides an incentive for taxpayers to increase investment in housing relative to other forms of investment. This feature of the U.S. tax code gives rise to potential over-investment in housing and inefficient allocation of resources. Furthermore, promoting one form of investment over another can produce deadweight loss. In 2004, the tax base decreased $998 billion as a consequence of itemized deductions. Approximately 36 percent ($356 billion) of lost tax revenues as a result of itemized deductions are due to interest payments and 96 percent ($340 billion) of lost tax revenue from interest deductions are attributed to the HMID (Slemrod and Bakija, 2008).

Feldstein (1983), in a compilation of 14 papers written on investment, tax systems, and inflation, declares that tax rules can decrease the user cost of residential capital relative to physical capital, resulting in housing over-investment. Along the same lines, it is possible that depreciation schemes of tax structures can favor long-lived assets, such as real estate. As noted by Delong and Summers (1991), machinery and equipment capital promotes growth more so than structures. Therefore, tax systems that incentivize purchases of housing over other forms of capital may be associated with lower subsequent growth. The source of the shift in investment composition may be depreciation allowances, inflation, or other features of the tax rules in a society. Cohen et al. (1997) hypothesize that the low effective tax rate on real estate is the main reason for substituting towards structures.

This investigation will build on the existing literature, focusing on one feature of the U.S. tax system, the HMID, and extending the analysis to a discussion of the impact of tax structure on economic growth. Consistent with the studies discussed above, the anticipated effect of the HMID is to lower the cost of real estate relative to physical capital. The impact of over-investment in housing is hypothesized to be lower subsequent economic growth.

Investment and Economic Growth

It is widely accepted in the field of long-run macroeconomics that investment share of gross domestic product (GDP) is positively and robustly correlated with economic growth. Mankiw et al. (1992) find that investment in physical capital (and human capital) is an important determinant of economic growth. They estimate a steady-state log production function, derived from the Solow model using ordinary least squares (OLS), and find that approximately 59% of variation in income can be explained by investment (in physical capital) and population growth. In addition, the augmented Solow model (which includes investment in human capital) accounts for about 80% of differences in income across countries.

Levine and Renelt (1992) obtain the result that investment promotes economic growth using extreme bounds analysis (EBA).[5] Sala-I-Martin (1997) relaxes the stringent methodology of Levine and Renelt (1992) and considers variables to be robust if they are significant and have the same sign for 95% of regressions. He finds that investment is positively related to GDP; however, he takes the analysis a step further by separating investment into two different categories: equipment and non-equipment.[6] While both types of investment are positively associated with income, the coefficient on equipment investment is approximately four times the coefficient on non-equipment investment, indicating that equipment investment contributes far more to economic growth than non-equipment investment.

Delong and Summers (1991) also find that machinery and equipment investment are strongly related to economic development. A three-percentage point increase in equipment investment as a share of GDP is associated with approximately a one-percentage point increase in GDP per year. Over the entire 25-year sample, this accounts for a 29% difference in na-

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[5]EBA identifies the highest and lowest values for the coefficient on the variable of interest significant at the 0.05 level. If the coefficient remains significant and of the same sign at the extreme upper bound (maximum value of the coefficient on the variable of interest plus two standard deviations) and the extreme lower bound (minimum value of the coefficient on the variable of interest minus two standard deviations) it is considered robust.

[6]Sala-I-Martin (1997) uses Delong and Summers (1991) definition of non-equipment investment, which includes structures and transportation equipment; however, Delong and Summers (1991) decompose investment even further and include structures and transportation equipment separately in an additional regression specification.

tional productivity.[7] Delong and Summers (1991) decompose investment into several different categories. Their results show that equipment investment has more explanatory power than any other component of investment—in particular, structures. After separating the two types of non-equipment investment (structures and transportation), the coefficient on transportation equipment is statistically insignificant. In this regression specification, equipment and machinery investment maintain its explanatory power. However, it is now clear that structures are driving the smaller magnitude of the coefficient on non-equipment investment. Capital (machinery) accumulation appears to be a key determinant of national economic growth. Note that Delong and Summers (1991), Levine and Renelt (1992), and Sala-I-Martin (1997) all exclude residential housing in their definition of capital.

It is possible that the HMID incentivizes purchases of structures (homes) relative to other types of investment. According to the long-run growth literature, this distortion of relative prices and resulting substitution effect could decrease national productivity. Thus, based on the conclusions of the studies discussed above, the expected sign of the coefficient on housing investment in the growth regression is negative.

Determinants of State or Regional Income Variation

This paper will attempt to determine if the HMID is important in explaining variation in U.S. state incomes; thus, it is valuable to consider previous works on the determinants of state or regional economic growth. Researchers have argued that tax policy, public infrastructure, size of private financial markets, rates of business failure, industry structure, geography or climate, culture, institutions, technology and education are significant factors affecting state productivity. Bauer et al. (2006) control for these alternate determinants and find that knowledge stocks are the factors with the most explanatory power. The authors have three measures of knowledge stocks: the fraction of the population with a high school degree, the proportion of the population with a bachelor's degree, and the stock of patents. Stock of patents held

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[7]In contrast, the coefficient on non-equipment investment is -0.015.

by individuals or businesses in a particular state, intended to proxy for innovation and new production technologies, is the most influential variable accounting for differences in development across states. In conclusion, Bauer et al. (2006) find that educational attainment and technological innovation or advancements are fundamental factors in promoting state growth. Furthermore, Gennaioli et al. (2011) highlight the significance of human capital in explaining regional income growth. Similarly, Gennaioli et al. (2011) model human capital as education; however, they decompose education into work and entrepreneurial education. The authors find that educational attainment is positively associated with income per capita, accounting for a large proportion of regional variation in GDP per capita.

This paper expands the current literature on state economic development. The factors previously found to be influential in explaining differences in regional income per capita will be used as control variables in the present analysis. Including formerly acknowledged determinants of state economic growth will alleviate any concern that the HMID is serving as a proxy for another factor that is important for development or that the results are biased due to an omitted variable.

4.3 Theory

The estimating equation 4.5.2 can be derived following the traditional Solow model. Equation 4.3.1 below is the continuous time Neo-classical Cobb-Douglas constant returns-to-scale technology production function augmented with real estate ($P(t)$):

$$Y(t) = K(t)^\alpha P(t)^\beta (A(t)L(t))^{1-\alpha-\beta} \tag{4.3.1}$$

where $Y(t)$ is output, $K(t)$ represents physical capital, $A(t)$ denotes technology, $L(t)$ is labor, and the parameters α and β are the respective factor shares.[8] Inputs are paid their marginal

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[8]In the context of examining the financial accelerator effect, Iacoviello (2005) includes real estate as an input in the production process. Following this assumption, housing is included in the production function above. Many growth economists have also added human capital to the production function (see, for example, Mankiw et al.

products, and labor and technology are assumed to grow exogenously, such that:

$$A(t) = A(0)e^{gt} \qquad (4.3.2)$$

$$L(t) = L(0)e^{nt} \qquad (4.3.3)$$

where n is the population growth rate and g is the rate of technological progress (percentage change in A). The stock variables evolve according to following equations:

$$\dot{k}(t) = s_k y(t) - (n + g + \delta_k)k(t) \qquad (4.3.4)$$

$$\dot{p}(t) = s_p y(t) - (n + g + \delta_p)p(t) \qquad (4.3.5)$$

where $\dot{k}(t)$ is the change in capital stock, $\dot{p}(t)$ is the change in housing stock, δ_k is the depreciation rate of physical capital and δ_p is the depreciation rate of housing. According to the literature, estimates of these two parameters can be quite different, which is intuitive as one would predict that real estate depreciates at a slower rate than machinery and equipment. Most estimates of the entire U.S. manufacturing sector range from about 10.6% to 12.6% (See Epstein and Denny (1980), Kollintzas and Choi (1985), and Bischoff and Kokkelenberg (1987)).[9] The housing stock has been shown to depreciate at a rate of about 2.5%, or 2% net of maintenance (Harding et al., 2007).[10] Lower case variables are in per effective units of labor terms ($y = Y/AL$, $k = K/AL$, $p = P/AL$). From equations 4.3.4 and 4.3.5, the steady state levels

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(1992)). However, this paper focuses on the role of housing in output growth so for simplicity, human capital is omitted.

[9]Note, some estimates are smaller, as in Nadiri and Prucha (1996), who find an estimated depreciation rate of about 5.9%. However, this estimate is still more than two times larger than the approximation for the depreciation rate of residential capital.

[10]Since this paper does not predict the size of the coefficients using the theoretical model, it is not imperative to choose an estimate for each depreciation rate. Rather, identifying that there is a difference between the depreciation rate of physical capital and residential capital is sufficient.

of capital and real estate can be derived:

$$k^* = \left(\frac{s_k^{1-\beta} s_p^{\beta}}{(n+g+\delta_k)^{1-\beta}(n+g+\delta_p)^{\beta}} \right)^{\frac{1}{1-\alpha-\beta}} \tag{4.3.6}$$

$$p^* = \left(\frac{s_k^{\alpha} s_p^{1-\alpha}}{(n+g+\delta_k)^{\alpha}(n+g+\delta_p)^{1-\alpha}} \right)^{\frac{1}{1-\alpha-\beta}} \tag{4.3.7}$$

where s_k is the investment rate in physical capital and s_p is the investment rate in housing. Using equations 4.3.1, 4.3.6, and 4.3.7, the estimating equation for income per capita can be derived. See Appendix B.1 for additional details.

$$\ln(\tilde{y}^*) = \ln A(0) + gt + \frac{\alpha}{1-\alpha-\beta} \ln(s_k) + \frac{\beta}{1-\alpha-\beta} \ln(s_p)$$
$$- \frac{\alpha}{1-\alpha-\beta} \ln(n+g+\delta_k) - \frac{\beta}{1-\alpha-\beta} \ln(n+g+\delta_p) \tag{4.3.8}$$

where $\ln(\tilde{y}^*)$ is the log of steady-state income per capita. The above reduced form equation can now be estimated.

4.4 Data

The data are a panel of U.S. states from 2005 to 2010. The natural log of real GDP (*GDP*) by state per capita is the dependent variable.[11] Real GDP per capita is used to measure state economic growth. The Bureau of Economic Analysis (BEA) measure of GDP is divided by the Census population statistics and deflated using a regional consumer price index (CPI) from the Bureau of Labor Statistics (BLS).

The variable of interest, retrieved from Internal Revenue Service (IRS) data, is the amount of the HMID per capita (*HMID*) utilized by state for each year. Figure 4.1 below shows the

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[11]The natural log of personal income per capita (*Personal Income*) is substituted as the dependent variable to check for robustness by using an alternate measure of economic performance.

distribution of the HMID per capita by state in 2009.
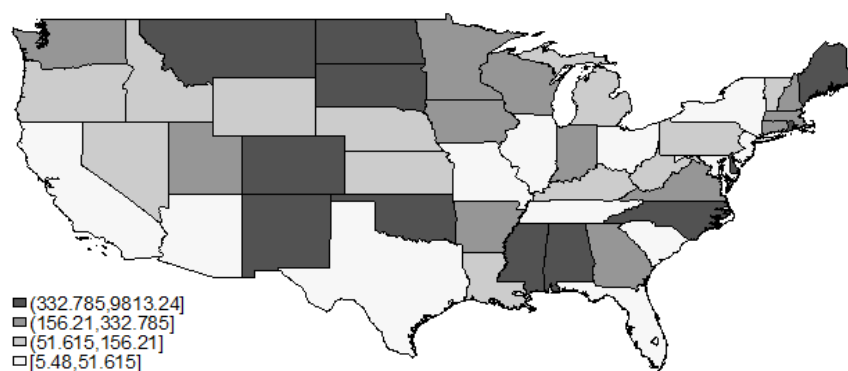
Figure 4.1: Home Mortgage Interest Deduction (per capita) by State 2009

It is evident that the HMID is utilized in various amounts across states. Of course, this does not account for differences in income or housing stock across states, it is purely for demonstrative purposes to show nominal variation (not holding any other variables constant).

Total real housing wealth (*Housing*) is equal to the average value of owner-occupied housing.[12] The Lincoln Institute of Land Policy Land Prices by State Dataset developed by Davis and Heathcote (2007) provides the data necessary for the average value of owner occupied housing. Bauer et al. (2006) use a proxy for state private capital stock measured as dollars in private financial market bank deposits (*Deposits*) taken from the Federal Deposit Insurance Corporation's Summary of Deposits. This measure of deposits is used, as well as, a variable that explicitly measures physical capital expenditures (total new and used) minus capital expenditures on buildings and structures (*Capital (No Bldgs)*), from the Survey of Manufacturers.[13]

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[12]Calomiris et al. (2012) use a measure of aggregate housing wealth as the average value of owner-occupied housing multiplied by the number of owner-occupants. However, since this analysis is conducted in per capita terms, just the average home value is used. Any aggregate housing stock measures use the Annual Social and Economic (ASEC) Supplement to the Current Population Survey (CPS) for annual data on the number of owner-occupied households in each state.

[13]In future work, I intend to use a variable of stock market wealth as a proxy for capita. Stock wealth is calculated using the Federal Reserve Flow of Funds 21 Statistical Release Table L100 for the first quarter in 2011. The distribution of mutual fund holdings across states is retrieved from the Investment Company Institute. Nominal stock wealth by state is defined as aggregate U.S. stock wealth times the percent of mutual fund holdings by state.

Poverty rates (*Poverty Rate*), collected from the Census Historical Poverty Table 21, are included as a control variable in some regression specifications. A measure of educational attainment the proportion of the population with a bachelor's degree or more (*Bachelor's Plus*), obtained from the CPS estimates, is also used as proxy for human capital, deemed to be an important determinant of state growth (Bauer et al. (2006)). Finally, the contract interest rate on conventional single-family mortgages (*CIR*), collected from Monthly Interest Rate Survey (MIRS) conducted by the Federal Housing Finance Agency, has been shown to be a significant factor in determining housing (Calomiris et al. (2012)).

Table 4.2 displays summary statistics for the United States over the entire sample, 2005 to 2010.

Table 4.2: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
GDP	21,262.41	3,799.91	14,868.72	34,197.19	298
Personal Income	18,029.28	2,312.59	14,043.02	25,331.50	298
HMID	647.75	256.07	243.47	1,434.46	298
Capital (No Bldgs)	195.83	93.98	21.81	578.96	245
Total Deposits	12,690.28	15,301.65	4,770.05	152,663.36	298
Housing	120,121.31	58,749.92	61,501.09	413,164.69	298
Bachelor's Plus	26.72	4.68	16.50	38.20	250
Poverty Rate	12.57	3.24	5.40	23.10	298
CIR	5.78	0.66	4.58	6.73	298

Notes: GDP, Personal Income, HMID, Capital (No Bldgs), Deposits, Housing, and Deficit are reported in real (base year 1982-1984=100) per capita terms. Bachelor's Plus and Poverty Rates are percentages of the population age 25 and over and total population respectively. CIR is a percent.

Another important component of the analysis is variation in tax policies by state. A state income tax is imposed by 41 states, and 31 of the 41 states with an income tax further incentivize homeownership with a state mortgage interest deduction. In addition to differences based on deductions, credits, and exemptions, 34 states use a progressive income tax system and marginal tax rates based on income bracket differ across states. Table 4.3 shows the lowest

and highest income tax rates for each state with a state income tax. See below for details.[14]

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[14]Data are collected as of the tax year 2009. State tax policy is assumed to not change significantly over the sample period. States without an income tax include: Alaska, Florida, Nevada, South Dakota, Texas, Washington, and Wyoming. New Hampshire and Tennessee tax only investment income.

Table 4.3: State Tax Policiies

State	Low State Income Tax Rate	High State Income Tax Rate	State MID
Alabama	2.00	5.00	yes
Arizona	2.59	4.54	yes
Arkansas	1.00	7.00	yes
California	1.25	9.55	yes
Colorado	4.63	4.63	yes
Connecticut	3.00	6.70	no
Delaware	0.00	6.95	yes
District Of Columbia			yes
Georgia	1.00	6.00	yes
Hawaii	1.40	11.00	yes
Idaho	1.60	7.80	yes
Illinois	3.00	3.00	no
Indiana	3.40	3.40	no
Iowa	0.36	8.98	yes
Kansas	3.50	6.45	yes
Kentucky	2.00	6.00	yes
Louisiana	2.00	6.00	no
Maine	2.00	8.50	yes
Maryland	2.00	6.50	yes
Massachusetts	5.30	5.30	no
Michigan	4.35	4.35	no
Minnesota	5.35	7.85	yes
Mississippi	3.00	5.00	yes
Missouri	1.50	6.00	yes
Montana	1.00	6.90	yes
Nebraska	2.56	6.84	yes
New Jersey	1.40	8.97	no
New Mexico	1.70	4.90	yes
New York	4.00	8.97	yes
North Carolina	6.00	7.75	yes
North Dakota	1.51	3.99	yes
Ohio	0.62	6.24	no
Oklahoma	0.50	5.25	yes
Oregon	5.00	11.00	yes
Pennsylvania	3.07	3.07	no
Rhode Island	3.75	9.90	yes
South Carolina	0.00	7.00	yes
Utah	5.00	5.00	yes
Vermont	3.55	9.40	yes
Virginia	2.00	5.75	yes
West Virginia	3.00	6.50	no
Wisconsin	4.60	7.75	yes

Sources: IRS SOI Table 2. Individual Income and Tax Data, by State and Size of Adjusted Gross Income

Morris, D. and J. Wang (2012, June). How and why states use the home mortgage interest deduction. State Tax Notes.

For more details on the variables used in the analysis, calculations, and sources, please see Table A1 in the Appendix.

4.5 Methodology

First, in order to establish the relationship between machinery investment, other forms of capital investment and economic growth, the analysis of Delong and Summers (1991) is replicated with state level data. The estimating equation is:

$$y_{it} = c_i + \gamma_1 k_{M,it} + \gamma_2 k_{N,it} + \delta_t + u_{1,it} \qquad (4.5.1)$$

where y_{it} is log of real GDP per capita, c_i are state fixed effects, and δ_t is a vector of year dummy variables. Physical capital investment is divided into two categories: $k_{M,it}$ is the log of machinery and equipment investment per capita and $k_{N,it}$ is the log of non-equipment investment per capita. Delong and Summers (1991) explore a few different classifications of the components of each of the capital variables. Results with various equipment and non-equipment capital definitions are presented in Section 4.6.

The second set of results empirically examine the hypothesis derived from the theoretical model presented in Section 4.3 following Mankiw et al. (1992), but adding residential capital to the specification. The regression equation is as follows:

$$y_{it} = c_i + \beta_1 k_{it} + \beta_2 p_{it} + \beta_3 X_{it} + \delta_t + u_{2,it} \qquad (4.5.2)$$

where y_{it} is the dependent variable (the log of real GDP or personal income per capita, depending on the model specification), c_i is unobserved individual state level heterogeneity, X_{it} is a matrix of control variables that are time variant and individual specific, k_{it} is the measure of physical capital (the log of real capital expenditures not including buildings or total deposits per capita) by state over time, p_{it} is the log of the real housing stock by state over time, δ_t is a

vector of $(T-1)$ time dummy variables, and $u_{2,it}$ is the error term (assumed to be uncorrelated with the explanatory variables). Time dummies are included in the regression to control for business cycle trends. Variables in the X_{it} matrix vary by specification. These variables include the poverty rate, percent of the population over age 25 with a bachelor's degree or more, and the log of the real state budget deficit per capita. All level variables are reported in log per capita terms, defined as the log of the variable divided by the Bureau of Economic Analysis measure of the state population.

Estimating equation 4.5.2 alone would lead to biased estimates. While the housing stock is an important determinant of output, the level of GDP or income influences the size of the housing stock. Therefore, in addition to estimating the above equation examining the effect of housing on economic activity, an equation for determinants of the housing stock should be simultaneously estimated. Aggregate housing has been shown to be mainly a function of the HMID, output or income, and the interest rate:

$$p_{it} = c_i + \alpha_1 HMID_{it} + \alpha_2 y_{it} + \alpha_3 Z_{it} + \delta_t + u_{3,it} \qquad (4.5.3)$$

where $HMID_{it}$ is the log of the amount of the HMID per capita utilized by state over time and Z_{it} is the contract interest rate (CIR).

State tax policy exhibits a fair amount of inertia over time due to lags in legislation, as well as other political issues. Over the five year sample, there was little to no change in the tax policies displayed in Table 4.3; however, there is significant variation across states. Since state variation in income tax policy and the state mortgage interest deduction are relatively time invariant (and do not significantly change over the sample), the effects are washed out by the state dummies. However, the federal home mortgage interest deduction will likely be more highly valued in a state with an income tax than without. Therefore, in some specifications, an interaction term between HMID and a dummy variable indicating whether or not the state has an income tax is included.

Equations 4.5.2 and equation 4.5.3 show that housing and income are jointly determined. The proper estimation technique for a simultaneous equations model is an instrumental variable (IV) approach. For this system of equations, the primary estimation technique is two-stage least squares (2SLS). The first stage is estimated by equation 4.5.3 and the second stage is equation 4.5.2. As a robustness check, three-stage least squares (3SLS) estimation is also used in which the third stage computes the generalized least squares (GLS) estimator using the asymptotic covariance matrix.

In order use IV estimation techniques, a few assumptions are made. First, it is assumed that $\alpha_2\beta_2 \neq 1$ for the reduced forms of y_{it} and p_{it} to exist. Second, the coefficient, α_3 on the contract interest rate is not equal to zero and can be used as an instrument for p_{it}. Under this assumption, Equation 4.5.2 is identified. See Tables 4.5 and A6 for 2SLS estimation results, and Tables 4.6 and A7 for 3SLS estimation results and verification of the identifying assumptions.

4.6 Results

Section 4.6 has two parts: Section 4.6 and Section 4.6. The first, Section 4.6 replicates the finding of Delong and Summers (1991) using state-level data. The second, Section 4.6 incorporates residential housing in a model predicting changes in real GDP per capita and estimates the impact of housing on economic activity, taking into account other factors, such as the HMID, that influence the housing stock.

Equipment Investment and GDP

Table 4.4 displays the regression results from specification 4.5.1. Here, machinery and equipment investment is defined as the log of real capital expenditures on machinery and equipment (new and used) per capita. Non-equipment investment is the log of real capital expenditures on buildings and structures. The dependent variable in all specifications is the log of real GDP per capita. The poverty rate is included in regression specifications (2) and

(4), and the percent of the population with a bachelor's degree or more is added to regression specifications (3) and (4) as an additional control.

Table 4.4: Equipment Investment and GDP

	(1)	(2)	(3)	(4)
Capital Machinery	0.0258**	0.0207**	0.0330***	0.0277**
	(0.0104)	(0.0101)	(0.0114)	(0.0112)
Capital Buildings	0.000439	-0.00266	0.00393	0.000857
	(0.00673)	(0.00650)	(0.00731)	(0.00717)
Poverty Rate		-0.00757***		-0.00629***
		(0.00183)		(0.00205)
Bachelor's Plus			0.00230	0.000927
			(0.00615)	(0.00599)
Observations	245	245	197	197
R-squared	0.193	0.260	0.266	0.312
Number of States	50	50	50	50

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The main result of Delong and Summers (1991) holds when extended from a panel of countries to a panel of U.S. states. Delong and Summers (1991) find that the most influential component of investment spending is equipment investment. As indicated by specifications (1), (3), and (4), a one percent increase in capital machinery expenditures leads to a 0.03% increase in GDP.[15] In all four columns of Table 4.4, the effect of capital expenditures on buildings and structures is statistically and economically insignificant. Table 4.4 shows that the results of Delong and Summers (1991) can be applied to U.S. state economic activity and that equipment investment is more closely linked to percent changes in GDP than other types of investment (including buildings and structures). These results are robust to other definitions of machinery and equipment investment and using only the 48 contiguous states. See Appendix B.3 for details.

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[15]Regression specification (2) implies the same result with a slightly smaller magnitude after controlling for only the poverty rate.

Housing Investment and GDP

The work of Delong and Summers (1991) is replicated above using U.S. states. However, Delong and Summers (1991) omit an important component of investment—residential investment. Table 4.5 below shows the results from the 2SLS model given by equations 4.5.2 and 4.5.3, which include residential housing and its determinants. The dependent variable is the log of real GDP per capita. Table A6 in Appendix B.4 shows the results with additional control variables.

Table 4.5: Equipment Investment, Housing Investment, and GDP (2SLS)

Variables	(1) GDP	(2) Housing	(3) GDP	(4) Housing
Capital (No Bldgs)	0.00463			
	(0.010)			
Housing	0.272***		0.262***	
	(0.036)		(0.031)	
Total Deposits			0.0373***	
			(0.013)	
GDP		2.626*		-1.729
		(1.367)		(1.836)
HMID		0.15		1.464***
		(0.441)		(0.549)
CIR		-0.288***		0.00386
		(0.111)		(0.128)
Observations	245	245	298	298

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Delong and Summers (1991) find that investment in structures has either a negative impact on changes in real GDP or a much smaller effect on changes in real GDP than investment in equipment and machinery. However, the results of the present anaylsis reveal that the impact of residential structures on growth is quite different. From Table 4.5, it is evident that investment in housing increases real GDP. Specifically, a 1% increase in the housing stock is associated

with an increase in real GDP per capita between 0.26 and 0.27%, depending on the specification. Investment in housing increases real GDP per capita by more than an increase in physical capital investment (not including structures). Physical capital does not have a statistically significant effect on real GDP per capita using the measure of physical capital, after controlling for housing. While capital does have a statistically significant effect on real GDP per capita using total deposits as a proxy, the magnitude is far less than the impact of housing.

The first stage of the model estimates the impact of real GDP, the CIR, and the HMID on economic growth. As anticipated, the HMID has a statistically significant and positive effect on the housing stock. A 1% increase in HMID utilization yields a 1.46% increase in the housing stock, when using total deposits as a proxy for capital as in Bauer et al. (2006). Real GDP per capita also has a strong, positive association with the housing stock in specification (1). Finally, the coefficient on the CIR also has the expected sign and is statistically significant when using the measure of physical capital expenditures. Increasing the CIR by one percentage point is associated with a 2.88% decrease in housing. An increase in the CIR makes housing more expensive and decreases the housing stock.

The 3SLS estimates are displayed in Table 4.6 below. Again, results with additional explanatory variables are reported in Appendix B.4 Table A7.

Table 4.6: Equipment Investment, Housing Investment, and GDP (3SLS)

Variables	(1) GDP	(2) Housing	(3) GDP	(4) Housing
Capital (No Bldgs)	0.00463			
	(0.008)			
Housing	0.272***		0.262***	
	(0.031)		(0.028)	
Total Deposits			0.0373***	
			(0.012)	
Bachelor's Plus				
Poverty Rate				
GDP		2.765**		-1.7
		(1.197)		(1.647)
HMID		0.233		1.448***
		(0.386)		(0.493)
CIR		-0.0345		-0.0196
		(0.080)		(0.115)
Observations	245	245	298	298

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results from the 2SLS estimates hold in the 3SLS estimates. From these results, we can conclude that encouraging individuals to substitute towards residential housing through the HMID has the potential to be beneficial for state economic activity. It is also evident that commercial real estate and residential real estate have significantly different implications for growth.

The main results presented in Tables 4.5 and 4.6 are robust to inclusion of only the 48 contiguous states and using log real personal income per capita as the dependent variable. See Appendix B.4 for details.

4.7 Conclusion

The original hypothesis given the economic growth theory and contributions from the previous literature is refuted by the results presented in Section 4.6. Theoretically, building off of Delong and Summers (1991), it is anticipated that incentivizing homeownership through the HMID would decrease economic growth by encouraging real estate purchases as opposed to physical capital. However, this paper shows that while the HMID is effective at promoting homeownership, it does not lead to lower levels of GDP. In fact, a 1% increase in housing investment increases real GDP by more than a 1% increase in physical capital investment. Given these results, the recent criticisms of the HMID do not appear to be justified. While this paper does not make any claims regarding the positive externalities of homeownership, it does conclude that the HMID increases state-level economic growth.

Future research should consider the following extensions. First, it would be informative to consider an interaction term between the HMID variable and a dummy variable indicating whether or not the state has an income tax. Intuitively, holding all else constant, the federal HMID is more beneficial for households in a state with an income tax. Second, in order to better align the theoretical model with the empirical specification, future research should consider investment in physical capital to be saving in the stock market. This would capture the individual household decision regarding their savings allocation. Finally, it would be interesting to consider instrument with lags and dynamic panel estimation techniques to account for the possibility of persistence in the relationship between the HMID and real GDP over time.

Appendices

A Monetary Policy, Access to Credit, and Long-term Mortgages: Appendix

A.1 Monetary Policy, Access to Credit, and Long-term Mortgages: Additional Notation

Table A1: Variables

Y	output
c	entrepreneur consumption
c'	patient household consumption
c''	impatient household consumption
b	entrepreneur debt
b'	amount patient households lend
b''	impatient household debt
h	entrepreneur housing
h'	patient household housing
h''	impatient household housing
π	inflation
R	nominal interest rate
RF	long-term interest rate
ρ	Lagrange multiplier on entrepreneur credit constraint
ρ''	Lagrange multiplier on impatient household credit constraint
q	housing prices
X	markup over marginal cost
F	lump-sum profits
w'	patient household wage
w''	impatient household wage
L'	patient household labor
L''	capital share in production
D	riskless bonds
T'	central bank transfers to patient households
T''	central bank transfers to impatient households

Table A2: Additional Notation

A	technology
E	expectations operator
H	total supply of housing
P^W	wholesale price index
S	marginal product of housing
e_R	interest rate shock
j	housing weight
m	loan-to-value ratio
r_R, r_Y, r_π, r_q	coefficients on policy rule
rr	real rate
s	income share
t	time
β	discount factor for households
γ	discount factor for entrepreneur
δ	depreciation rate of capital
ϵ	elasticity of demand for final goods
ν	labor disutility
θ	price rigidity
κ	Phillips curve slope
λ	Lagrange multiplier on borrowing constraint
μ	capital share in production
η	housing share in production
π	inflation
$'$	patient households
$''$	impatient households
$\hat{\ }$	percentage deviation from steady state
$-$	steady-state value
upper case variables	nominal
lower case variables	real

A.2 Monetary Policy, Access to Credit, and Long-term Mortgages: Equations in the system

Patient household real budget constraint

$$
\begin{aligned}
c_t' + D_t + q_t(h_t' - h_{t-1}') + \frac{(R_{t-1}^F)^2}{(1 + R_{t-1}^F)} \frac{b_{t-1}'}{\pi_t} + \frac{(R_{t-2}^F)^2}{(1 + R_{t-2}^F)} \frac{b_{t-2}'}{\pi_t \pi_{t-1}} \leq \\
b_t' + w_t' L_t' + R_{t-1} D_{t-1}' + T_t' - \frac{(M_t' - M_{t-1}')}{P_t}
\end{aligned}
\tag{A.2.1}
$$

Patient household labor supply

$$
\frac{w_t'}{c_t'} = L_t'^{\eta-1}
\tag{A.2.2}
$$

Patient household housing demand

$$
\frac{q_t}{c_t'} = \frac{j}{h_t'} + \beta' E_t \left[\frac{q_{t+1}}{c_{t+1}'} \right]
\tag{A.2.3}
$$

Patient household Euler with respect to one-period debt (riskless bonds)

$$
\frac{1}{c_t'} = \beta' E_t \left[\frac{R_t}{\pi_{t+1} c_{t+1}'} \right]
\tag{A.2.4}
$$

Patient household Euler with respect to two-period debt

$$
\frac{1}{c_t'} = \frac{\beta' RF_t^2}{1 + RF_t} E_t \left[\frac{1}{c_{t+1}' \pi_{t+1}} + \frac{\beta'}{c_{t+2}' \pi_{t+1} \pi_{t+2}} \right]
\tag{A.2.5}
$$

Impatient household real budget constraint

$$
c_t'' + q_t(h_t'' - h_{t-1}'') + \frac{(R_{t-1}^F)^2}{(1 + R_{t-1}^F)\pi_t} b_{t-1}'' + \frac{(R_{t-2}^F)^2}{(1 + R_{t-2}^F)\pi_t \pi_{t-1}} b_{t-2}'' \leq b_t'' + w_t'' L_t'' + T_t'' - \frac{(M_t'' - M_{t-1}'')}{P_t}
$$

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Impatient household labor supply

$$\frac{w_t''}{c_t''} = L_t''^{(\eta-1)} \tag{A.2.6}$$

Impatient household housing demand

$$\frac{q_t}{c_t''} = \frac{j}{h_t''} + \beta'' E_t\left[\frac{q_{t+1}}{c_{t+1}''}\right] + \rho_t'' m E_t[q_{t+1}\pi_{t+1}] \tag{A.2.7}$$

Impatient household Euler equation (two-period debt only)

$$\frac{1}{c_t''} = \frac{RF_t^2}{1+RF_t} E_t\left[\frac{\beta''}{c_{t+1}''\pi_{t+1}} + \frac{\beta''^2}{c_{t+2}''\pi_{t+1}\pi_{t+2}} + \rho_t'' + \frac{\beta''\rho_{t+1}''}{\pi_{t+1}}\right] \tag{A.2.8}$$

The production function

$$Y_t = A_t h_{t-1}^v L_t'^{\alpha(1-v)} L_t''^{(1-\alpha)(1-v)} \tag{A.2.9}$$

Impatient household real borrowing constraint

$$\frac{b_t'' RF_t^2}{1+RF_t} + \frac{b_{t-1}'' RF_{t-1}^2}{(1+RF_{t-1})\pi_t} \leq m'' E_t[q_{t+1}\pi_{t+1}h_t''] \tag{A.2.10}$$

Entrepreneurs real credit constraint

$$\frac{b_t RF_t^2}{1+RF_t} + \frac{b_{t-1} RF_{t-1}^2}{(1+RF_{t-1})\pi_t} \leq m E_t[q_{t+1}\pi_{t+1}h_t] \tag{A.2.11}$$

Labor demand for patient household

$$w_t' = \frac{(1-v)\alpha Y_t}{X_t L_t'} \tag{A.2.12}$$

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Labor demand for impatient household

$$w_t'' = \frac{(1-v)(1-\alpha)Y_t}{X_t L_t''}$$

(A.2.13)

Entrepreneur housing demand

$$\frac{q_t}{c_t} = E_t \left[\frac{\gamma}{c_{t+1}} \left(\frac{vY_{t+1}}{X_{t+1}h_t} + q_{t+1} \right) + \rho_t m q_{t+1} \pi_{t+1} \right]$$

(A.2.14)

Entrepreneur Euler equation (two-period debt only)

$$\frac{1}{c_t} = \frac{(R_t^F)^2}{1+R_t^F} E_t \left[\frac{\gamma}{c_{t+1}\pi_{t+1}} + \frac{\gamma^2}{c_{t+2}\pi_{t+1}\pi_{t+2}} + \rho_t + \frac{\gamma\rho_{t+1}}{\pi_{t+1}} \right]$$

(A.2.15)

Aggregate demand

$$Y_t = c_t + c_t' + c_t''$$

(A.2.16)

Housing market equilibrium condition (housing stock fixed)

$$H = h_t + h_t' + h_t''$$

(A.2.17)

Loan market equilibrium condition

$$0 = b_t + b_t' + b_t''$$

(A.2.18)

Patient household one-period bonds

$$D_t = 0$$

(A.2.19)

Central bank lump sum transfers

$$T_t = 0 \tag{A.2.20}$$

Lump-sum profits

$$F_t = \left(1 - \frac{1}{X_t}\right) Y_t \tag{A.2.21}$$

Stochastic AR(1) technology process

$$A_t = A_{t-1}^{\rho_A} e_{A,t} \tag{A.2.22}$$

Policy Rule

$$R_t = (\pi_{t-1}^{1+r_\pi} (Y_{t-1}/Y)^{r_Y} \overline{rr}) e_{R,t} \tag{A.2.23}$$

Non-linear New-Keynesian Phillips Curve

A.3 Monetary Policy, Access to Credit, and Long-term Mortgages: Steady State Equations

From impatient household labor supply, equation A.2.6

$$w'' = L''^{\eta-1} c''$$

(A.3.1)

From impatient household euler, equation A.2.8

$$\rho'' = \frac{1}{c''(1+\beta'')} \left(\frac{1+RF}{RF^2} - \beta'' - \beta''^2 \right)$$

(A.3.2)

From impatient household housing demand, equationA.2.7

$$h'' = \frac{c'' j}{q(1+\beta'') - \rho'' mqc''}$$

(A.3.3)

From impatient household borrowing constraint, equation A.2.10

$$\beta'' = \frac{mqh''(1+RF)}{2RF^2}$$

(A.3.4)

From patient household labor supply, equation A.2.2

$$w' = L'^{\eta-1} c'$$

(A.3.5)

From patient household housing demand, equation A.2.3

$$h' = \frac{c' j}{(1+\beta')q}$$

(A.3.6)

From patient household euler with respect to one-period debt, equation A.2.4

$$R = \frac{1}{\beta'}$$

(A.3.7)

From patient household euler with respect to two-period debt, equationA.2.5

$$RF = \frac{1}{1 + \beta'} \tag{A.3.8}$$

A_t is a stochastic process, equation A.2.22

$$A = 1 \tag{A.3.9}$$

From patient household one-period debt, equation A.2.19

$$D = 0 \tag{A.3.10}$$

From aggregate demand, equation A.2.16

$$Y = c + c' + c'' \tag{A.3.11}$$

From equilibrium housing market condition,[1] equation A.2.17

$$h = 1 - h' - h'' \tag{A.3.12}$$

From labor demand for impatient households, equation A.2.13

$$w'' = \frac{(1-v)(1-\alpha)Y}{L'' X} \tag{A.3.13}$$

From entrepreneur euler equation, equation A.2.15

$$c = \frac{1 + RF}{RF^2 \rho(1+\gamma)} - \frac{\gamma}{\rho} \tag{A.3.14}$$

---

[1]Note: housing stock is fixed at 1

From loan market equilibrium condition, equation A.2.18

$$b^{'} = -b - b^{''} \tag{A.3.15}$$

From lump-sum profits, equation A.2.21

$$F = \left(1 - \frac{1}{X}\right) Y \tag{A.3.16}$$

Lump-sum transfers, equation A.2.20

$$T = 0 \tag{A.3.17}$$

From the New-Keynesian Phillips Curve, equation A.3.18

$$\pi = 1 \tag{A.3.18}$$

A.4 Monetary Policy, Access to Credit, and Long-term Mortgages: Log-linearized Model

This section outlines the complete log-linearized model. Hats denote percentage change from the steady state and bars represent steady state values. I omit the expectations operator on $t + 1$ and $t + 2$ variables as a notational convenience, but $t + 1$ and $t + 2$ variables should be considered the conditional expected value based the information set in time t.

$$\hat{Y}_t = \frac{\bar{c}}{\bar{Y}}\hat{c}_t + \frac{\bar{c}'}{\bar{Y}}\hat{c}'_t + \frac{\bar{c}''}{\bar{Y}}\hat{c}''_t \tag{A.4.1}$$

$$\hat{b}_t\bar{b} + \hat{b}'_t\bar{b}' + \hat{b}''_t\bar{b}'' = 0 \tag{A.4.2}$$

$$\hat{h}_t\bar{h} + \hat{h}'_t\bar{h}' + \hat{h}''_t\bar{h}'' = 0 \tag{A.4.3}$$

Equations A.4.1 through A.4.3 are market clearing conditions where A.4.1 is aggregate demand, A.4.2 is the market clearing condition for debt, indicating that total borrowing by impatient households and entrepreneurs must be equal to total lending by patient households, and A.4.3 is the market clearing condition for housing, in which total housing stock (H) is normalized to one.

$$\hat{c}_t = \hat{\pi}_{t+1} + \hat{c}'_{t+1} - \hat{R}_t \tag{A.4.4}$$

$$\frac{(1 + \overline{RF})}{\beta'\overline{RF}^2}\hat{c}'_t = \frac{-(1 + \beta')(2 + \overline{RF})}{(1 + \overline{RF})}\hat{RF}_t + \hat{c}'_{t+1} + (1 + \beta')\hat{\pi}_{t+1} + \beta'\hat{c}'_{t+2} + \beta'\hat{\pi}_{t+2} \tag{A.4.5}$$

$$\frac{(1 + \overline{RF})}{\overline{RF}^2} \hat{c}_t'' = -(\beta''(1 + \beta'') + \bar{\rho}'' \bar{c}''(1 + \beta)) \left(\frac{2 + \overline{RF}}{1 + \overline{RF}}\right) \hat{RF}_t$$

$$+ \beta'' \hat{c}_{t+1}'' + \beta''(1 + \beta'' + \bar{\rho}'' \bar{c}'') \hat{\pi}_{t+1} + (\beta'')^2 \hat{\pi}_{t+2} + (\beta'')^2 \hat{c}_{t+2}'' - \bar{\rho}'' \bar{c}''(\hat{\rho}_t'' + \beta'' \hat{\rho}_{t+1}'')$$

$$\text{(A.4.6)}$$

$$\frac{(1 + \overline{RF})}{\overline{RF}^2} \hat{c}_t = -(\gamma(1 + \gamma) + \bar{\rho}\bar{c}(1 + \gamma)) \left(\frac{2 + \overline{RF}}{1 + \overline{RF}}\right) \hat{RF}_t$$

$$+ \gamma \hat{c}_{t+1} + \gamma(1 + \gamma + \bar{\rho}\bar{c}) \hat{\pi}_{t+1} + \gamma^2 \hat{\pi}_{t+2} + \gamma^2 \hat{c}_{t+2} - \bar{\rho}\bar{c}(\hat{\rho}_t + \gamma \hat{\rho}_{t+1}) \quad \text{(A.4.7)}$$

Equations A.4.4 through A.4.7 are the Euler equations derived from the constrained utility maximization problems of the respective agents. Specifically, A.4.4 is the patient household Euler equation for one-period debt, A.4.5 is the patient household Euler equation with respect to two-period debt, A.4.6 is the impatient household Euler equation, and A.4.7 is the entrepreneur Euler equation.

$$\hat{q}_{t+1} + \hat{\pi}_{t+1} + \hat{h}_t'' = \frac{\bar{b}'' \overline{RF}^2}{(1 + \overline{RF}) m \bar{h}'' \bar{q}} \left(\hat{b}_t'' + \hat{b}_{t-1}'' - \hat{\pi}_t + \left(\frac{2 + \overline{RF}}{1 + \overline{RF}}\right)(\hat{RF}_t + \hat{RF}_{t-1})\right)$$

$$\text{(A.4.8)}$$

$$\hat{q}_{t+1} + \hat{\pi}_{t+1} + \hat{h}_t = \frac{\bar{b} \overline{RF}^2}{(1 + \overline{RF}) m \bar{h} \bar{q}} \left(\hat{b}_t + \hat{b}_{t-1} - \hat{\pi}_t + \left(\frac{2 + \overline{RF}}{1 + \overline{RF}}\right)(\hat{RF}_t + \hat{RF}_{t-1})\right) \quad \text{(A.4.9)}$$

Equations A.4.8 and A.4.9 are the credit constraints for the impatient households and entrepreneurs respectively.

$$\hat{\pi}_t = \beta \hat{\pi}_{t+1} - \kappa \hat{X}_t \tag{A.4.10}$$

The New-Keynesian Phillips curve is equation A.4.10.

$$\hat{A}_t = \rho_A \hat{A}_{t-1} + \hat{e}_{A,t} \tag{A.4.11}$$

Equation A.4.11 is the AR(1) process for A.

$$\hat{R}_t = (1 - r_R)(1 + r_\pi)\hat{\pi}_{t-1} + r_Y(1 - r_R)\hat{x}_{t-1} + r_R\hat{R}_{t-1} + \hat{e}_{R,t} \tag{A.4.12}$$

The central bank policy rule is equation A.4.12.

$$\frac{\bar{X}\bar{F}}{\bar{Y}}\hat{F}_t = (\bar{X} - 1)\hat{Y}_t + \hat{X}_t \tag{A.4.13}$$

Equation A.4.13 represents lump-sum profits to retailers.

$$\frac{j}{\bar{h}'}\hat{h}'_t = \frac{\bar{q}}{\bar{c}'}(\hat{c}'_t - \hat{q}_t - \beta'\hat{c}'_{t+1} + \beta'\hat{q}_{t+1}) \tag{A.4.14}$$

$$\frac{j\bar{c}''}{\bar{h}''\bar{q}}\hat{h}''_t = m\bar{c}''\bar{\rho}''(\hat{\rho}''_t + \hat{q}_{t+1} + \hat{\pi}_{t+1}) - \hat{q}_t + \hat{c}''_t + \beta''\hat{q}_{t+1} - \beta''\hat{c}''_{t+1} \tag{A.4.15}$$

$$\hat{q}_t = \hat{c}_t + \left(\frac{\gamma v\bar{Y}}{\bar{q}\bar{x}\bar{h}}\right)\left(-\hat{c}_{t+1} + \hat{Y}_{t+1} - \hat{X}_{t+1} - \hat{h}_t\right) - \gamma\hat{c}_{t+1} + (\gamma + \bar{c}\bar{\rho}m)\hat{q}_{t+1} + \bar{c}\bar{\rho}m(\hat{p}_t + \hat{\pi}_{t+1}) \tag{A.4.16}$$

Equation A.4.14 is patient household housing demand, A.4.15 is impatient household housing demand, and A.4.16 is entrepreneur housing demand.

$$\hat{w}'_t = (\eta - 1)\hat{L}'_t + \hat{c}'_t \tag{A.4.17}$$

$$\hat{w}''_t = (\eta - 1)\hat{L}''_t + \hat{c}''_t \tag{A.4.18}$$

$$\hat{w}_t' = \hat{Y}_t - \hat{X}_t - \hat{L}_t' \tag{A.4.19}$$

$$\hat{w}_t'' = \hat{Y}_t - \hat{X}_t - \hat{L}_t'' \tag{A.4.20}$$

Equations A.4.17 through A.4.20 define the labor market, A.4.17 is patient household labor supply, A.4.18 is impatient household labor supply, A.4.19 is patient household labor demand, and A.4.20 is impatient household labor demand.

$$\hat{Y}_t = \hat{A}_t + \nu\hat{h}_{t-1} + \alpha(1-\nu)\hat{L}_t{}' + (1-\alpha)(1-\nu)\hat{L}_t{}'' \tag{A.4.21}$$

The production function is equation A.4.21.

$$\begin{aligned}
\bar{b}'\hat{b}_t' = \bar{c}'\hat{c}_t' &+ \bar{q}\bar{h}'(\hat{h}_t{}' - \hat{h}_{t-1}') + \bar{D}\hat{D}_t + \frac{\bar{b}'\overline{RF}^2(2+\overline{RF})}{(1+\overline{RF})^2}\left(\hat{RF}_{t-1} + \hat{RF}_{t-2}\right) - \bar{L}'\bar{w}'(\hat{w}_t{}' + \hat{L}_t{}') \\
&- \bar{D}\bar{R}(\hat{R}_{t-1} + \hat{D}_{t-1}) + \frac{\overline{RF}^2\bar{b}'}{(1+\overline{RF})}\left(\hat{b}_{t-1}' - 2\hat{\pi}_t + \hat{b}_{t-2}' - \hat{\pi}_{t-1}\right)
\end{aligned} \tag{A.4.22}$$

A.4.22 is the patient household budget constraint.

$$\begin{aligned}
\bar{b}''\hat{b}_t'' = \bar{c}''\hat{c}_t'' &+ \bar{q}\bar{h}''(\hat{h}_t{}'' - \hat{h}_{t-1}'') + \frac{\bar{b}''\overline{RF}^2(2+\overline{RF})}{(1+\overline{RF})^2}\left(\hat{RF}_{t-1} + \hat{RF}_{t-2}\right) - \bar{L}''\bar{w}''(\hat{w}_t{}'' + \hat{L}_t{}'') \\
&- \bar{T}''\hat{T}_t'' + \frac{\overline{RF}^2\bar{b}''}{(1+\overline{RF})}\left(\hat{b}_{t-1}'' - 2\hat{\pi}_t + \hat{b}_{t-2}'' - \hat{\pi}_{t-1}\right)
\end{aligned} \tag{A.4.23}$$

A.4.23 is the impatient household budget constraint.

$$\hat{D}_t = 0 \tag{A.4.24}$$

A.4.24 is the condition that sets riskless bonds equal to zero in equilibrium.

$$\hat{T}_t = 0 \qquad\qquad\qquad (A.4.25)$$

A.4.25 is the condition that sets lump-sum transfers equal to zero in equilibrium.

A.5 Monetary Policy, Access to Credit, and Long-term Mortgages: Solution Method

Using the log-linearized model, of the 32 endogenous variables (including the same variable in different time periods), 23 are identified by equations in the system and 3 are lags or pre-determined variables. The remaining 6 endogenous variables are identified by redating the backward looking equations one period forward and substituting out to pin down the $t + 2$ variables. From this point, the well-known solution method of Blanchard and Kahn (1980) is applied to evaluate determinacy.

B The Home Mortgage Interest Deduction and Economic Growth: Appendix

B.1 The Home Mortgage Interest Deduction and Economic Growth: Derivation of Estimating Equation

First, we need to write the production function in effective units of labor terms. We multiply both sides of equation A.4.21 by $\frac{1}{AL}$ and the intensive form of the production function is

$$y(t) = k(t)^\alpha p(t)^\beta \tag{B.1.1}$$

where the notation is consistent with that described in Section 4.5. In the steady state, $\dot{k}(t)$ and $\dot{p}(t)$ are equal to zero, so in order to solve for steady state levels of $k(t)$ and $p(t)$, we set equations 4.3.4 and 4.3.5 equal to zero

$$0 = s_k y(t) - (n + g + \delta_k)k(t) \tag{B.1.2}$$

$$0 = s_p y(t) - (n + g + \delta_p)p(t) \tag{B.1.3}$$

and solve for $p(t)$ and $k(t)$

$$p(t) = \left(\frac{s_p k(t)^\alpha}{n + g + \delta_p}\right)^{\frac{1}{1-\beta}} \tag{B.1.4}$$

$$k(t) = \left(\frac{s_k p(t)^\beta}{n + g + \delta_k}\right)^{\frac{1}{1-\alpha}} \tag{B.1.5}$$

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Plug $p(t)$ into $k(t)$ (or vice versa) and after algebraic manipulation, it is obvious that

$$k^* = \left(\frac{s_k^{1-\beta} s_p^\beta}{(n+g+\delta_k)^{1-\beta}(n+g+\delta_p)^\beta} \right)^{\frac{1}{1-\alpha-\beta}} \qquad \text{(B.1.6)}$$

$$p^* = \left(\frac{s_k^\alpha s_p^{1-\alpha}}{(n+g+\delta_k)^\alpha(n+g+\delta_p)^{1-\alpha}} \right)^{\frac{1}{1-\alpha-\beta}} \qquad \text{(B.1.7)}$$

Income per capita ($\tilde{y}(t)$) is given by

$$\tilde{y}(t) = A(t)k(t)^\alpha p(t)^\beta \qquad \text{(B.1.8)}$$

after multiplying both sides of equation A.4.21, the production function, by $\frac{1}{L}$. In the steady state, k^* and p^* can by substituted into equation B.1.8 for $k(t)$ and $p(t)$ respectively. Taking logs, income per capita can be represented as

$$\begin{aligned} \ln(\tilde{y}^*) = \ln A(0) + gt &+ \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_p) \\ &- \frac{\alpha}{1-\alpha-\beta}\ln(n+g+\delta_k) - \frac{\beta}{1-\alpha-\beta}\ln(n+g+\delta_p) \quad \text{(B.1.9)} \end{aligned}$$

The above reduced form equation can now be estimated.

B.2 The Home Mortgage Interest Deduction and Economic Growth: Data Descriptions

Table A1 below provides complete descriptions, units, and sources for all of the variable used in the analysis.

Table A1: Data Descriptions

Name	Description	Units	Source
Bachelor's Plus	Educational Attainment - Bachelor's degree or higher	Percent of population 25 years and over	ACS
Capital (No Bldgs)	Total capital expenditures (new and used) minus capital expenditures on on buildings and structures	Real (1982-84 dollars) per capita	SM
Capital Auto	Capital expenditures on automobiles, trucks, etc. for highway use	Real (1982-84 dollars) per capita	SM
Capital Auto, Comp, Mach, Other	Sum of Capital Auto, Computers, Machinery, and Other	Real (1982-84 dollars) per capita	SM
Capital Auto, Mach, Other	Sum of Capital Auto, Machinery, and Other	Real (1982-84 dollars) per capita	SM
Capital Buildings	Capital Expenditures on buildings and structures	Real (1982-84 dollars) per capita	SM
Capital Computers	Capital expenditures on computers and peripheral data processing equipment	Real (1982-84 dollars) per capita	SM
Capital Expenditures	Total capital expenditures (new and used)	Real (1982-84 dollars) per capita	SM
Capital Mach and Other	Sum of Capital Machinery and Other	Real (1982-84 dollars) per capita	SM
Capital Machinery	Capital expenditures on machinery and equipment (new and used)	Real (1982-84 dollars) per capita	SM
Capital Other	Capital expenditures on all other machinery and equipment	Real (1982-84 dollars) per capita	SM
CIR	Contract Interest Rate - Terms on conventional single-family mortgages	Percent	MIRS (FHFA)
CPI	Consumer price index - all urban consumers by Census region	Index base year 1982-84=100	BLS
EIR	Effective interest rate on conventional single-family mortgages	Percent	MIRS (FHFA)

GDP	Gross domestic product by state	Real (1982-84 dollars) per capita	BEA
Housing	Home value; This average value of owner-occupied houses (inclusive of land and structure) is estimated in two steps. First, the average value for each state is estimated in 1980, 1990, and 2000 using micro data from the Decennial Census of Housing (DCH). Then the Federal Housing Finance Agency (FHFA) quarterly repeat-sales (constant quality) house price indexes for each state are used to scale the home value series by quarter between 1980 and 2000 and to extend the home value series back from 1980 to 1975 and forward from 2000 to the most recent quarter. The growth rates of the reported FHFA indexes are adjusted so that their growth between 1980-1990 and 1990-2000 match the decennial growth of average house values from the DCH data. The 1980-1990 growth-rate adjustments are applied to the pre-1980 FHFA data and the 1990-2000 growth-rate adjustments are applied to the post-2000 FHFA data.	Real (1982-84 dollars) per capita	LILP
HMID	Mortgage Interest paid	Real (1982-84 dollars) per capita	IRS
Occupied Housing	Housing tenure - occupied housing units	Housing units	ACS
Owner-Occupied Housing	Housing tenure - owner-occupied housing units	Housing units	ACS
Personal Income	Personal income per capita (divided by the midyear population). Personal Income is the income that is received by all persons from all sources. It is calculated as the sum of wages and salaries, supplements to wages and salaries, proprietors' income with inventory valuation and capital consumption adjustments, rental income of persons with capital consumption adjustment, personal dividend income, personal interest income, and personal current transfer receipts, less contributions for government social insurance.	Real (1982-84 dollars) per capita	BEA
Population	Total population	Population	ACS

Poverty Rate	Poverty rate by state; percent of people who were in poverty in a calendar year. Annual poverty rates from the Current Population Survey and the decennial census long form are based on income reported at an annual figure. In the Survey of Income and Program Participation (SIPP), income is reported a few months at a time, several times a year. Therefore, in the SIPP, annual poverty rates are calculated using the sum of family income over the year divided by the sum of poverty thresholds that can change from month to month if one's family composition changes.	Percent	Census/CPS
Real Estate Taxes	Total real estate taxes	Real (1982-84 dollars) per capita	IRS
Renter-Occupied Housing	Housing tenure - renter-occupied housing units	Housing units	ACS
State Taxes	Real state and local income taxes	Real (1982-84 dollars) per capita	IRS
Total Deposits	Summary of deposits - state totals - all FDIC-insured institutions	Real (1982-84 dollars) per capita	FDIC

Notes: American Community Survey (ACS), Bureau of Economic Analysis (BEA), Bureau of Labor Statistics (BLS),

Current Population Survey (CPS), Federal Deposit Insurance Corporation (FDIC), Federal Housing Finance Agency (FHFA),

Lincoln Institute of Land Policy (LILP), Internal Revenue Service (IRS), Monthly Interest Rate Survey (MIRS), Survey of Manufacturers (SM)

B.3   The Home Mortgage Interest Deduction and Economic Growth: Equipment Investment and GDP

Table A2 below shows the summary statistics for the various capital measures for all 50 states from 2005 to 2010.

Table A2: Capital Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Capital Machinery	5.209	0.457	3.953	6.361	235
Capital Buildings	3.485	0.486	1.922	5.391	235
Capital Auto, Comp, Mach, Other	5.913	0.448	4.676	7.054	231
Capital Auto, Mach, Other	5.882	0.454	4.636	7.044	231
Capital Mach and Other	5.857	0.466	4.565	7.04	235
Capital Auto	1.501	0.451	0.198	3.249	232
Capital Computers	2.315	0.5	0.522	4.21	236

Table A3 estimates the same regression specifications as in Table 4.4, but with other capital measures as a robustness check. The results confirm the findings in Section 4.6. Columns (1) through (4) show that a 1% increase in spending on capital machinery and equipment (defined several different ways) is correlated with a 0.03% increase in GDP. For more details regarding the various measures of capital expenditures, see Appendix B.2. In all specifications, spending on buildings and structures is statistically and economically insignificant.

Table A3: Various Capital Measures and Economic Growth

	(1)	(2)	(3)	(4)
Capital Machinery	0.0258**			
	(0.0104)			
Capital Buildings	0.000439	-0.000391	-0.000401	0.000531
	(0.00673)	(0.00684)	(0.00683)	(0.00670)
Capital Auto, Comp, Mach, Other		0.0270**		
		(0.0105)		
Capital Auto, Mach, Other			0.0270**	
			(0.0104)	
Capital Mach and Other				0.0259**
				(0.0102)
Observations	245	240	240	245
R-squared	0.193	0.182	0.183	0.194
Number of States	50	50	50	50

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The results from estimating equation 4.5.1 hold when we consider only the 48 contiguous states, dropping Alaska and Hawaii, as is common in the state-level growth literature. See Table A4 below.

Table A4: Equipment Investment and Economic Growth for 48 States

Variables	(1)	(2)	(3)	(4)
Capital Machinery	0.0254**	0.0199*	0.0337***	0.0287**
	(0.0106)	(0.0103)	(0.0113)	(0.0112)
Capital Buildings	0.00182	-0.00160	0.00727	0.00394
	(0.00699)	(0.00680)	(0.00756)	(0.00749)
Poverty Rate		-0.00712***		-0.00549***
		(0.00185)		(0.00204)
Bachelor's Plus			0.00299	0.00168
			(0.00639)	(0.00627)
Observations	235	235	189	189
R-squared	0.196	0.258	0.283	0.320
Number of States	48	48	48	48

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A5 below replicates the findings in Table A3 after omitting observations for Alaska and Hawaii.

Table A5: Various Capital Measures and Economic Growth for 48 States

Variables	(1)	(2)	(3)	(4)
Capital Machinery	0.0254**			
	(0.0106)			
Capital Buildings	0.00182	0.00123	0.00114	0.00181
	(0.00699)	(0.00705)	(0.00705)	(0.00698)
Capital Auto, Comp, Mach, Other		0.0269**		
		(0.0107)		
Capital Auto, Mach, Other			0.0268**	
			(0.0105)	
Capital Mach and Other				0.0254**
				(0.0104)
Observations	235	231	231	235
R-squared	0.196	0.186	0.186	0.197
Number of States	48	48	48	48

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.4 The Home Mortgage Interest Deduction and Economic Growth: Housing Investment and GDP

Table A6 estimates the system of equations 4.5.2 and 4.5.3 by 2SLS using the proportion of the population with a Bachelor's degree or higher and the poverty rate as additional control variables.

Table A6: Equipment Investment, Housing Investment, and GDP (2SLS)

Variables	(1) GDP	(2) Housing	(3) GDP	(4) Housing	(5) GDP	(6) Housing	(7) GDP	(8) Housing	(9) GDP	(10) Housing	(11) GDP	(12) Housing
GDP		2.927**		-0.809		2.993***		1.06		3.114***		2.364**
		(1.157)		(2.053)		(1.100)		(0.963)		(0.938)		(1.148)
HMID		-0.00917		0.973*		0.0349		0.645**		-0.0603		0.165
		(0.345)		(0.535)		(0.362)		(0.293)		(0.294)		(0.312)
CIR		-0.331***		-0.0818		-0.311***		-0.161**		-0.342***		-0.259***
		(0.112)		(0.134)		(0.102)		(0.076)		(0.108)		(0.0932)
Capital (No Bldgs)	0.00917				0.00444				0.00897			
	(0.012)				(0.010)				(0.012)			
Bachelor's Plus	-0.00292		-0.00333						-0.003		-0.00331	
	(0.006)		(0.005)						(0.006)		(0.005)	
Poverty Rate					-0.00113		-4.98E-05		-0.00129		-0.000192	
					(0.002)		(0.002)		(0.002)		(0.002)	
	(0.012)				(0.010)				(0.012)			
Housing	0.251***		0.249***		0.262***		0.260***		0.240***		0.247***	
	(0.053)		(0.047)		(0.039)		(0.034)		(0.057)		(0.050)	
Total Deposits			0.0295**				0.0373***				0.0294**	
			(0.014)				(0.013)				(0.014)	
Observations	197	197	250	250	245	245	298	298	197	197	250	250

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A7 estimates the system of equations 4.5.2 and 4.5.3 by 3SLS using the proportion of the population with a Bachelor's degree or higher and the poverty rate as additional control variables.

Table A7: Equipment Investment, Housing Investment, and GDP (3SLS)

Variables	(5) GDP	(6) Housing	(7) GDP	(8) Housing	(9) GDP	(10) Housing	(11) GDP	(12) Housing	(13) GDP	(14) Housing	(15) GDP	(16) Housing
Capital (No Bldgs)	0.00707				0.00446				0.00648			
	(0.010)				(0.006)				(0.008)			
Housing	0.254***		0.249***		0.262***		0.254***		0.242***		0.253***	
	(0.045)		(0.041)		(0.034)		(0.031)		(0.048)		(0.044)	
Total Deposits			0.0294**				0.0161				0.00412	
			(0.012)				(0.010)				(0.008)	
Bachelor's Plus	0.0015		-0.00309						0.00126		0.00111	
	(0.003)		(0.004)						(0.002)		(0.002)	
Poverty Rate					-0.00113		-0.00240*		-0.00136		-0.00185	
					(0.001)		(0.001)		(0.001)		(0.001)	
GDP		2.941***		-0.833		2.759***		0.893		2.979***		2.155**
		(0.978)		(1.804)		(0.962)		(0.864)		(0.793)		(1.007)
HMID		0.191		0.985**		0.255		0.748***		0.201		0.347
		(0.288)		(0.470)		(0.314)		(0.262)		(0.241)		(0.271)
CIR		-0.0419		-0.0701		-0.0155		-0.0133		-0.0354		-0.0266
		(0.066)		(0.118)		(0.062)		(0.060)		(0.056)		(0.0616)
Observations	197	197	250	250	245	245	298	298	197	197	250	250

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A8 estimates the system of equations 4.5.2 and 4.5.3 by 2SLS but only using the 48 contiguous states, as a robustness check for Table 4.5.

Table A8: Equipment Investment, Housing Investment, and GDP (2SLS, 48 States)

Variables	(1) GDP	(2) Housing	(3) GDP	(4) Housing
Capital (No Bldgs)	0.00417			
	(0.010)			
Housing	0.266***		0.261***	
	(0.035)		(0.031)	
Total Deposits			0.0346**	
			(0.015)	
GDP		3.057**		-2.242
		(1.543)		(2.747)
HMID		0.0223		1.634**
		(0.500)		(0.822)
CIR		-0.353**		0.0657
		(0.139)		(0.214)
Observations	235	235	286	286

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A9 estimates the same system using 3SLS and all U.S. states except Alaska and Hawaii.

Table A9: Equipment Investment, Housing Investment, and GDP (3SLS, 48 States)

Variables	(1) GDP	(2) Housing	(3) GDP	(4) Housing
Capital (No Bldgs)	0.00417			
	(0.009)			
Housing	0.266***		0.261***	
	(0.031)		(0.028)	
Total Deposits			0.0346***	
			(0.013)	
GDP		2.974**		-2.181
		(1.350)		(2.464)
HMID		0.2		1.598**
		(0.436)		(0.737)
CIR		-0.0295		0.0123
		(0.103)		(0.192)
Observations	235	235	286	286

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A10 estimates the simultaneous equations model using 2SLS, but the log of real personal income is the dependent variable.

Table A10: Equipment Investment, Housing Investment, and Personal Income (2SLS)

Variables	(1) Personal Income	(2) Housing	(3) Personal Income	(4) Housing
Personal Income		2.265**		4.489
		(0.997)		(4.874)
HMID		0.308		-0.284
		(0.306)		(1.350)
CIR		-0.226***		-0.298
		(0.074)		(0.229)
Capital (No Bldgs)	0.00864			
	(0.008)			
Housing	0.260***		0.260***	
	(0.029)		(0.026)	
Total Deposits			0.00371	
			(0.011)	
Observations	245	245	298	298

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A11 uses 3SLS and log real personal income as the dependent variable.

Table A11: Equipment Investment, Housing Investment, and Personal Income (3SLS)

Variables	(1) Personal Income	(2) Housing	(3) Personal Income	(4) Housing
Personal Income		2.361***		5.419
		(0.873)		(4.369)
HMID		0.382		-0.436
		(0.267)		(1.211)
CIR		-0.0195		-0.0647
		(0.047)		(0.199)
Capital (No Bldgs)	0.00864			
	(0.007)			
Housing	0.260***		0.260***	
	(0.026)		(0.023)	
Total Deposits			0.00371	
			(0.010)	
Observations	245	245	298	298

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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Publications

ApostolovaMihaylova, Maria, William Cooper, Gail Hoyt, and Emily C. Marshall. "Heterogeneous gender effects under loss aversion in the economics classroom: A field experiment." *Southern Economic Journal* 81, no. 4 (2015): 980-994.

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"Endogenous growth and household leverage," (with Hoang Nguyen and Paul Shea), *working paper*

"International evidence of the flypaper effect," (with James Saunoris), *working paper*

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"Uncovering the hidden relationship between the economy and crime: The role of the shadow economy," (with Michael Rocque and James Saunoris), *working paper*