Credit Channels in a Liquidity Trap[*]

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Abstract

We study liquidity trap dynamics driven by nonfundamental shifts in expectations in a New Keynesian model with housing, credit frictions and a Taylor rule. Highly leveraged borrowing through nominal debt backed by real estate collateral greatly magnifies the decline in output and house prices during a liquidity trap recession. We argue our model shares some important features with the recent US recession.

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1 Introduction

We examine whether a loss in confidence can bring about a liquidity trap recession in a model with nominal rigidities that features a housing sector and credit frictions. Our analysis is motivated by the recent recession in the US during which there was an unusually large decline in economic activity, brief deflation, short-term interest rates close or at the zero lower bound, and significant financial turmoil. These characteristics have been much discussed in the popular press and amongst academics but as of yet, there is little or no consensus on the sources of the crisis and on the appropriate policy responses.

Recent models of the interactions between financial frictions and monetary policy at the zero lower bound have been based on various assumptions regarding the source of the liquidity trap recession. In Gertler and Karadi (2009), exogenous destruction of the physical capital stock decreases asset prices and causes a balance sheet driven downturn. Del Negro, Eggertson, Ferrero and Kiyotaki (2010) consider an exogenous tightening of borrowing constraints faced by capital producing entrepreneurs. Curdia and Woodford (2010) focus on an exogenous temporary increase in credit spreads. In Eggertson and Krugman (2010), borrowing constraints for impatient households tighten exogenously. All these studies explain the observed correlation between zero nominal interest rates and financial turmoil as directly resulting from an exogenous shock to credit conditions or asset prices.

We explore the hypothesis that a sudden deterioration in expectations has affected credit conditions and asset prices, driving the economy in a liquidity trap. We present a model in which a rational self-fulfilling loss in confidence can occur because monetary policy may lose its ability to

stabilize the economy. This happens when policy becomes involuntarily overly tight as the interest rate instrument reaches the zero lower bound and there is deflation after agents act upon their expectations. Financial market distress, rather than being the direct cause of the recession, acts only as an endogenous propagation mechanism, albeit a very strong one. In our model environment, financial frictions affect only a relatively small sector in the economy directly. Yet, tightening credit conditions play a large role for the dynamics of an expectations driven liquidity trap. Thus, our model is consistent with the fact that financial frictions seem to have been much more important in this recession than in most previous ones.

To set the scene, Figure 1 shows US output, consumption, inflation, the short term nominal interest rate, and a real house price index for the sample period 2005:1-2010:2. The first panel shows real GDP and consumption as deviations from their pre-crisis trends.[1] According to this measure, output and consumption have both fallen 7-8 percent below trend since the end of 2007, with a marked deterioration in 2008 when Lehman Brothers was allowed to fail. The second panel shows the annualized quarter-to-quarter inflation rate based on the implicit consumption (PCE) deflator in deviation from the 2000-2007 average of 2.4%. This broad measure of inflation fell substantially in mid-2008 and in 2008Q4-2009Q1 the US experienced two quarters of deflation. Inflation thereafter has been below its pre-crisis level but has remained positive. The next panel shows the effective federal funds rate. The Federal Reserve rapidly cut interest rates from mid-2007 onwards and reached the zero lower bound late 2008. This coincided with the acceleration of the output decline and falling PCE prices. Finally, the last panel shows a detrended real house price index.[2]

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[1]We estimated quadratic trends for the logarithms using quarterly data from 1955:1 until 2006:4 and then extrapolated the trends from 2007:1 onwards.

[2]The real house price measure is the Conventional Mortgage Home Price series collected by Freddie-Mac divided by the PCE deflator. The trend is computed the same way as GDP and consumption.

This measure indicates that real house prices have fallen 20-25 percent below the historical trend.

Our theoretical framework, which is based on Iacoviello (2005), extends the New Keynesian model analysed in Mertens and Ravn (2010) with a housing sector and with financial frictions in the tradition of Kiyotaki and Moore (1997). Following Iacoviello (2005), the economy is inhabited by patient households who buy short term nominal debt from impatient entrepreneurs. The entrepreneurs face a borrowing constraint according to which debt cannot exceed a certain fraction of the (expected) value of housing collateral. Real estate serves a dual role as a factor of production for entrepreneurs and as residential housing for households. Monetary policy follows an interest rate rule that is constrained by the zero lower bound.

The model displays global equilibrium indeterminacy, even if the Taylor principle is locally satisfied. We analyze sunspot equilibria in which pessimism succeeds in driving the economy into downward spiral of falling output and declining goods and house prices during which the lower bound on the interest rate becomes binding. In models without credit frictions, such sunspot equilibria display output drops that arise because of rising real interest rates and nominal rigidities. In the model that we study, house and goods price deflation triggers debt deflation and house price collateral effects that generate output drops that are easily 3 to 4 times larger than in an otherwise identical model without an active credit market. Looser lending standards and higher leverage give rise to larger output losses in an expectations driven liquidity trap. We argue that the model dynamics during an expectations driven liquidity trap share some important features with the recent US experience as displayed in Figure 1.

3

The remainder of the paper is organized as follows. Section 2 describes the model environment and discusses the existence of expectations driven liquidity traps. In Section 3 , we examine the dynamics of an expectations driven liquidity trap and analyze the role of credit frictions. Section 4 concludes.

2 Expectations Driven Liquidity Traps in a Model with Housing and Credit

2 .1 Environment

The theoretical framework is a version of the New Keynesian model that includes a housing sector and collateralized lending as in Iacoviello (2005). There are four types of agents: households that consume goods and housing services and supply labor; entrepreneurs that produce a wholesale good using labor and real estate capital; monopolistically competitive retailers that sell differentiated goods and set prices subject to a Calvo price setting friction; and a government that is in charge of fiscal and monetary policies. A difference in time preferences between households and entrepreneurs leads to an active credit market in which borrowing is constrained by the value of housing collateral. There is a fixed supply of housing.

Households There is a continuum of identical and infinitely lived households that derive utility from a composite consumption good $c_{h,t} \geq 0$, housing $h_{h,t} \geq 0$, leisure $1 - n_{h,t}$ where $n_{h,t} \in [0,1]$ denotes hours worked, and real money balances, $m_{h,t} \geq 0$. The preferences are given by

$$\mathcal{U}_h = E_0 \sum_{t=0}^{\infty} \beta_h^t \left(\ln(z_{h,t}) + \theta \frac{(1 - n_{h,t})^{1-\kappa} - 1}{1 - \kappa} + V\left(m_{h,t}\right) \right), \quad \theta, \kappa > 0 \tag{1}$$

$$z_{h,t} = \left(\rho^{1/\zeta} h_{h,t}^{1-1/\zeta} + c_{h,t}^{1-1/\zeta} \right)^{1/(1-1/\zeta)}, \quad \rho, \zeta > 0 \tag{2}$$

4

where E_t denotes the mathematical expectations operator conditional on all information available at date t and $\beta_h \in (0,1)$ is the households' subjective discount factor. The composite consumption index $c_{h,t}$ is given by the Dixit-Stiglitz aggregator

$$c_{h,t} = \left(\int_0^1 c_{h,t}(i)^{1-1/\eta} di \right)^{1/(1-1/\eta)} , \eta > 1 \tag{3}$$

where $c_{h,t}(i)$ is the quantity of good $i \in [0,1]$ consumed in period t. Finally, we assume that

$$\lim_{m \to \infty} \partial V(m) / \partial m < 0 \tag{4}$$

which implies that real money demand remains finite even if short term nominal interest rates reach zero.

Let P_t denote the price index of consumption goods in period t, defined by expenditure minimization as

$$P_t = \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{1}{1-\eta}} \tag{5}$$

were $P_t(i)$ is the price of good i. The relevant intertemporal budget constraints for the household are

$$P_t c_{h,t} + Q_t h_{h,t} + \frac{B_{h,t}}{1+i_t} + M_{h,t} \leq W_t n_{h,t} + Q_t h_{h,t-1} + B_{h,t-1} + M_{h,t-1} + \Upsilon_t + T_t \tag{6}$$

$$B_{h,-1}, M_{h,-1}, h_{h,-1} \text{ given}$$

Besides holding cash balances $M_{h,t}$, the household can purchase a one period nominal discount bond with a face value of one unit of currency at the price $1/(1+i_t)$. The nominal interest rate on the bond is i_t. The remaining expenditures are on consumption $P_t c_{h,t}$ and housing $Q_t h_t$ where Q_t is the price of one unit of housing. The household earns labor income $W_t n_{h,t}$ where W_t is the nominal wage rate. The household's resources entering period t are the sum of the payout on its bond portfolio, B_{t-1}, nominal cash balances, M_{t-1}, housing wealth $Q_t h_{t-1}$, dividend income received from firm ownership Υ_t and transfers T_t from the government.

The households face the no Ponzi constraints

$$\lim_{s\to\infty} E_t \frac{B_{t+s}}{(1+i_t)\cdots(1+i_{t+s})} \geq 0 \tag{7}$$

The household's intertemporal problem is to maximize utility in (1) subject to the nonnegativity and time endowment constraints, the budget constraints and initial asset positions in (6), and the condition in (7). Optimality implies the following conditions for consumption (8), labor supply (9), housing (10) and money demand (11):

$$1 = (1+i_t)\beta_h E_t \left[\frac{\lambda_{h,t+1}}{\lambda_{h,t}} \frac{P_t}{P_{t+1}} \right] \tag{8}$$

$$\frac{W_t}{P_t} = \theta(1-n_{h,t})^{-\kappa}/\lambda_{h,t} \tag{9}$$

$$\frac{Q_t}{P_t} = \left(\frac{\rho c_{h,t}}{h_{h,t}} \right)^{\frac{1}{\zeta}} + \beta_h E_t \left[\frac{\lambda_{h,t+1}}{\lambda_{h,t}} \frac{Q_{t+1}}{P_{t+1}} \right] \tag{10}$$

$$\frac{i_t}{1+i_t} = V_m(m_{h,t})/\lambda_{h,t} \tag{11}$$

where $\lambda_{h,t} = z_{h,t}^{1/\zeta-1} c_{h,t}^{-1/\zeta}$.

Entrepreneurs   A continuum of identical risk averse entrepreneurs produce a single wholesale good using inputs of labor $n_{e,t} \geq 0$ and commercial real estate $h_{e,t} \geq 0$. The production technology is

$$y_t^w = A h_{e,t-1}^{\nu} n_{e,t}^{1-\nu} \ , \ A > 0 \text{ and } \nu \in (0,1) \tag{12}$$

where y_t^w is output of the wholesale good. Entrepreneurs derive utility from consumption of the composite good, $c_{e,t} \geq 0$, and their preferences are given by

$$\mathcal{U}_e = E_0 \sum_{t=0}^{\infty} \beta_e^t \ln c_{e,t} \tag{13}$$

where $\beta_e \in (0, \beta_h)$ is the entrepreneurs' subjective discount factor. As in Iacoviello (2005), entrepreneurs are more impatient than households. Entrepreneurs sell wholesale goods to retailers in a competitive market at a price P_t^w and can issue short-term nominal debt $B_{e,t}$ at a price $1/(1+i_t)$. The maximum amount of debt is constrained by the expected next period value of real estate collateral

$$B_{e,t} \ \leq \ \mu E_t \left(Q_{t+1} h_{e,t} \right) \tag{14}$$

This borrowing constraint requires that debt repayments in period $t+1$ do not exceed a fraction $0 < \mu < 1$ of the expected collateral value of the entrepreneur's stock of real estate. Entrepreneurs

7

face the sequence of budget constraints:

$$P_t c_{e,t} + Q_t h_{e,t} + W_t n_{e,t} + B_{e,t-1} \quad \leq \quad P_t^w y_t^w + \frac{B_{e,t}}{1+i_t} + Q_t h_{e,t-1} \tag{15}$$

$$h_{e,-1}, B_{e,-1} \text{ given}$$

The entrepreneur's intertemporal problem is to maximize utility in (13) subject to the nonnegativity, the technology in (12), the borrowing constraints in (14), the budget constraints and initial asset positions in (15). As Iacoviello (2005), we look at equilibria in which the collateral constraint always binds (and we check that there is no incentive to default along the equilibrium paths). As a consequence, borrowing by entrepreneurs is at all times constrained by the value of real estate collateral and the borrowing constraint in (14) holds with equality. The entrepreneurs' conditions for consumption (16), labor demand (17) and real estate (18) are given by

$$1 \quad = \quad (1+i_t)\beta_e E_t \left[\frac{c_{e,t}}{c_{e,t+1}} \frac{P_t}{P_{t+1}} \right] + \lambda_{b,t} \tag{16}$$

$$\frac{W_t}{P_t} \quad = \quad (1-\nu)\frac{P_t^w}{P_t} \frac{y_t^w}{n_{e,t}} \tag{17}$$

$$\frac{Q_t}{P_t} \quad = \quad \beta_e E_t \left[\frac{c_{e,t}}{c_{e,t+1}} \left(\nu \frac{P_{t+1}^w}{P_t} \frac{y_{t+1}^w}{h_{e,t}} + \frac{Q_{t+1}}{P_{t+1}} \right) \right] + \lambda_{b,t}\mu E_t \left[\frac{Q_{t+1}}{P_{t+1}} \frac{P_{t+1}}{P_t} \frac{1}{1+i_t} \right] \tag{18}$$

where $\lambda_{b,t} > 0$ is a Lagrange multiplier associated with the borrowing constraint.

Retailers There is a monopolistically competitive sector of retailers indexed by $i \in [0,1]$. Retailer i purchases the wholesale good from the entrepreneurs, transforms it at no cost into a differentiated

8

good $c_t(i)$ and sells at the price $P_t(i)$ taking into account downward sloping demand

$$c_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\eta} (c_{h,t} + c_{e,t})$$

Price setting is subject to the Calvo friction: Each period, whether the retailer can reset the price is determined by a Poisson process with arrival rate $(1 - \xi) \in (0, 1]$. The problem of retailer i after receiving the opportunity to reset the price in period t is to choose a new price $P_t^*(i)$ to maximize

$$E_t \sum_{s=t}^{\infty} \xi^{s-t} Q_{t,s} \Upsilon_{is}(P_t^*(i)) \tag{19}$$

subject to the demand functions in equation (19). $Q_{t,s} = \beta_h^{s-t} \left(\lambda_{h,s}/\lambda_{h,t}\right) (P_t/P_s)$ is the discount factor of the households between period t and s and $\Upsilon_{is}(P_t^*(i))$ are period s profits of retailer i when charging $P_t^*(i)$, which are given by

$$\Upsilon_{is}(P_t^*(i)) = (P_t^*(i) - P_s^w) \left(\frac{P_t^*(i)}{P_s}\right)^{-\eta} (c_{h,s} + c_{e,s}) \tag{20}$$

The first-order condition for $P_t^*(i)$ can be expressed as:

$$E_t \sum_{s=t}^{\infty} \xi^{s-t} Q_{t,s} \left[\left(P_t^*(i) - \frac{\eta}{\eta - 1} P_s^w\right) c_s(i)\right] = 0 \tag{21}$$

Government The government is in charge of monetary and fiscal policies. We specify monetary policy by an interest rate rule:

$$1 + i_t = \max\left(1, \left(\frac{\widetilde{\pi}}{\beta_h}\right) \left(\frac{\pi_t}{\widetilde{\pi}}\right)^{\phi_\pi}\right) \tag{22}$$

9

where $\pi_t = P_t/P_{t-1}$ is inflation, $\widetilde{\pi}$ is an inflation target, and ϕ_π is a parameter that determines the response of short-term interest rates to inflation. The real money supply m_t is adjusted to implement the interest rate rule, which is subject to the zero bound. We assume that ϕ_π is sufficiently large to satisfy local determinacy conditions (i.e., the Taylor Principle) in the neighborhood of the steady state where inflation is at its intended level $\tilde{\pi}$. Fiscal policy is Ricardian: government bonds are in zero supply and the government varies lump sum taxes to the households to balance its budget each period.

2.2 Equilibrium and Calibration

Equilibrium Definition   We focus on symmetric equilibria in which all households, entrepreneurs and retailers have the same decision rules. Define the real wage $w_t = W_t/P_t$, the optimal reset price relative to the general price level $p_t^* = P_t^*/P_t$, the average retail markup $x_t = P_t/P_t^w$, the real house price $q_t = Q_t/P_t$, the dispersion of prices $v_t = \int_0^1 (P_t(i)/P_t)^{-\eta} di \geq 1$ and real transfers to households $t_t = T_t/P_t$.

A rational expectations equilibrium is sequence of allocations $(c_{h,t}, c_{e,t}, m_{h,t}, n_{h,t}, n_{e,t}, y_t^w, h_{h,t}, h_{e,t}, b_{h,t}, b_{e,t})_{t=0}^\infty$, a price vector $(\pi_t, \lambda_{b,t}, w_t, q_t, x_t, p_t^*, v_t)_{t=0}^\infty$ and government policies (i_t, m_t, t_t) such that (i) households and entrepreneurs maximize utility subject to all constraints, (ii) retailers maximize profits, (iii) monetary policy is guided by the interest rate rule and fiscal policies are consistent with the government budget constraint, and (vi) goods, asset and labor markets clear, for given initial conditions $b_{h,-1}, b_{e,-1}, h_{h,-1} > 0, h_{e,-1} > 0, m_{h,-1} > 0$ and $v_{-1} \geq 1$.

Housing is in fixed supply, such that clearing in the real estate market requires

$$h_{h,t} + h_{e,t} = \bar{h} \tag{23}$$

Clearing in the labor and credit markets requires

$$b_{h,t} = b_{e,t} \tag{24}$$

$$n_{h,t} = n_{e,t} \tag{25}$$

Equalizing supply and demand for retail good i and aggregating across retailers implies that

$$\int_0^1 c_t(i)di = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\eta} (c_{h,t} + c_{e,t})di \tag{26}$$

Market clearing in the market for wholesale goods therefore requires that

$$y_t = c_{h,t} + c_{e,t} = y_t^w / v_t \tag{27}$$

where y_t is real gross domestic product and the price dispersion term $v_t = \int_0^1 (P_t(i)/P_t)^{-\eta} di$ is determined recursively as

$$v_t = \xi \pi_t^\eta v_{t-1} + (1-\xi) p_t^{*-\eta} \tag{28}$$

From equation (27) it is clear that price dispersion, $v_t \geq 1$, acts like an inefficiency wedge that arises because retailers charge different prices in equilibrium due to the Calvo friction. Finally, the

law of motion for aggregate inflation is implicitly given by

$$1 = \xi \pi_t^{\eta-1} + (1 - \xi) \, p_t^{*1-\eta} \tag{29}$$

In practice, we look at equilibria that are solutions to a system of stochastic difference equations given in Appendix A.

Temporary Expectations Driven Liquidity Traps   It is well known at least since Sargent and Wallace (1975) that under an interest rate rule rational expectations monetary models can display equilibrium indeterminacy. More recently, Atkeson, Chari and Kehoe (2010) show that the Taylor principle is neither necessary nor sufficient for uniqueness. As in Benhabib, Schmitt-Grohé and Uribe (2001a,b, 2002), the model described above has multiple steady states to which equilibrium sequences may converge. There is an *intended* steady state in which inflation equals the target $\tilde{\pi}$. But there is also an *unintended* deflationary steady state, a permanent liquidity trap, where inflation approaches $\pi \to \beta_h < 1$. As discussed in Mertens and Ravn (2010), a permanent liquidity trap does not lead to large deviations of economic activity from the intended outcome in the standard New Keynesian model. The costs of a permanent liquidity trap are restricted to the inefficiencies generated by price dispersion in deflationary environment, which are modest for moderate degrees of nominal rigidities. Here, we follow Mertens and Ravn (2010) and instead analyze rational expectations equilibria in which there are temporary liquidity traps driven by a loss in confidence. In these equilibria large drops in economic activity can occur.

We study sunspot equilibria, in which rational agents condition their expectations on an information set that contains a random variable that otherwise has no impact on fundamentals. We

interpret this random sunspot variable, denoted by ψ_t, as measuring exogenous variation in confidence or sentiment. The confidence variable ψ_t evolves according to a two-state discrete Markov chain with states $\psi_t \in \{\psi_O, \psi_P\}$ (optimism and pessimism), and a transition matrix given by

$$R = \begin{bmatrix} q_O & 1 - q_O \\ 1 - q_P & q_P \end{bmatrix} \tag{30}$$

where $R_{ji} = \Pr\left(\psi_t = \psi_j | \psi_{t-1} = \psi_i\right)$. Thus, q_O (q_P) is the persistence of the state where agents are optimistic (pessimistic).

We restrict attention to equilibria for which the dynamic path of $u_t = [y_t, c_{h,t}, c_{e,t}, n_t, \pi_t, \lambda_{b,t},$ $q_t, x_t, i_t]'$ can be generated from recursion of a state space system of the form

$$u_t = f_j(s_t) \quad \text{if } \psi_t = \psi_j \tag{31}$$

$$s_{t+1} = h_j(s_t) \quad \text{if } \psi_t = \psi_j , \ j = O, P \tag{32}$$

The vector of endogenous states $s_t = [b_{t-1}, h_{e,t-1}, v_{t-1}]'$ contains the total volume of credit b_t, the housing stock of entrepreneurs $h_{e,t}$ and price dispersion v_t. Sequences that are generated by (31)-(32) are solutions the system of stochastic difference equations in Appendix A for a given realization of the confidence variable. In a sunspot equilibrium, $f_O(s_t) \neq f_P(s_t)$ and $h_O(s_t) \neq h_P(s_t)$. Therefore output, inflation and all other variables are stochastic processes whose values depend on the realization of the variable ψ_t. In the sunspot equilibria we look at, temporary liquidity traps with $i_t = 0$ occur when the confidence variable indicates pessimism, i.e. $\psi_t = \psi_P$, while more familiar dynamics with $i_t > 0$ occur in the state where agents are optimistic $\psi_t =$

13

ψ_O. The economy switches between periods of conventional monetary policy and liquidity trap recessions depending on exogenous but rational shifts in confidence.

Calibration   We calibrate the model so that a period corresponds to one quarter. We assume that the real interest rate is 4 percent per year and set the households' discount factor $\beta_h = 0.99$. The discount factor of entrepreneurs is $\beta_e = 0.98$ which ensures that entrepreneurs' debt issuance is constrained by the collateral constraint in all experiments. We set θ such that in the intended steady state households work one third of their time endowment and we assume that $\kappa = 2.65$. This value implies a Frisch labor supply elasticity of around 0.75, which is in upper end of the range deemed realistic by labor economists.

We assume $\xi = 0.65$ such that firms are able to adjust prices approximately once every three quarters, which is in line with the micro evidence of for instance Nakamura and Steinsson (2008). As discussed by Mertens and Ravn (2010), higher but arguably less plausible values of the Calvo parameter lead to much larger output losses in a liquidity trap. The value of $\eta = 10$ translates to a markup of 11 percent in the intended steady state. The constant A is set to normalize the output in the intended steady-state to 1.

Following Iacoviello (2005), we set ρ such that 80 percent of total housing is residential and set $v = 0.03$. Next, we set the price elasticity of household housing demand $\zeta = 0.75$. This value is a compromise between the low estimates of the housing demand price elasticity found in the empirical literature, e.g. Hanushek and Quigley (1980), and the more elastic assumption in the macro literature.[3] Finally, we assume that $\mu = 0.9$ so that the collateral constraint is relatively loose. The

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[3]In Iacoviello (2005), the elasticity is one.

government pursues a zero inflation target, $\widetilde{\pi} = 1$, and the feedback coefficient in the Taylor is $\phi_\pi = 1.5$, which implies that the intended steady state is locally determinate.

Finally, we assume that the stochastic process for ψ_t has an absorbing optimistic state, i.e. $q_O = 1$. Allowing for $q_O < 1$ implies that the dynamics in the optimistic state are different from the conventional dynamics around the intended steady-state. This complicates the numerical solution procedure as well as the intuition for most of our results. We set $q_P = 0.8$ so that the expected duration of the pessimistic state (conditional upon starting in this state) is 5 quarters. These transition probabilities are identical to those of the fundamental driven liquidity traps examined e.g. by Christiano, Eichenbaum and Rebelo (2009) and Eggertson (2010), as well as the nonfundamental liquidity traps in Mertens and Ravn (2010), and therefore facilitate comparison with earlier work. All parameter values are summarized in Table 1.

Solution Method We solve for linear approximations to the functions $f_j(\cdot)$ and $h_j(\cdot)$ for $j = O, P$ in (31) -(32). These functions are found by solving an augmented linear system in which the equilibrium conditions are locally approximated around a point $(\bar{u}^O, \bar{s}^O, \bar{u}^P, \bar{s}^P)$. $(\bar{u}^j, \bar{s}^j)$ is the point to which u_t and s_t converge as $t \to \infty$ *conditional* on being in state ψ_j. Given our assumption that $q_O = 1$, $(\bar{u}^O, \bar{s}^O)$ corresponds to the intended steady state, while $(\bar{u}^P, \bar{s}^P)$ is the limit point conditional on being in a liquidity trap, as we impose that in the pessimistic state ψ_P the zero lower bound on nominal interest rates is binding. We henceforth refer to $(\bar{u}^P, \bar{s}^P)$ as the liquidity trap limit point. Details can be found in Appendix B.

In the model of this paper, the linearized dynamics are generally indeterminate and the dimension of indeterminacy is one. This means that, given initial conditions s_0 and $\psi_0 = \psi_P$, there is

15

more than one trajectory to the rest point $(\bar{u}^P, \bar{s}^P)$ in the pessimistic state. Expanding the state space with an additional (deterministic or stochastic) nonfundamental variable, it is possible to trace out an infinite number of trajectories. We restrict attention to trajectories that are spanned by s_t and ψ_t only.[4] Thus, while we consider solutions that are not minimal state variable solutions, the state space is augmented in a minimal way by the binary confidence variable ψ_t. We have checked the accuracy of the approximation in the simpler New Keynesian model in Mertens and Ravn (2010) for which a nonlinear global solution is available. The differences between the linearized and the nonlinear dynamics were negligible for most parameter values.

3   Liquidity Trap Recessions and Credit Markets

In the New Keynesian model, stochastic fluctuations in confidence can generate temporary liquidity traps with output losses that far exceed the difference between intended and unintended steady state levels of output, see Mertens and Ravn (2010). In the model with housing and credit, these liquidity trap recessions are exacerbated by the presence of credit frictions and housing collateral. The main reason is that the real interest rate and house prices must always adjust to clear the credit and housing markets.

Suppose the households and entrepreneurs grow pessimistic about monetary policy's ability to stabilize the economy and expect a temporary but persistent drop in income. The households lower their demand for consumption goods as well as housing. The nominal friction and goods market

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[4]The stable manifold in the linear system is of dimension 4, whereas s_t is of dimension 3. We compute the paths that are spanned by all possible 3-dimensional vector spaces generated from the stable manifold. Of the resulting four candidate equilibrium paths, we eliminate those that violate boundary conditions such as $v_t < 1$. We have checked our solutions by applying the grid search method for Markov Switching DSGE models in Farmer, Wagonner and Zha (2010). The grid search picks up the same solutions, but it also finds additional unbounded but mean square stable solutions to the linear system. We ignore these unbounded solutions.

clearing require both a reduction in output and a fall in goods prices. Given the fixed supply of housing, the reduction in housing demand also lowers the real house price. The reduction in output lowers income for entrepreneurs, the fall in prices increases their real debt burden while the persistent reduction in house prices lowers the value of the entrepreneurs' collateral and tightens their borrowing constraint. Lower income, debt deflation and the housing price collateral channel all force entrepreneurs to reduce both consumption of final goods and demand for commercial real estate as a factor of production. The reductions in demand for final consumption goods and housing further contribute to a fall in goods and house prices as well as output, leading the monetary authority to reduce interest rates to zero.

The fact that the wave of pessimism is temporary has important implications: it makes the retailers more reluctant to cut prices in the face of falling demand, as they are considering the profit impact of their decision in all states of the world including a recovery. Furthermore, with constant short term nominal interest rates, a fall in goods prices leads to a temporary increase in the real rate, triggering intertemporal substitution of household consumption and an additional decline in the demand for residential housing. These effects are reinforced by debt deflation, house price collateral effects and a drop in output resulting from cuts in real estate used in production. The real interest rate must reconcile entrepreneurs' lower demand for credit with the increased desired savings of households, while the real house price must adjust to reconcile the drop in demand for residential and commercial real estate with the fixed supply of housing. The negative spiral of falling goods and house prices and rising real interest rates ends when household income and wealth have fallen sufficiently to eliminate excess savings, house prices have fallen enough to convince households to hold the excess supply of housing, and goods prices equate aggregate consumption to output. In

17

addition, output is lowered because of an increase in price dispersion implied by declining prices. Equilibrium is reached at lower levels of output and credit such that the initial loss of confidence becomes a self-fulfilling prophecy consistent with rational expectations.

Locally, the monetary authority can prevent the downwards spiralling savings glut and deterioration in credit flows by lowering nominal interest rates sufficiently to offset the real rate increases. Globally, however, it is unable to do so because of the zero lower bound. As a result, liquidity trap recessions, house price collapses and steep reductions in credit flows can occur in equilibrium after a sufficiently large drop in confidence. These dynamics can occur for any of the values of the structural parameters determining preferences, technology and policy, but not for any value of the persistence of the confidence variable ψ_t. There is a critical value of q_P below which the deflationary spiral never converges. Thus, expectations driven liquidity traps can only occur if they are expected to be sufficiently persistent, see Mertens and Ravn (2010).

3.1 Dynamics of an Expectations Driven Liquidity Trap

Figure 2 provides the liquidity trap dynamics for the benchmark parameter values in Table 1 assuming that (i) the economy is in the pessimistic state at date 0, $\psi_0 = \psi_p$, and (ii) the initial values of the endogenous state variables correspond to their intended steady state values. The full line depicts the paths assuming that the pessimistic beliefs persist for $T = 5$ quarters, the expected duration of the liquidity trap. The broken lines display the paths assuming the pessimistic beliefs persist indefinitely such that the economy converges to the liquidity trap limit point. We show the realizations of aggregate output and real house prices relative to the intended steady state values, and annualized values of the short-term interest rate and inflation. For the benchmark calibration,

18

there are two different transition paths to the liquidity trap limit point that satisfy our conditions for a rational expectations equilibrium. In one of these paths, output and prices are immediately close to the limit point, while in the other there is overshooting and a subsequent gradual adjustment.

While in an expectations driven liquidity trap, the short term nominal interest rate is at the zero bound. Once agents turn optimistic, both equilibrium paths imply temporarily higher interest rates and a gradual downward adjustment to the 4 percent level of the intended steady state. The liquidity trap is associated with a period of significant deflation. In the limit, the rate of deflation is approximately 7 percent per year in both equilibria. In the transition period, one of the paths involves initially a larger amount of deflation, while the other has around 7 percent deflation for the entire duration of the liquidity trap. There is also a considerable drop in house prices. In the limit, house prices fall approximately 4 percent relative to the general price level, such that house prices in nominal terms decline by around 11 percent. Again, the two equilibrium paths differ in that one of them is associated with an initial overshooting of house prices.

The spell of zero interest rates is associated with a substantial drop in aggregate consumption and output. In the benchmark calibration, aggregate output falls by approximately 3 percent in the limit, while in the overshooting path output initially falls by close to 4 percent. These output losses are large. In a model without housing and credit frictions, but an otherwise identical calibration, Mertens and Ravn (2010) find an output loss of around 1 percent. In comparison, the output loss in the case where the economy permanently transitions to the liquidity trap steady state is no larger than 0.2 percent of the intended steady state output level, illustrating the importance of the temporary nature of the liquidity trap. Persistent output losses of this magnitude that are unrelated to any

change in fundamentals have significant effects on welfare.

Despite the model's many abstractions, the dynamics of the expectations driven liquidity trap arguably share several important qualitative features with the recent crisis in the US, as depicted in Figure 1. The monetary authority lowers short term interest rates to the lower bound, there is a marked fall in inflation and even deflation, and there is a large drop in output together with strong house price depreciation. The timing of events in the model is also similar to the data: The drop in interest rates coincides with a deceleration of inflation and a strong sudden decline in output and consumption. Quantitatively, the drop in output generated by the model is smaller than our measure of the output gap based on an extrapolated trend. The extent of the house price depreciation in the US is also substantially larger than in the model and started well before the drop in output. The biggest discrepancy is in the dynamics of inflation, which remains in negative territory in the model for the duration of the liquidity trap, whereas inflation has been low, but positive, during most of 2009. Nonetheless, given the relative simplicity of the model, the results suggest that a large expectational shock is an important candidate among the potential impulses driving the dynamics in the recent US crisis, in particular for explaining the dramatic deterioration in late 2008 following the failure of Lehman Brothers.

3 .2 Comparative Statics and Dynamics

The output loss during an expectations driven liquidity trap is greatly exacerbated by the credit frictions: on the one hand because of debt deflation and nominal credit contracts, on the other hand because of the house price collateral channel. This is despite the fact that the role of these credit channels for more conventional business cycle dynamics, i.e. the propagation of small shocks in

20

the neighborhood of the intended steady state, is quantitatively not very strong in the model. This is mainly because the only sector facing credit constraints, the commercial real estate sector, is only a small fraction of the economy. Thus, it is worth understanding in some more detail how the credit and housing sectors matter in an expectations driven liquidity trap recession.

Sensitivity Analysis Figure 3 depicts output and real house prices, both in percentage deviation from the intended steady state levels, as well as inflation rates in the liquidity trap limit point. These are the output and prices to which the economy converges in all equilibria while in the pessimistic state.

The first row of Figure 3 shows how outcomes depend on μ, the loan-to-value parameter that determines the leverage position of entrepreneurs. When the collateral constraint is relaxed and the entrepreneurs are more highly leveraged, the decline in output during a liquidity trap crisis becomes larger. Moreover, the effect of leverage is very nonlinear. For relatively low leverage, output losses are moderate and do not depend too much on the exact value of μ. However, as μ becomes larger, output losses in a liquidity trap increase substantially and become very sensitive to the exact value of the loan-to-value parameter. For example, an increase in the loan-to-value ratio from 80 percent to 95 percent implies that the output loss in the liquidity trap more than doubles. This confirms that the collateral constraint plays a very important role as a transmission mechanism, in particular when leverage is high. Greater indebtedness of entrepreneurs strengthens the debt deflation and house price collateral effects in the negative spiral of falling prices and output. This suggests that the process of financial innovation and deregulation that has occurred over the last decades may have come at the cost of potentially large output losses during an expectations driven liquidity trap, see also Mertens and Ravn (2011).

21

The output loss and price declines are also sensitive to the price elasticity of housing demand, ζ, and the elasticity of wholesale production to commercial real estate, ν. The effects are illustrated in the middle and last row in Figure 3 respectively. The elasticity of households' housing demand matters in determining the drop in house prices required to achieve equilibrium in the housing market. Lower elasticities (lower ζ) imply larger drops in house prices and exacerbate the negative effect on the collateral value of real estate in the entrepreneurs' borrowing constraint. A stronger house price collateral channel leads to larger output and price declines. The elasticity of commercial real estate in production, ν, determines how much production must be scaled down in the face of tightening credit conditions and also pins down the expenditure share of entrepreneurs in GDP. In our benchmark calibration we set this parameter equal to 3 percent which is the approximate contribution of commercial real estate to value added in the economy.[5] Increasing this elasticity only slightly leads to much larger output losses, more deflation and lower house prices. This shows that even though deteriorating credit conditions may only affect a relatively small sector in the economy, in this case the commercial real estate sector, in general equilibrium the consequences can be very severe.

Decomposing the Credit Channels   Next, we look at the relative contribution of the debt deflation channel and the house price collateral channel. Figure 4 illustrates the dynamics of output in a liquidity trap in four different scenarios. The first scenario in panel (a) is the benchmark model. The second scenario in panel (b) assumes that entrepreneurs can issue real (indexed) bonds such that deflation no longer increases the real value of the entrepreneurs' debt. The output drop is less than 50 percent of the one in the benchmark model. In the third scenario in panel (c) we remove

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[5]The entrepreneurs' expenditure share in GDP is 0.6%.

the collateral channel by replacing the borrowing constraint in equation (14) with the constraint:

$$B_{e,t} \leq \overline{B} \tag{33}$$

where we calibrate $\overline{B}$ so that it equals the collateral value in the intended steady-state of the benchmark model. This version of the model therefore retains the fact that deflation increases the real debt of entrepreneurs but removes all feedback from house prices to the borrowing constraint. The results are stark: The output loss in a liquidity trap without the house price collateral channel is only around 1 percent. Finally, in panel (d) of Figure 4 we set $\overline{B} = 0$ so that there is no credit and no leverage in the economy. In this case, the model produces an output loss in the liquidity trap identical to the one in the standard New Keynesian model analysed in Mertens and Ravn (2010) of around 0.9 percent. Thus, it is the combination of leverage, nominal debt, and collateral constraints that generate the large financial accelerator effects in the benchmark model.

4 Conclusion

We have examined the dynamics of expectations driven temporary liquidity traps in a New Keynesian model with housing and credit frictions. These can occur in equilibrium when agents lose confidence in the ability of monetary policy to stabilize the economy as a result of the zero lower bound on short term interest rates. Such liquidity traps share many aspects of the recent financial crisis in the US: When agents become pessimistic, a downward spiral of falling goods and house prices ensues while output drops significantly below normal levels. The output loss is substantially exacerbated by endogenously deteriorating credit conditions because of debt deflation and the effects of house prices on the value of collateral. Quantitatively, the model we have studied does

not account fully for the output and house price declines. Moreover, it predicts a more persistent period of deflation relative to the US experience so far. Nonetheless, given that we have abstracted from a host of other empirically plausible frictions and have neglected other possible shocks to the economy, we believe that nonfundamental shifts expectations should be high on the list of possible causal factors behind the crisis.

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Appendix A   Dynamic Equilibrium System

We solve for equilibrium sequences $(y_t,\ c_{h,t},\ c_{e,t},\ h_{e,t},\ n_t,\ b_t,\ \pi_t,\ v_t,\ \lambda_{b,t},\ q_t,\ x_t,\ i_t)_{t=0}^{\infty}$ that are solutions to the following system of stochastic difference equations

$$y_t = c_{h,t} + c_{e,t} \tag{A.1}$$

$$1 = \beta_h E_t \left[\frac{\lambda_{h,t+1}}{\lambda_{h,t}} \frac{1+i_t}{\pi_{t+1}} \right] \tag{A.2}$$

$$1 = \beta_e E_t \left[\frac{c_{e,t}}{c_{e,t+1}} \frac{1+i_t}{\pi_{t+1}} \right] + \lambda_{b,t} \tag{A.3}$$

$$q_t = \left(\frac{\rho c_{h,t}}{\bar{h} - h_{e,t}} \right)^{1/\zeta} + \beta_h E_t \left[\frac{\lambda_{h,t+1}}{\lambda_{h,t}} q_{t+1} \right] \tag{A.4}$$

$$q_t = \beta_e E_t \left[\frac{c_{e,t}}{c_{e,t+1}} \left(q_{t+1} + v \frac{v_{t+1} y_{t+1}}{x_{t+1} h_{e,t}} \right) \right] + \mu E_t \left[q_{t+1} \frac{\pi_{t+1}}{1+i_t} \right] \tag{A.5}$$

$$\frac{b_t}{q_t h_{e,t}} = \mu E_t \left[\frac{q_{t+1}}{q_t} \pi_{t+1} \right] \tag{A.6}$$

$$q_t h_{e,t} + c_{e,t} = v \frac{v_t y_t}{x_t} + \frac{b_t}{1+i_t} - \frac{b_{t-1}}{\pi_t} + q_t h_{e,t-1} \tag{A.7}$$

$$v_t y_t = A h_{e,t-1}^{v} n_t^{1-v} \tag{A.8}$$

$$\theta(1 - n_t)^{-\kappa} = (1-v) \frac{v_t y_t}{x_t n_t} \lambda_{h,t} \tag{A.9}$$

$$p_t^* \pi_t = \frac{E_t \sum_{s=t}^{\infty} (\beta_h \xi)^{s-t} \lambda_{h,s} / x_s \left(\prod_{j=0}^{s-t} \pi_{t+j} \right)^{\eta} y_s}{E_t \sum_{s=t}^{\infty} (\beta_h \xi)^{s-t} \lambda_{h,s} \left(\prod_{j=0}^{s-t} \pi_{t+j} \right)^{\eta-1} y_s} \tag{A.10}$$

$$v_t = \xi \pi_t^{\eta} v_{t-1} + (1-\xi) p_t^{*-\eta} \tag{A.11}$$

$$1 + i_t = \max\left(\frac{\tilde{\pi}}{\beta_h} \left(\frac{\pi_t}{\tilde{\pi}} \right)^{\phi_\pi}, 1 \right) \tag{A.12}$$

$$b_{-1}, h_{e,-1}, v_{-1} \text{ given}$$

where $\lambda_{h,t} = z_{h,t}^{1/\zeta-1} c_{h,t}^{-1/\zeta}$, $z_{h,t} = \left(\rho^{1/\zeta} h_{h,t}^{1-1/\zeta} + c_{h,t}^{1-1/\zeta} \right)^{\zeta/(\zeta-1)}$ and

$p_t^* = \left((1 - \xi \pi_t^{\eta-1})/(1-\xi) \right)^{1/(1-\eta)}$. Equilibrium solutions must also satisfy all boundary conditions, including $v_t \geq 1$, $i_t \geq 0$ and $\lambda_{b,t} \geq 0$.

Appendix B   Solution Technique

With an appropriate redefinition of variables, the system (A.1)-(A.12) can be written as

$$E_t \left[F \left(u_t, s_t, u_{t+1}, s_{t+1} \right) \right] = 0 \tag{B.1}$$

Consider the system

$$q_O F \left(u_t^O, s_t^O, u_{t+1}^O, s_{t+1}^O \right) + (1 - q_O) F \left(u_t^O, s_t^O, u_{t+1}^P, s_{t+1}^P \right) = 0 \tag{B.2}$$

$$q_P F \left(u_t^P, s_t^P, u_{t+1}^P, s_{t+1}^P \right) + (1 - q_P) F \left(u_t^P, s_t^P, u_{t+1}^O, s_{t+1}^O \right) = 0 \tag{B.3}$$

with appropriate boundary conditions. Let $u_t = u_t^i$ and $s_t = s_t^i$ if $\psi_t = \psi_i$, $i = O, P$. If $\{u_t^O, u_t^P, s_t^O, s_t^P\}_{t=0}^{\infty}$ is a solution to (B.2)-(B.3), then $\{u_t, s_t\}_{t=0}^{\infty}$ is a solution to (B.1). We approximate equilibrium solutions by loglinearizing (B.2)-(B.3) around the points $(\bar{u}^O, \bar{s}^O, \bar{u}^P, \bar{s}^P)$. Given that we set $q_O = 1$, we choose $\bar{u}^O$ and $\bar{s}^O$ to be the roots of $F \left(\bar{u}^O, \bar{s}^O, \bar{u}^O, \bar{s}^O \right) = 0$, such that $\bar{u}^O, \bar{s}^O$ is just the intended steady state. Given that $q_O = 1$, the loglinear approximation of the functions $h_O(\cdot)$ and $f_O(\cdot)$, denoted by $\tilde{h}_O(\cdot)$ and $\tilde{f}_O(\cdot)$, can be found using standard methods from the subsystem $F \left(u_t^O, s_t^O, u_{t+1}^O, s_{t+1}^O \right) = 0$. A good choice for the approximation point $(\bar{u}^P, \bar{s}^P)$ in the pessimistic

state would be the roots of

$$q_P F\left(\bar{u}^P, \bar{s}^P, \bar{u}^P, \bar{s}^P\right) + (1-q_P)F\left(\bar{u}^P, \bar{s}^P, f_O(h_O(\bar{s}^P)), h_O(\bar{s}^P)\right) \quad = \quad 0 \tag{B.4}$$

One solution of this equation is always $(\bar{u}^O, \bar{s}^O)$, the intended steady state. Depending on parameter values, there may exist a second solution, referred to as the liquidity trap limit point, in which the nominal interest rate is zero (see Mertens and Ravn (2010)). The liquidity trap limit point $(\bar{u}^P, \bar{s}^P)$ is the point to which the variables converge as $t \to \infty$ conditional on being in a liquidity trap state ψ_P. Finding the true functions $h_O(\cdot)$ and $f_O(\cdot)$ for the model in this paper is nontrivial, and in practice we replace these functions in (B.4) by $\tilde{h}_O(\cdot)$ and $\tilde{f}_O(\cdot)$ to find the approximate values of $(\bar{u}^P, \bar{s}^P)$. The loglinearization of (B.2)-(B.3) around $(\bar{u}^O, \bar{s}^O, \bar{u}^P, \bar{s}^P)$ results in a linear system in which conventional solution methods and stability analysis can be applied.
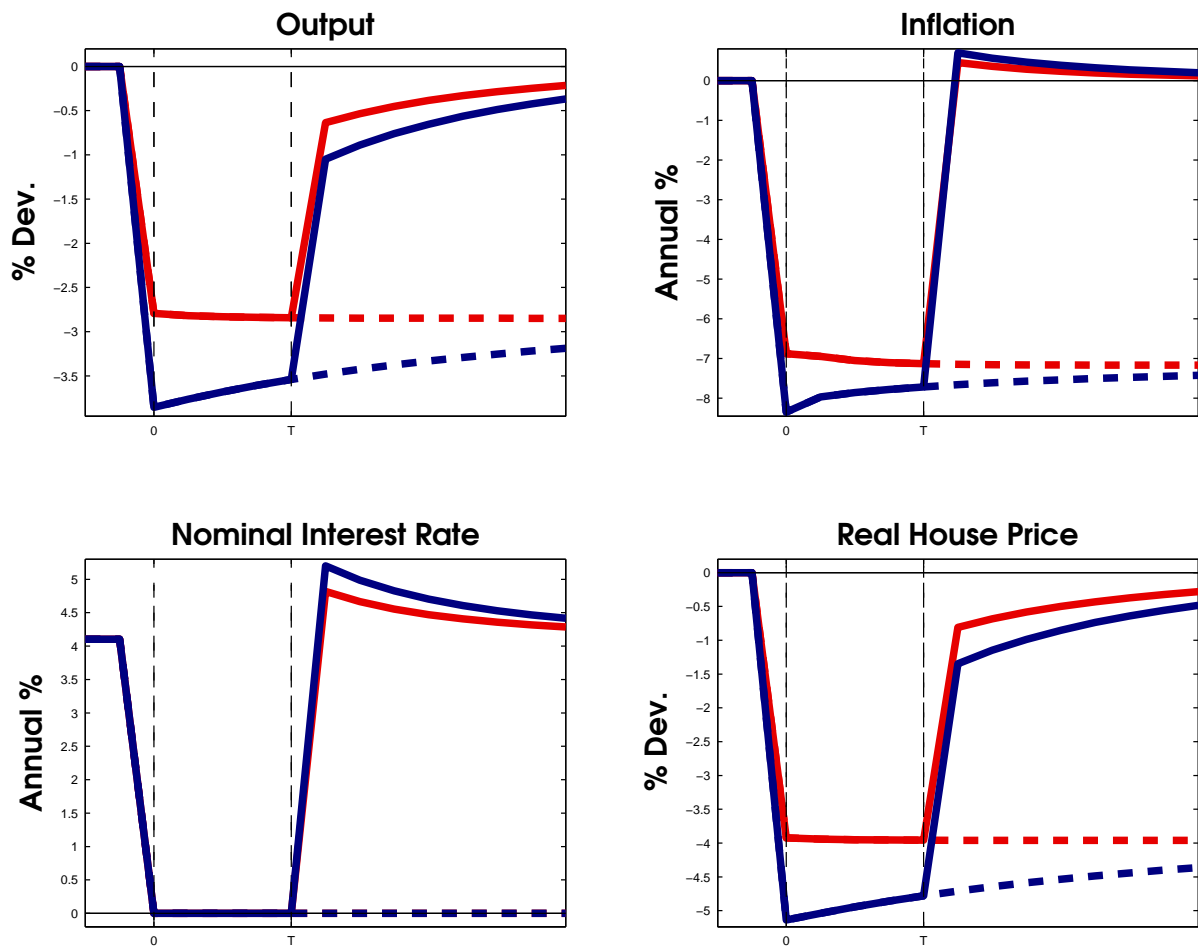
Table 1: Benchmark Parameter Values

|		
β_h	0.99	Households' Discount Factor
β_e	0.98	Entrepreneurs' Discount Factor
κ	2.65	Leisure Curvature
η	10	Price Elasticity of Consumption
ζ	0.75	Price Elasticity of Residential Housing
μ	0.90	Loan-to-Value Ratio
ν	0.03	Housing Elasticity in Production
ξ	0.65	Calvo Parameter
$\tilde{\pi}$	1	Inflation Target
ϕ_π	1.5	Feedback in Taylor Rule
q_O	1	Transition Probability ψ_t
q_P	0.8	Transition Probability ψ_t
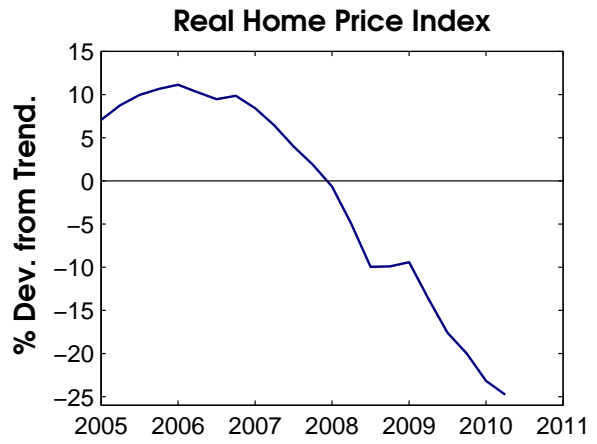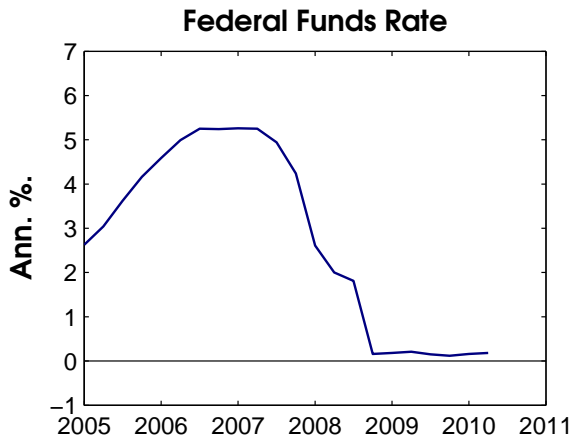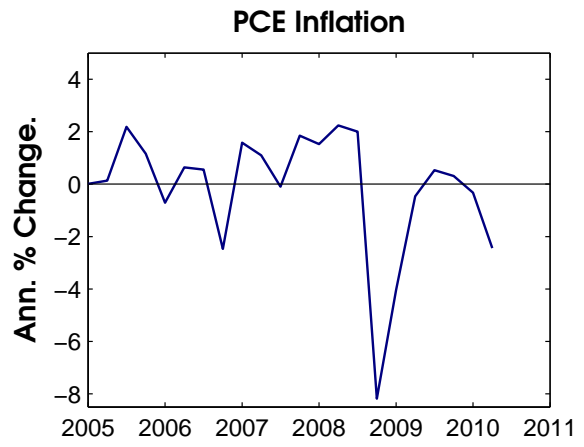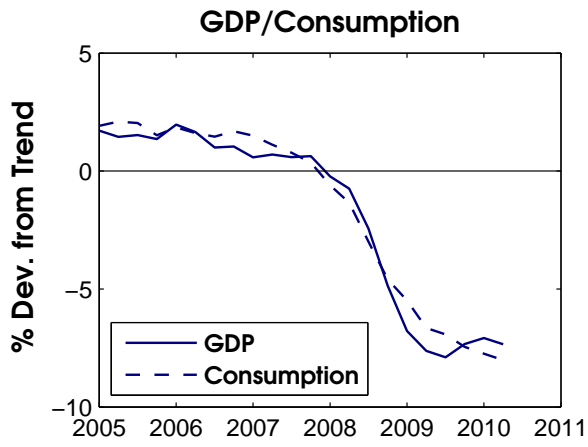
Figure 1: The Recent Recession in the US

Figure 2: Liquidity Trap Recession: Equilibrium Paths
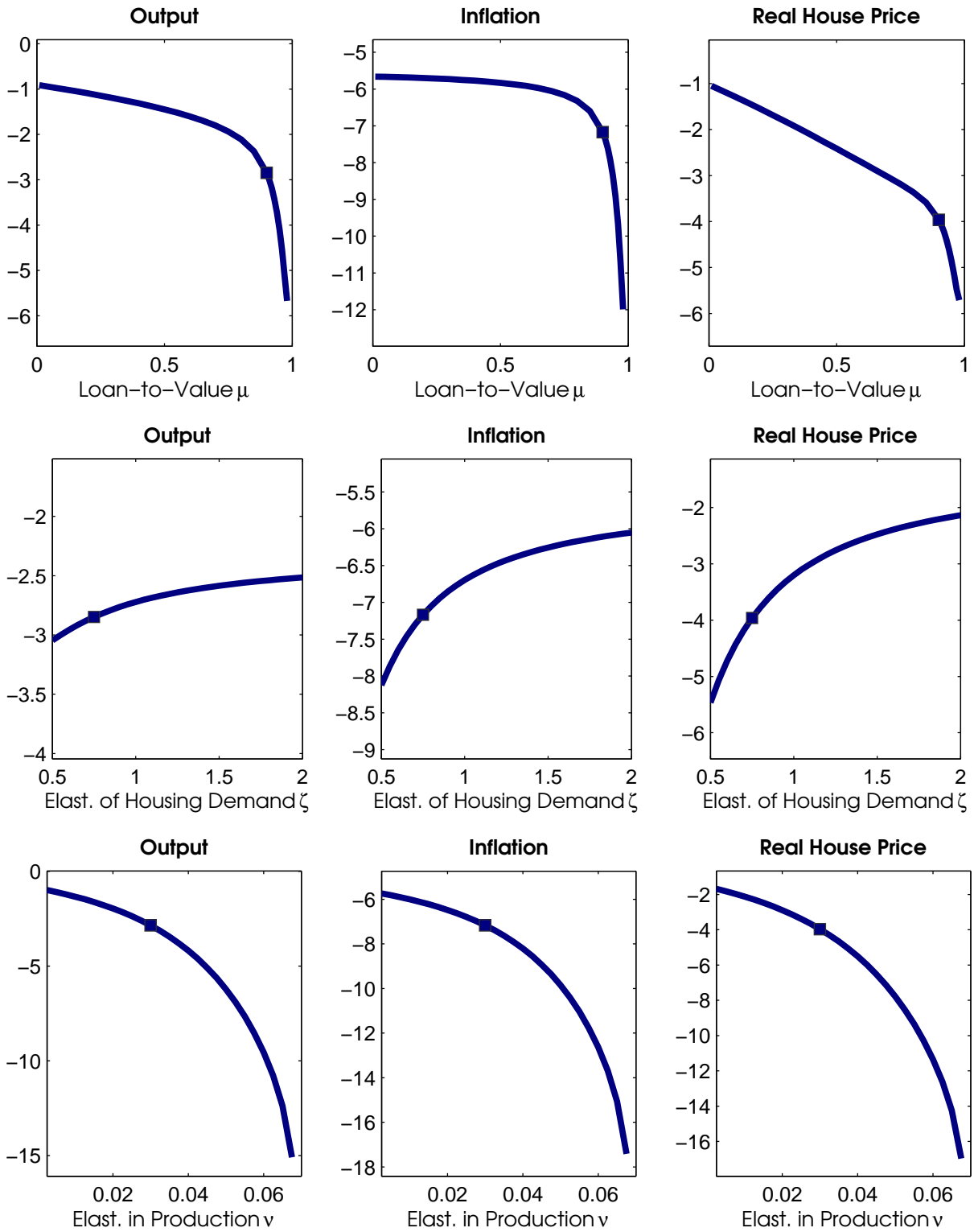
Figure 3: Sensitivity Analysis. The benchmark parameter values are marked by a square.
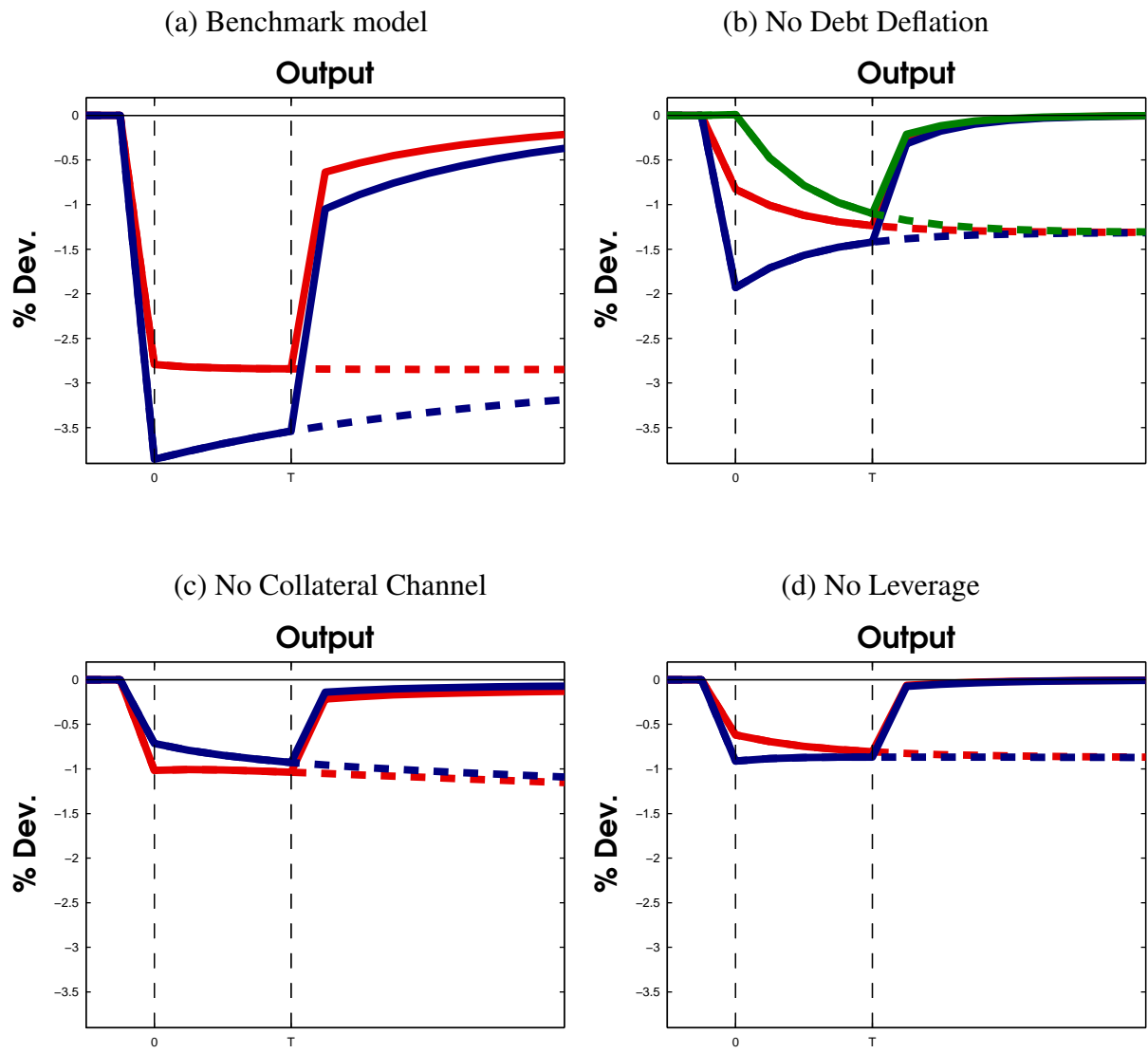
Figure 4: Role of Credit Market Channels