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Macroeconomic Implications of Consumer Default Policies, Mortgage Bailout Guarantees & Unemployment Insurance

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Abstract

In this dissertation, I examine the effects of three broad government interventions in the economy: 1) bankruptcy and foreclosure laws; 2) bailout guarantees in the mortgage market; and 3) unemployment insurance.

In the first chapter, I develop a general-equilibrium model of housing and default to jointly analyze the effects of bankruptcy and foreclosure policies. Heterogeneous households have access to mortgages and unsecured credit and can default separately on both types of debt. I show that the interaction between foreclosure and bankruptcy decisions is crucial for explaining the observed cross-state correlation between default policies and default rates. I use the model to argue that a major recent reform to bankruptcy has unintended consequences: it substantially increases bankruptcy rates, despite being intended to reduce them, and also increases foreclosure rates. Nevertheless, the reform yields large welfare gains.

In the second chapter, I ask what are the macroeconomic and distributional effects of government bailout guarantees for Government Sponsored Enterprises (e.g., Fannie Mae)? A model with heterogeneous, infinitely-lived households and competitive housing and mortgage markets is constructed to evaluate this question. Households can default on their mortgages via foreclosure. The bailout guarantee is a tax-financed mortgage interest rate subsidy.

Eliminating this subsidy leads to a large decline in mortgage origination and increases aggregate welfare by 0.5% in consumption equivalent variation, but has little effect on foreclosure rates and housing investment. The interest rate subsidy is a regressive policy: it hurts low-income and low-asset households.

Finally, I evaluate the positive and normative implications of unemployment benefits. In the third chapter, we exploit a policy discontinuity at U.S. state borders to identify the effects of unemployment insurance policies on unemployment. Our estimates imply that most of the persistent increase in unemployment during the Great Recession can be accounted for by the unprecedented extensions of unemployment benefit eligibility. In contrast to the existing recent literature that mainly focused on estimating the effects of benefit duration on job search and acceptance strategies of the unemployed -- the micro effect -- we focus on measuring the general equilibrium macro effect that operates primarily through the response of job creation to unemployment benefit extensions. We find that it is the latter effect that is very important quantitatively.

The last three recessions in the United States were followed by jobless recoveries: while labor productivity recovered, unemployment remained high. In the fourth chapter, we argue that countercyclical unemployment

benefit extensions lead to jobless recoveries. We augment the standard Mortensen-Pissarides model to incorporate unemployment benefit expiration and state-dependent extensions of unemployment benefits. In the model, an extension of unemployment benefits raises the outside option of unemployed workers in wage bargaining, thereby reducing firm profits from hiring and slowing down the recovery of vacancy creation in the aftermath of a recession. We calibrate the model to US data and show that it is quantitatively consistent with observed labor market dynamics, in particular the emergence of jobless recoveries after 1985. Furthermore, counterfactual experiments indicate that unemployment benefits are quantitatively important in explaining jobless recoveries.

In the fifth chapter, we use an equilibrium search model with risk-averse workers to characterize the optimal cyclical behavior of unemployment insurance. Contrary to the current US policy, we find that the path of optimal unemployment benefits is pro-cyclical - positively correlated with productivity and employment. Furthermore, optimal unemployment benefits react non-monotonically to a productivity shock: in response to a fall in productivity, they rise on impact but then fall significantly below their pre-recession level. As compared to the current US unemployment insurance policy, the optimal state-contingent unemployment benefits smooth cyclical fluctuations in unemployment and deliver substantial welfare gains.

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**MACROECONOMIC IMPLICATIONS OF CONSUMER
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GUARANTEES & UNEMPLOYMENT INSURANCE**

Kurt E. Mitman

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ABSTRACT

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DEFAULT POLICIES, MORTGAGE BAILOUT
GUARANTEES & UNEMPLOYMENT INSURANCE**

Kurt E. Mitman

Dirk Krueger

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**MACROECONOMIC
IMPLICATIONS OF CONSUMER
DEFAULT POLICIES,
MORTGAGE BAILOUT
GUARANTEES &
UNEMPLOYMENT INSURANCE**

Chapter 1

Macroeconomic Effects of Bankruptcy and Foreclosure Policies

In the United States, households hold two types of debt, secured and unsecured, and they hold large amounts of it, currently averaging more than 100 percent of disposable income. There are two channels for defaulting on this debt: bankruptcy for unsecured borrowing and foreclosure for secured mortgage borrowing. Households exercise these default options in substantial numbers - in 2010 more than 1.5 million households filed for bankruptcy and more than 1 million homes were foreclosed. In this paper, I use a calibrated structural model to argue that the two channels for default - bankruptcy and foreclosure - are fundamentally linked by household behavior. Understanding this link is critical for explaining the observed cross-state variation in bankruptcy and foreclosure rates and evaluating the consequences of reforms to bankruptcy and foreclosure policies.

Despite being separate legal processes, bankruptcy and foreclosure can be complements or substitutes: bankruptcy may prevent foreclosure by discharging a household's unsecured debt, thereby freeing up income for making mortgage payments. On the other hand, foreclosure could lead to bankruptcy if banks can sue households who default on their mortgages to recoup losses (in addition to seizing their homes). Further, households take into account the different channels for default when choos-

ing the optimal composition of secured and unsecured debt in their portfolios. Thus, a change to bankruptcy laws, for example, may impact secured credit holdings and foreclosure rates if households respond by adjusting their debt portfolios.

The fraction of households that choose to exercise the bankruptcy or foreclosure option varies greatly across U.S. states. In 2010, bankruptcy rates ranged from a low of 0.4 percent of households in Alaska to a high of 2.9 percent of households in Nevada. Similarly, foreclosure rates ranged from 0.4 percent of mortgages in North Dakota to 2.9 percent of mortgages in Nevada. A natural candidate to explain the cross-state variation in default rates is the variation in state bankruptcy and foreclosure laws.

States vary significantly in two pertinent dimensions of default law: the homestead exemption in bankruptcy and recourse in foreclosure. The homestead exemption specifies how much home equity the household can keep after the discharge of unsecured debt when a household files for Chapter 7 bankruptcy. In recourse states, after forfeiting their home, foreclosed households are still liable for the difference between the recovered value of the house and the face value of the mortgage, as opposed to no-recourse states where households can walk away from their mortgages with no additional liability. In Figures 1.1(a) and 1.1(b), I plot state bankruptcy and foreclosure rates as a function of the homestead exemption. The figures illustrate the significant variation in default rates and laws across states. In addition, Figure 1.1(a) illustrates a *negative correlation* between the generosity of the bankruptcy law and the bankruptcy rate. This relationship is striking: one might expect that more generous bankruptcy laws would make households more likely to go bankrupt. In fact, in an empirical study Fay, Hurst, and White (2002) find that a household's chance of going bankrupt is increasing in the financial benefit from doing so. However, micro analysis is silent on whether portfolios of debt held by households are systematically different in states with different homestead exemptions. If more generous bankruptcy policies result in higher interest rates on unsecured debt, they may lead to lower unsecured

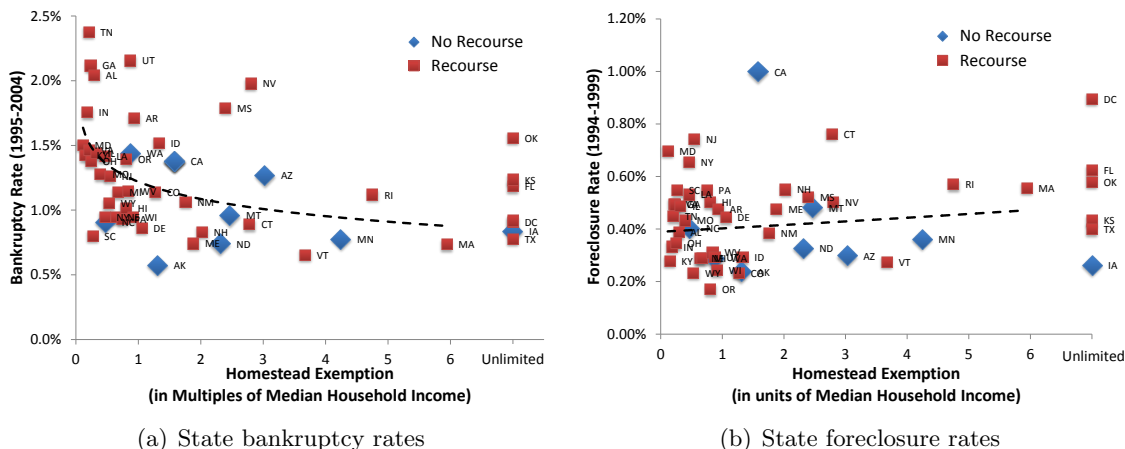


Figure 1.1: Bankruptcy and Foreclosure Rates Across States.

Notes: The homestead exemptions in terms of median income is calculated by state law for the homestead exemption in the year 2000 and median household income from the Census in 2000. Average state bankruptcy rates 1995-2004 are computed using bankruptcy filings from the American Bankruptcy Institute and the number of households in each state from the Census. Average state foreclosure rates 1994-1999 are computed from the Mortgage Banker Association’s quarterly National Delinquency Survey from 1994-1999. The dashed lines are smoothed versions of the data.

debt holdings and therefore lower bankruptcy rates. This observed relationship between bankruptcy and the homestead exemption suggests that accounting for general equilibrium effects of policies might be important in reconciling micro and macro facts related to bankruptcy.

Motivated by these observations, I ask three questions in this paper: (1) What fraction of cross-state variation in default rates can be explained by differences in bankruptcy and foreclosure laws? (2) What are the effects of a major reform to bankruptcy, the 2005 Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA)? and (3) If the government could standardize exemption and recourse policy across states, what policy should it adopt?¹

To address these questions, I analyze theoretically and quantitatively the effects of the homestead exemption and recourse on household portfolio and default choices, default rates and welfare. I construct a heterogeneous-agent general-equilibrium

¹The U.S. Congress has attempted and failed to standardize state exemption policy numerous times in the last 35 years amid intense debate over the optimal level of exemptions.

incomplete-markets model. The model has elements in common with the bankruptcy model of Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007) and the foreclosure model of Jeske, Krueger, and Mitman (2011). Households can finance purchases of a housing good with mortgages, and can save in bonds or borrow in unsecured debt. Households face idiosyncratic income and housing risk and can default separately on their mortgages and unsecured credit. Households who default on mortgages forfeit their housing collateral. In addition, in recourse states, the difference between the face value of the mortgage and the collateral is stochastically converted into unsecured credit. Households who file for bankruptcy have all unsecured debts discharged and can keep home equity up to the homestead exemption, but are then excluded from filing for bankruptcy again for a period of time.

My main theoretical contribution is to characterize how the bankruptcy decision depends on the entire household portfolio. Unlike Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007), I find that the net worth of a household is not a sufficient statistic for understanding a household's decision to go bankrupt. The bankruptcy decision depends jointly on the level of unsecured debt, home equity and non-exempt home equity. Given these three quantities, I prove that the set of income realizations that triggers bankruptcy is a closed interval. Further, I show that for a fixed level of net worth, a household with more home equity is more likely to declare bankruptcy since it stands to gain more from having its unsecured debt discharged. In addition, I show that the probability of going bankrupt is decreasing in the amount of non-exempt home equity, as the non-exempt portion is seized in bankruptcy.

My main quantitative result is that the model can account for 20 percent of the overall variation in state bankruptcy rates, and for 80 percent of the variation that cross-state regressions attribute to differences in laws. The model predicts, consistent with state level data, lower bankruptcy rates in states with higher homestead exemptions. More generous exemptions lessen the penalty from bankruptcy and therefore

increase the probability of homeowners going bankrupt. This raises the equilibrium interest rate on unsecured borrowing. This higher interest rate, coupled with access to secured borrowing, causes households to substitute secured credit for unsecured by taking on more highly leveraged mortgages. Therefore, in states with higher exemptions, the household portfolio is more heavily weighted toward secured debt, resulting in lower bankruptcy rates, but higher foreclosure rates. Generating the negative correlation between bankruptcy rates and the homestead exemption depends crucially on the ability of households to endogenously substitute between the two types of credit. I show in a counter-factual analysis where secured borrowing and foreclosure are not allowed, that this version of the model does not reproduce the observed negative relationship between bankruptcy rates and the homestead exemption. This thought experiment highlights the importance of modeling secured and unsecured credit together.

Third, I use the calibrated model to evaluate the effects of a recent major reform to bankruptcy law: the 2005 Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA). The reform prohibited households earning above median income in their state from filing for bankruptcy. Analyzing the transition path induced by the reform, I find that bankruptcy rates initially drop, but then rise significantly for several years until converging to a rate roughly double the pre-reform level. The fraction of households with negative net worth and the total unsecured debt outstanding also increase significantly along the transition. Since income is highly persistent, households with above median income have a high probability of staying above median income (and being precluded from filing for bankruptcy) in subsequent periods, and thus their default risk is low. As a result, these households face much lower prices for unsecured debt, and optimally take on more of it than before the reform. If they remain above median income they repay or roll over the debt, but if they fall below the income threshold they optimally choose to go bankrupt. This simultaneously

generates increased indebtedness and higher bankruptcy rates.

Even though the BAPCPA reform only changed bankruptcy law, I find that it has significant effects on foreclosure rates as well. Along the transition foreclosure rates increase for several years and then converge to a level 0.6 percentage points higher. My findings provide support for the hypotheses of Morgan, Iverson, and Botsch (2009) and Li, White, and Zhu (2010) that BAPCPA contributed to the subsequent observed rise in foreclosure rates. As mentioned above, households become increasingly indebted causing a left-ward shift in the wealth distribution. Both before and after BAPCPA, households with low net worth take on more highly leveraged mortgages than high net worth households because they have fewer resources to finance housing purchases. Thus, increasing the mass of low net worth households increases the foreclosure rate. In addition, households with non-exempt home equity take on less unsecured debt (since it provides less insurance against housing risk), resulting in portfolios more heavily weighted toward mortgage debt.

Despite the increase in default rates, using a utilitarian welfare measure, households on average are willing to pay more than 1.4 percent of lifetime consumption to implement the policy. The mechanism behind the welfare gain is the increased state-contingency of unsecured debt after BAPCPA. Restricting bankruptcy only to households who earn below median income moves the unsecured debt contract closer to an insurance contract against low income realizations. Households can take on unsecured debt and exempt home equity at lower prices than before the reform. In the event of a low income realization, households can declare bankruptcy and keep the home equity. Thus, using a combination of home equity and unsecured credit, households can insure themselves against low income realizations.

Finally, I address the question of what level of exemption and recourse policy the federal government should enact were it to standardize default policies across states. I find that, under a utilitarian welfare function, the optimal joint policy is no-recourse

foreclosure and a homestead exemption of roughly 25 percent of the state median income. The intuition for the result is as follows. Households in the economy face two types of risk: income risk and house price risk. By preventing recourse, secured debt can more effectively provide insurance against housing risk, since it does not expose households to the risk of also having to go bankrupt. The optimal size of the homestead exemption balances the insurance value of being able to keep home equity after bankruptcy with the increased cost of credit associated with the higher default risk.

The rest of the paper is organized as follows. In Section 1, I review the existing literature. In Section 2, I describe the model economy. In Section 3, I provide theoretical characterizations of household decisions and endogenous prices. The calibration procedure and the relevant data targets are presented in Section 4. The characteristics of the calibrated economy are discussed in Section 5. In Section 6, I discuss the results of policy experiments. Section 7 concludes.

1.1 Connections to Existing Literature

This paper is related to multiple areas of the literature on incomplete markets and household default. Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007) and Livshits, MacGee, and Tertilt (2007) study economies with savings and competitively priced unsecured debt, with prices depending on loan size and household characteristics.² In their models, these authors abstract from a household portfolio of exempt assets and liabilities and only consider the net household position since their focus is only on bankruptcy and unsecured credit. In my framework, I include an exempt housing asset and show that the net position is not sufficient to determine the default decision. Including assets and liabilities allows the model to be consistent with the large

²Athreya (2002) provides an early analysis of an incomplete markets model integrating a bankruptcy option. However, he assumes that all loans are pooled, so that loan pricing does not depend on household characteristics or loan sizes.

fraction of bankrupt households who have positive home equity. Further, the endogenous penalty of having non-exempt assets seized generates average credit spreads on unsecured credit that are consistent with what is observed in the data, which the existing literature has had trouble matching. Pavan (2008) and Li and Sarte (2006) incorporate durables into equilibrium default models to study the effects of homestead exemptions, but abstract from secured debt. Hintermaier and Koeniger (2009) analyze optimal debt portfolios in a life-cycle model of durable and non-durable consumption, but without the possibility of mortgage default.

Recent papers by Jeske, Krueger, and Mitman (2011), Corbae and Quintin (2011), Chatterjee and Eyigungor (2011) and Garriga and Schlagenhauf (2009) build equilibrium models of housing, endogenous leverage choice, and foreclosure. Those papers abstract from unsecured debt and bankruptcy, and are primarily focused on understanding the effects of government housing market policy or the 2007 housing bust.³ I see my paper as complementing those papers by providing insight on how BAPCPA may have contributed to the subsequent rise in foreclosures. To my knowledge, this is the first study to investigate the joint causes and consequences of foreclosure and bankruptcy in a structural, dynamic, general equilibrium model.⁴

Another strand of the literature has empirically investigated the effects of homestead exemptions and recourse. These papers provide an empirical benchmark to evaluate the predictions of the model. Gropp, Scholz, and White (1997) find that in states with higher homestead exemptions households with lower wealth are more likely to be denied auto loans. Pence (2006) finds smaller mortgages are originated in states with borrower friendly foreclosure laws. Complementing that work, Ghent and Kudlyak (2011) estimate that recourse laws significantly reduce the probability of foreclosure.

³There is also an important, empirically focused literature that investigates the causes and consequences of the recent housing bust, see e.g. Foote et al. 2009 or Mian, Sufi, and Trebbi (2011).

⁴This work also complements a growing empirical literature that focuses on the interaction between foreclosure and bankruptcy (e.g., Carroll and Li (2008), Li and White (2009)).

1.2 Model

I model each state in the US as an endowment economy, populated with a measure one continuum of households, a measure one continuum of banks and a measure one continuum of real estate construction companies. Time is modeled discretely and all agents are infinitely lived.

1.2.1 Households

Each period, households receive an idiosyncratic endowment of the consumption good y . The endowment is assumed to follow a stochastic process consisting of a persistent and a transitory component:

$$\log(y) = z + \varepsilon$$

where

$$z' = \rho z + \sqrt{(1 - \rho^2)}\eta$$

where ε and η are independent normally distributed random variables with variances σ_ε^2 and σ_η^2 .

Households derive period utility $U(c, s)$ from consumption and housing services s , which can be purchased at a price p_s relative to the consumption good. Households are expected utility maximizers and discount the future with parameter β .

Households can save or borrow by purchasing one-period bonds with face value b' , with negative values interpreted as unsecured loans. The “price” of a bond with face value b' can be a function of all observable household characteristics as well as asset choices and is denoted $q_b(\cdot)$. The timing is such that for savings the household pays $b' \times q_b(b', \cdot)$ in the current period to receive b' in the subsequent period. For unsecured borrowing, the household receives $-b' \times q_b(b', \cdot)$ and has to repay $-b'$ in the subsequent period or has to go bankrupt.

Households can purchase perfectly divisible houses h' at a price p_h per unit of housing. Each unit of the housing good generates a unit flow of housing services, which can be rented out in the same period of purchase. I assume that houses are subject to *idiosyncratic* depreciation shocks, δ' .⁵ The shocks are distributed according to CDF $F(\delta')$, with negative values of δ' corresponding to house appreciation. The realizations of δ' are assumed to be independent across time and households. A law of large numbers is assumed to hold such that $F(\cdot)$ represents the cross-sectional distribution of depreciation shocks.

Households can finance housing purchases with mortgages with face value denoted by m' . The mortgage is secured by the housing good owned by the household, and the price $q_m(\cdot)$ can be a function of all observable household characteristics as well as goods and asset choices. I assume that neither households nor financial intermediaries can commit to long term mortgage contracts.⁶ A mortgage therefore is a one-period contract to receive $m' \times q_m(m', \cdot)$ units of the consumption good in the current period and to repay m' in the subsequent period or to go into foreclosure.

⁵The depreciation shock is intended to capture individual (as opposed to aggregate) changes in house values. In a steady state environment with constant aggregate house prices, this shock will generate households with negative home equity, which I later prove is a necessary condition for going into foreclosure. Alternatively, one could assume that the shocks are to the per unit price of the house, as opposed to the physical stock. That model is equivalent except for the case of sufficiently large shocks that would cause the price of the home to fall below the value of the services it generates. Given that the probability of such shocks is small, this modeling choice is inconsequential.

⁶On the household side, the assumption is innocuous given access to low cost mortgage refinance and home-equity lines of credit. On the bank side, long term contracts provide households insurance against inflation risk, real-interest rate risk and income risk. Since I am focused on steady-state equilibria, there is no aggregate inflation or interest rate risk that households need to insure against. In Section 3, I show that in no-recourse states households are also insured against income risk. A result of the assumption is that households face significant risk from housing shocks because they must refinance every period. This is most likely to affect results regarding how much negative home equity households are willing to tolerate before going into foreclosure. It is not clear that missing on that margin, however, significantly impacts the cross-state variation in defaults or evaluating reforms to bankruptcy laws, and is thus defensible for my analysis.

1.2.2 Legal Environment

Foreclosure

Households have the option to default on mortgages after the realization of the housing depreciation and income shocks. When a household defaults, the depreciated housing collateral is seized via a foreclosure technology. If the depreciated housing collateral exceeds the face value of the mortgage, the excess is returned to the household,⁷ i.e. the household receives $\max\{\gamma(1 - \delta')p_h h' - m', 0\}$, where m', h' are the mortgage and house size before the default decision respectively, δ' is the realized depreciation shock, and $\gamma \leq 1$ represents the foreclosure technology. If the housing collateral (after depreciation and foreclosure) is less than the face value of the mortgage, the difference is converted into unsecured debt via a stochastic deficiency judgment technology. Deficiency judgments $\mathcal{J} = 1$ occur with probability $\psi \in [0, 1]$, with probability $1 - \psi$, $\mathcal{J} = 0$.⁸ The unsecured position of the households after foreclosure can be represented as:

$$b_F = b' + \mathcal{J}(\gamma(1 - \delta')p_h h' - m')$$

where $\mathbb{E}[\mathcal{J}] = \psi$. A no-recourse state is a state where $\psi = 0$.⁹

Bankruptcy

Bankruptcy is modeled after the U.S. Chapter 7 bankruptcy law. Chapter 7 is by far the most commonly exercised bankruptcy option, accounting for more than 70 percent

⁷This is consistent with foreclosure law. If the value of the collateral exceeds the outstanding debt, the bank must return the excess after liquidating the collateral and covering any associated foreclosure costs.

⁸The assumption of stochastic deficiency judgments is an abstraction to capture the decision of the bank to sue a household motivated by the fact that banks do not pursue deficiency judgments for all households who go into foreclosure even if it is legally allowed.

⁹Assuming that there is no additional penalty from foreclosure in no-recourse states yields a sharp characterization of the infinite-dimensional mortgage pricing function. In the US, a foreclosure would show up on the credit report of a household, potentially affecting the future ability to obtain a new mortgage. However, if households provide a sufficiently high down payment, the bad credit can be overcome. As such, it is reasonable to assume no additional penalty. In the model, just foreclosed households tend to have low wealth, and optimally choose not to purchase housing despite having access to credit, further mitigating the issue.

of all bankruptcies.¹⁰ The amount of home equity that can be kept in bankruptcy - the state homestead exemption - is denoted by χ . The bankruptcy decision is made after the foreclosure decision and deficiency judgment realization. The timing convention is chosen to preclude the possibility of the household having an empty budget set after both default decisions. If a household declares bankruptcy, in the current period the following happens:

1. The household can keep home equity up to the exemption
2. Any non-exempt home equity is applied to unsecured debt
3. Unsecured debt is set to 0 and the household cannot accumulate bonds
4. The household cannot change its home equity balance
5. The household's credit history state changes to bad

The restrictions on savings and home equity come from the process of liquidation and exemptions. Households can sell their homes in bankruptcy and keep the exempt equity only if they use or intend to use that equity to purchase another home. In some states, e.g. Florida and Texas, exempt equity proceeds from the sale of a home must be placed into a homestead account until the new homestead is purchased.

Households with bad credit histories are excluded from unsecured borrowing and cannot declare bankruptcy, but they are not excluded from the mortgage market. Further, households with bad credit histories face a proportional consumption penalty λ to represent, among other things, the increased difficulty of getting a cell phone or a lease, for households with a bankruptcy on a credit record. A household's credit history changes to a good history with probability α and remains bad with probability $1 - \alpha$.

¹⁰The other option for households is Chapter 13 bankruptcy. Chapter 13 involves a repayment of debts over a 3-5 year period. Close to 50 percent of households who enter into Chapter 13 do not successfully complete the repayment plan, and a significant fraction end up converting to Chapter 7. It is important to note that the homestead exemption is still relevant for Chapter 13. Creditors must receive at least as much repayment as they would under the discharge of debt in Chapter 7.

1.2.3 Household Decision Problem

Households can be in one of two credit history states, $\mathcal{H} = \{G, BC\}$, G represents a good credit history and BC represents having a bad credit history. The relevant state variables at the beginning of the period are the household portfolio, b, h, m , credit history, \mathcal{H} and shocks δ, y, z . Let $X = (b, h, m, \delta, y, z)$, which summarizes the household state. Denote by a the cash-at-hand, or net resource household of a household after the foreclosure and bankruptcy decisions, and $\eta = \max\{p_h h(1 - \delta) - m, 0\}$ the non-negative home equity of a household after the default decisions. The dynamic programming problem of the household can be written as follows:

An agent who begins the period with a good credit history, has lifetime utility given by:

$$V^G(b, h, m, \delta, y, z) = \max_{\mathcal{F} \in \{0,1\}} \mathbb{E}_{\mathcal{J}} \max \{W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z), W_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z)\} \quad (1.1)$$

where $\mathbb{E}_{\mathcal{J}}$ is the expectation over a deficiency judgment if the household goes in to foreclosure, and $W_{\mathcal{F}}^{NB}$ and $W_{\mathcal{F}}^B$ are the value of not going bankrupt and going bankrupt, respectively, conditional on the foreclosure choice. Conditional on choosing not to go bankrupt ($W_{\mathcal{F}}^{NB}$), the households solves:

$$\begin{aligned} W_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z) &= \max_{c, s, m', h' \geq 0, b'} \left\{ U(c, s) + \beta \mathbb{E}_{(\delta', y', z')|z} V^G(b', h', m', \delta', y', z') \right\} \\ \text{subj. to} \quad &c + p_s s + [p_h - p_s] h' - m' q_m(b', h', m', z, G) + b' q_b(b', h', m', z) \leq a_{\mathcal{F}} \\ \text{where:} \quad &\underbrace{a_{\mathcal{F}=0} = (1 - \delta) p_h h - m + b + y}_{\text{No Foreclosure}} \quad \text{and} \quad \underbrace{a_{\mathcal{F}=1} = b_F + y}_{\text{Foreclosure}} \end{aligned}$$

The household chooses contemporaneous consumption and new bond, housing and mortgage positions. A household who went bankrupt ($W_{\mathcal{F}}^B$), and conditional on the

foreclosure choice, solves:

$$\begin{aligned}
W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z) &= \max_{c, h, m', h' \geq 0} \left\{ U(c, s) + \beta \mathbb{E}_{(\delta', y', z')|z} V^{BC}(b', h', m', \delta', y', z') \right\} \\
\text{subj. to } & c + p_s s = y \quad b' = 0 \\
& [p_h - p_s]h' - m' q_m(b', h', m', z, BC) = \eta_{\mathcal{F}} \\
\text{where: } & \eta_{\mathcal{F}=0} = \underbrace{\min\{(1 - \delta)p_h h - m, \chi\}}_{\text{Exempt home equity}} \quad \text{and} \quad \eta_{\mathcal{F}=1} = 0
\end{aligned}$$

where now the household consumes only out of the period's endowment, can't save or borrow in bonds and keeps the same amount of exempt home equity. V^{BC} is the value function of a household that starts the period with a bad credit history and is given by:

$$\begin{aligned}
V^{BC}(b, h, m, \delta, y, z) &= \max_{\mathcal{F} \in \{0,1\}} \mathbb{E}_{\psi} \left\{ \max_{c, s, h', m', b' \geq 0} U(c, s) + \beta \mathbb{E}_{(\delta', y', z')|z} \left[\begin{array}{l} \alpha V^G(X') + \\ (1 - \alpha) V^{BC}(X') \end{array} \right] \right\} \\
\text{subj. to } & \lambda(c + p_s s) + [p_h - p_s]h' - q_m m' + q_b b' \leq a_{\mathcal{F}} \\
\text{where: } & a_{\mathcal{F}=0} = (1 - \delta)p_h h - m + b + y \quad \text{and} \quad a_{\mathcal{F}=1} = b_F + y
\end{aligned}$$

Notice that the timing is such that the housing services generated by the house h' can be traded in the same period as the purchase, which is why the effective per unit cost of buying a house is $p_h - p_s$. If households are indifferent between either going bankrupt or not, it is assumed they do not go bankrupt. If households are indifferent between foreclosing or not foreclosing it is assumed they foreclose if they have negative equity and do not foreclose if they have positive equity.¹¹

The solutions to these four coupled Bellman equations imply binary decision rules for foreclosure and bankruptcy, $f^*(X', \mathcal{H})$ and $B_{\mathcal{J}}^*(X')$, respectively, (where a value of

¹¹Note that the value functions for households with bad credit histories V^{BC} or that chose not to go bankrupt V^{NB} , may not be well defined as written. Since cash at hand can be negative, it is possible that there are no feasible choices (b', h', m') that result in non-negative consumption (c, s) . In that case, households declare bankruptcy and receive no consumption for the period.

1 implies default) where recall \mathcal{J} is an indicator representing whether the household received a deficiency judgment. In addition, the solutions also imply policy rules for housing, mortgage and bond choice.

1.2.4 Real Estate Construction Sector

The real estate sector is populated by a continuum of competitive firms who possess a linear, reversible technology to produce houses, $H = C_h$, where H is the output of houses and C_h is the input of consumption good (which could be negative if there is disinvestment in housing). The representative firm solves the following maximization problem:

$$\begin{aligned} \max_{H, C_h} \quad & p_h H - C_h \\ \text{subj. to} \quad & H = C_h \end{aligned}$$

Therefore, the equilibrium house price is given by $p_h = 1$. In effect, the model has an exogenous house price, but an endogenous rental price p_s (which clears the market for housing services) and thus endogenous house-price to rent ratios.

1.2.5 Financial Intermediaries

Banks can borrow at the risk-free interest rate, denoted r_b , which they take as given. Issuing debt, both secured and unsecured, is costly because of administrative and screening costs. To capture these costs, I impose a proportional real resource cost r_a for issuing each unit of a mortgage or negative face value bond. Thus, the effective cost of financing one unit of debt is $r_b + r_a$. It is assumed that agents simultaneously apply for mortgages and unsecured loans and that banks can observe the portfolio choices b', h', m' , persistent state z and the credit history. The banking sector is competitive, and banks are assumed to make zero expected profit loan-by-loan (as in

Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007) for unsecured debt and Jeske, Krueger, and Mitman (2011) for mortgages). The zero-profit assumption allows me to analyze the mortgage and bond problems separately.

Mortgage Problem

The price for a mortgage depends on the foreclosure and bankruptcy decision rules of the household. Banks have access to foreclosure and deficiency judgment technologies as described in Section 2.3.1. The price of a mortgage of size m' to purchase a house of size h' will reflect all of the expected possible outcomes. If the household forecloses on a mortgage with face value m' used to purchase a house of size h' , the bank recovers the depreciated value of the house processed through the foreclosure technology,¹² $\gamma h'(1 - \delta')$. In addition, with probability ψ the bank wins a deficiency judgment, $m' - \gamma h'$, but only recovers that value if the household does not file for bankruptcy. If a household goes bankrupt, the bank can recover any bonds held by the household.¹³ Therefore, in general, the price of a mortgage will depend on all the observable characteristics of the household and the bond position b' in addition to m' and h' . The typical bank will only issue mortgage contracts with a non-positive expected net-return:

$$q_m(b', h', m', z, G)m' \geq \frac{1}{1 + r_b + r_a} \times \mathbb{E}_{y', \delta', z' | z} \left\{ (1 - f^*(X')m' + f^*(X') \times \right. \quad (1.2)$$

$$\left. \left[\psi((1 - B_1^*(X'))m' + B_1^*(X')(\gamma(1 - \delta')h') + \max\{b', 0\}) + (1 - \psi)(\gamma(1 - \delta')h') \right] \right\}$$

where $B_1^*(X')$ is the bankruptcy decision of a household after receiving a deficiency judgment. A household with a bad credit history cannot declare bankruptcy, and thus the mortgage price is characterized as above, but with $B^*(\cdot) = 0$. For a household

¹²Since $p_h = 1$, I omit it from the remainder of the analysis.

¹³The seizure of bonds is assumed to be efficient to represent the fact that secured debt is treated as senior debt in bankruptcy, and thus is paid before fees and administrative costs.

with a bad credit history, the price also takes into account that the foreclosure decision is made after the realization of whether the household will enter the subsequent period with a good credit history, so there is an additional expectation. The conditions for the typical bank to issue a mortgage for those two cases can be found in the Appendix.

Unsecured Credit Problem

When households are saving in bonds, $b' \geq 0$, q_b represents the price of buying a bond that pays b' units of consumption good tomorrow. There is no default risk on savings and thus:

$$q_b(b', g', m', z) \leq \frac{1}{1 + r_b} \quad (1.3)$$

which from the zero profit condition immediately implies that the price only depends on the risk-free rate, $q_b = \frac{1}{1+r_b}$ when $b' \geq 0$.

The price of a bond with negative face value b' depends on the household's default probability and its non-exempt assets. If a household declares bankruptcy and has home equity in excess of the homestead exemption χ the bank can recover a fraction of it. Let ξ' denote the non-exempt portion of a household's home equity, namely $\xi' = \max\{h'(1 - \delta') - m' - \chi, 0\}$. Through the bankruptcy technology, the bank can recover $\max\{-b', \zeta\xi'\}$ from a household that declares bankruptcy, where $\zeta \leq 1$ represents the bankruptcy recovery technology. The condition for the bank issuing unsecured debt of size b' to a household with characteristics X is therefore:

$$-b'q_b(b', h', m', z) \geq \frac{1}{1 + r_b + r_a} \times \left\{ \mathbb{E}_{\mathcal{J}, y', \delta', z' | z} [-b'(1 - B_{\mathcal{J}}^*(X')) + B_{\mathcal{J}}^*(X')\zeta\xi'] \right\} \quad (1.4)$$

1.2.6 Equilibrium Definition

The pair (ψ, χ) summarizes the legal environment for the state. Each state is treated as a small open economy for the purpose of the bond and mortgage market taking

the risk-free rate r_b as given. The housing market is closed, reflecting the fact that housing services must be consumed in the same geographic location as the housing good. Let μ denote the cross sectional distribution of households over the credit history, cash at hand, income and home equity. I focus on a stationary recursive equilibrium.

Definition Given (ψ, χ) and r_b , a Stationary Recursive Competitive Equilibrium comprises:

- Value functions for the households, $\{V : \mathcal{H} \times \mathbb{R}^3 \times [\underline{\delta}, 1] \times Y \times Z \rightarrow \mathbb{R}\}$,
 $\{W : \{B, NB, BC\} \times \{0, 1\} \times \mathbb{R} \times Y \times Z \rightarrow \mathbb{R}\}$
- Default decision rules and policy functions for the households:
 $\{f^* : \mathcal{H} \times \mathbb{R}^3 \times [\underline{\delta}, 1] \times Y \times Z \rightarrow \{0, 1\}\}$,
 $\{B^* : \mathbb{R}^3 \times [\underline{\delta}, 1] \times Y \times Z \times \{0, 1\} \rightarrow \{0, 1\}\}$
and $\{c, s, b', m', h' : \{B, NB, BC\} \times \mathbb{R} \times Y \times Z \rightarrow \mathbb{R}\}$
- Price p_s , pricing functions $\{q_m : \mathcal{H} \times \mathbb{R}^3 \times Z \rightarrow \mathbb{R}_+\}$ and $\{q_b : \mathbb{R}^3 \times Z \rightarrow \mathbb{R}_+\}$
- An invariant distribution: $\{\mu^* : \{B, NB, BC\} \times \mathbb{R} \times Y \times Z \rightarrow \mathbb{R}_+\}$

such that:

1. **Households Maximize:** Given prices and the pricing functions, the value functions solve (1.1), and c, s, b', h', m' are the associated policy functions, and B^*, f^* are the associated default rules.
2. **Zero Profit Mortgages:** Given f^*, B^*, q_m solves (1.2) with equality for any contract traded in equilibrium
3. **Zero Profit Unsecured Debt:** Given B^*, q_b solves (1.4) with equality for any contract traded in equilibrium
4. **Zero Profit Bonds:** $q_b = \frac{1}{1+r_b}$ when $b' \geq 0$.

5. **Rental Market Clearing:**
$$\sum_{\mathcal{I} \in \{B, NB, BC\}} \int h'_{\mathcal{I}} d\mu = \sum_{\mathcal{I} \in \{B, NB, BC\}} \int s_{\mathcal{I}} d\mu$$

6. **Invariant Distribution:** The distribution μ^* is invariant with respect to the Markov process induced by the exogenous Markov process z and the policy functions m', h', b', B^*, f^*

1.3 Theoretical Results

The purpose of this section is to provide theoretical results that characterize household default decisions and interest rates on debt that will guide the interpretation of the quantitative results. In addition, the theory will prove useful in the computation of equilibria. I characterize the bankruptcy and foreclosure decisions. Further, I analyze how housing, foreclosure, and the homestead exemption affect the household bankruptcy decision. I fully characterize mortgage interest rates for no-recourse states.

1.3.1 Existence and Characterization of the Household Problem

In order to prove the existence of a solution to the household problem, I need to make an assumption on preferences. I assume that utility is bounded above and that the utility of consuming zero is small enough that a household will always prefer to go bankrupt rather than having zero consumption in a given period.¹⁴ Under this assumption, which is formalized in the appendix, a solution to the household problem exists. Further, consistent with the penalties associated with bankruptcy, a household with a bad credit history *ceterus paribus* has lower lifetime utility than one with a good credit history.

Proposition 1. Existence of a Solution to the Household Problem

¹⁴In my quantitative analysis I will assume a constant relative risk aversion utility function with CRRA parameter greater than 1 which satisfies this condition.

(1) The household value functions V^H exist and are unique; (2) The value functions are bounded and increasing in a ; (3) A bad credit score reduces utility, i.e. $V^G \geq V^{BC}$

The proof of the existence of a solution to the household problem follows from standard contraction mapping arguments (boundedness from below comes from the option to default). The details of all proofs can be found in the appendix.

Now that I have shown a solution to the household problem exists, I proceed to characterize the bankruptcy decision. Since the bankruptcy decision is made after the foreclosure decision, similar to Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007), I can characterize the bankruptcy decision in terms of a *bankruptcy set* $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$, where b_F is unsecured credit after deficiency judgments, η is home equity, and ξ is non-exempt home equity. The bankruptcy set is the set of realizations of the endowment y for which the household finds it optimal to declare bankruptcy as opposed to repaying b_F . The bankruptcy set depends on those four variables alone because they capture the benefits of bankruptcy (the discharge of unsecured debt b_F and preservation of exempt equity $\eta - \xi$) as well as the costs (the loss of non-exempt equity ξ).

Proposition 2. Bankruptcy Characterization

- (a) For any values of unsecured debt b_F , home equity η , and non-exempt home equity ξ , the bankruptcy set is either a closed interval, i.e. $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z) = [\underline{y}^B, \bar{y}^B]$, or empty, i.e. $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z) = \emptyset$.
- (b) The bankruptcy set expands with indebtedness b_F , i.e. $\bar{\mathcal{B}}^*(\hat{b}_F, \eta, \xi, z) \subseteq \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ for $b_F < \hat{b}_F$.

The proposition is illustrated graphically in Figure 1.2(a). The intuition for this result is that households with very low endowment realizations prefer to take on debt to increase contemporaneous consumption above the period endowment (consumption

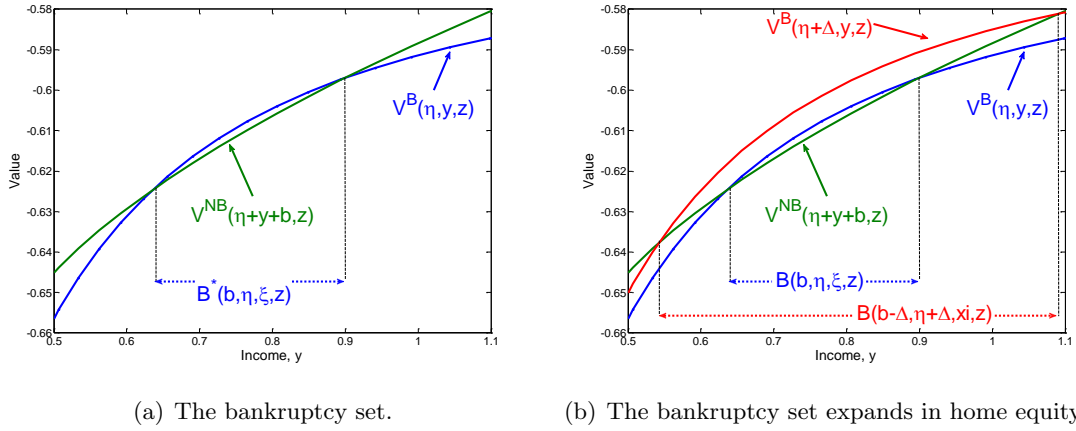


Figure 1.2: Graphical illustration of Propositions 2 and 3.

in bankruptcy). Whereas households with high endowments prefer to maintain access to credit, and thus repay, but may consume less than if they had declared bankruptcy.

Next, I characterize how the portfolio of the household affects the bankruptcy decision. Unlike Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007), the bankruptcy decision depends on more than the net asset position of the household. Households with more non-exempt home equity are less likely to go bankrupt. Intuitively, as the household holds more non-exempt home equity the cost of going bankrupt increases (more housing wealth would be lost), but the benefit of going bankrupt is constant. Thus, the set of endowment realizations for which the household goes bankrupt shrinks. Having a substantial amount of non-exempt home equity effectively increases the punishment of going bankrupt. This mechanism is important for understanding the equilibrium price effects generated in the quantitative analysis. Further, for a given net asset position a greater share in home equity increases the chance of bankruptcy. This result is illustrated graphically in Figure 1.2(b). Keeping the net asset position fixed but changing its composition does not affect the value of repaying,¹⁵ but more home equity increases the value of going bankrupt. Therefore, the set of endowment values for which the household goes bankrupt expands. These

¹⁵Since after repayment the relevant state variable for the household is the consolidated asset position.

results are formalized in Proposition 3:

Proposition 3. Home Equity, Exemptions and Bankruptcy

- (a) *The bankruptcy set contracts in non-exempt home equity ξ , i.e. $\bar{\mathcal{B}}^*(b_F, \eta, \xi_1, z) \subseteq \bar{\mathcal{B}}^*(b_F, \eta, \xi_2, z)$, for $\xi_2 < \xi_1$.*
- (b) *Holding net assets constant (i.e. fixing $\eta + b_F$) the bankruptcy set is expanding in home equity, i.e. $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z) \subseteq \bar{\mathcal{B}}^*(b_F - x, \eta + x, \xi, z)$ for $x > 0$. Or equivalently, the bankruptcy set is increasing in the difference of home equity and debt $\eta - b_F$.*
- (c) *When home equity exceeds the homestead exemption, the bankruptcy set is decreasing in home equity, i.e. $\bar{\mathcal{B}}^*(b_F, \eta + x, \xi + x, z) \subseteq \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ for $x > 0$.*
- (d) *When there is no homestead exemption, i.e. $\chi = 0$, the bankruptcy set only depends on the net asset position $\eta + b_F$ and the persistent income state z .*
- (e) *The bankruptcy set is empty if net assets exceed the homestead exemption, i.e. if $\eta + b_F > \chi$, then $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z) = \emptyset$.*

Having characterized the bankruptcy decision, working backwards I now analyze the foreclosure decision. How foreclosure is related to bankruptcy depends crucially on the probability of a deficiency judgment, ψ . In order to understand how ψ controls the complementarity between foreclosure and bankruptcy, I first characterize when households repay their mortgages for sure. Since the housing market is frictionless, if the foreclosure technology is inefficient ($\gamma < 1$), households will always repay their mortgages if the depreciated value of the house is greater than the face value of the mortgage.

Proposition 4. *If the foreclosure technology is inefficient, $\gamma < 1$, $f^*(X, \mathcal{H}) = 0$ for all b, z , and y when $h(1 - \delta) \geq m$.*

For two special cases the foreclosure decision follows a cutoff rule in the depreciation shock δ' . If banks cannot obtain deficiency judgments (i.e., no-recourse, $\psi = 0$), households will choose to foreclose on their mortgages whenever they have negative home equity. Since households face no additional cost of foreclosure, it is always optimal to “walk away.” Thus, under no-recourse Proposition 4 becomes an if-and-only-if statement - households only repay their mortgage when the value of the house exceeds the value of the mortgage (formalized in Proposition 5). In no-recourse states, therefore, the foreclosure decision is independent of the bond position or income of the household.

Proposition 5. *If there is no recourse, $\psi = 0$, the foreclosure decision follows a cutoff rule in δ , i.e. there exists $\delta^*(h, m)$ such that $f^*(X, \mathcal{H}) = 1$ for all $\delta \geq \delta^*(h, m)$ and 0 otherwise for all b, y, z . Further, the cutoff depends only on the leverage $\kappa = \frac{m}{h}$, and $\delta^*(\kappa) = 1 - \kappa$.*

Consider now the other extreme in which deficiency judgments always occur, $\psi = 1$. If the foreclosure technology is inefficient, a household will either repay, or both foreclose and go bankrupt:

Proposition 6. *If deficiency judgments always occur, $\psi = 1$, the foreclosure decision follows a cutoff rule in δ , which in general will depend on b, h, m, y, z . Further, any household with a good credit history that chooses foreclosure will subsequently go bankrupt. Households in bankruptcy or with bad credit history will optimally choose b', h', m' such that foreclosure is never optimal.*

If foreclosure is inefficient, the household can repay by paying $m - (1 - \delta)h$ or choose foreclosure and have additional unsecured debt $m - \gamma(1 - \delta)h$. If the household does not subsequently go bankrupt, it will always prefer to repay, since it yields a higher net asset position. Therefore, a foreclosed household will subsequently go bankrupt to erase the deficiency.

Propositions 5 & 6 show that in the limiting cases of ψ the foreclosure decision follows a cutoff rule. In addition, these limiting cases suggest that ψ partially controls the complementarity between foreclosure and bankruptcy.¹⁶ In my quantitative analysis I find that higher values of ψ lead to a higher probability of declaring bankruptcy conditional on choosing foreclosure.

1.3.2 Mortgage and Unsecured Interest Rates

Characterizing the intermediary pricing of mortgages and unsecured debt is limited by the partial characterization of the household foreclosure decision. However, when there is no recourse the sharp characterization of the foreclosure decision (Proposition 5), allows a full characterization of mortgage prices and a partial characterization of unsecured debt prices.

Proposition 7. *If there is no recourse, mortgages are priced exclusively based on leverage:*

$$\begin{aligned} q_m(h', m', b', z, \mathcal{H}; \psi = 0) &= \frac{1}{1 + r_b + r_a} \left\{ F(\delta^*(\kappa')) + \frac{\gamma}{\kappa'} \int_{\delta^*(\kappa')}^1 (1 - \delta') dF(\delta') \right\} \\ &= q_m(\kappa'; \psi = 0) \end{aligned}$$

where κ' and $\delta^*(\kappa')$ are defined as in Proposition 5. This result is the same as that obtained in Jeske, Krueger, and Mitman (2011). Note that $q_m(\kappa')$ is strictly decreasing in κ' , thus mortgage interest rates are increasing in leverage κ' . The interest rates are increasing to reflect the increasing risk of foreclosure.¹⁷

Proposition 8. *If there is no recourse:*

$$1. \ b' \leq \hat{b}' \text{ implies } q_b(b', h', m', z) \leq q_b(\hat{b}', h', m', z).$$

¹⁶When $\psi = 0$ the foreclosure decision is independent of the subsequent bankruptcy decision, but when $\psi = 1$ foreclosure always results in bankruptcy.

¹⁷In no-recourse states the mortgage interest rates are independent of the credit history of households, since the bankruptcy decision has no effect on the ability of the bank to recover the housing collateral in the case of foreclosure.

2. If in addition the homestead exemption is zero, $\chi = 0$:

$$(a) \ h' \leq \hat{h}' \text{ implies } q_b(b', h, m', z) \leq q_b(b', \hat{h}', m', z)$$

$$(b) \ m' \geq \hat{m}' \text{ implies } q_b(b', h', m, z) \leq q_b(b', h', \hat{m}', z)$$

From Proposition 2, since the bankruptcy set is expanding in indebtedness, the price of unsecured debt will be decreasing in indebtedness. Further, from Proposition 3, if there is no homestead exemption, the bankruptcy set depends only on the net asset position. Since the net asset position is increasing in the size of the house and decreasing in the size of the mortgage, unsecured debt prices will increase in house size and decrease in mortgage size. Recall that because of the timing convention, decreasing prices q_b are equivalent to increasing implied interest rates.

1.4 Calibration and Model Fit

The goal of the calibration is to assure that the model can account for aggregate facts related to both secured and unsecured borrowing, foreclosure, and bankruptcy. In order to capture the heterogeneity in state law but still match national level data I treat each state as a small open economy and then aggregate state-level moments. I allow states to vary only in the homestead exemption χ , whether there is recourse ($\psi > 0$), and the level of median income,¹⁸ keeping technology and preference parameters constant across states. The model needs to be solved for every combination of homestead exemption and recourse, χ and ψ .

To balance richness in variation with computational feasibility, I restrict the current calibration to consider seven configurations of the homestead exemption and recourse law. I allocate each state in the US to one of the seven bins - three homestead exemption bins for no-recourse states and four homestead exemption bins for recourse states. For each bin I calculate the average homestead exemption and median

¹⁸The income process is the same across states modulo its median level.

income, weighting by state populations. The relative weight of the seven economies in calculating aggregate statistics is determined by the relative proportion of households from those states. For ease of exposition, I refer to the seven binned economies by the name of a representative state from the bin: Washington, California, Minnesota, Maryland, Michigan, Massachusetts and Florida.¹⁹

The values for the homestead exemption χ are constructed from state laws and state-level median household income estimates from the Current Population Survey published by the U.S. Census Bureau. The values used for the homestead exemption and income are taken from the year 2000 (see appendix for details). For each state, median income is normalized to 1, so χ is in units of state median income. For example, median household income in Pennsylvania was \$40,106, with an exemption of \$30,000 for couples, yielding a $\chi^{PA} \approx 0.75$.

Good data on deficiency judgments do not exist, so I take the value of ψ as a parameter to calibrate. Li and White (2009) analyze a sample of prime and sub-prime mortgages and find that roughly 28% of households who have foreclosure proceedings initiated against them also file for bankruptcy. I take this value as my target for calibrating ψ .²⁰

In addition to state-specific laws regarding bankruptcy, the legal environment is described by α and λ , the parameters governing how long a household has a bad credit record and the consumption penalty, respectively. By law, households cannot file for Chapter 7 bankruptcy twice in any six year period. The Fair Credit Reporting Act stipulates that bankruptcy filings cannot remain on a household's record for more than 10 years. Since the model period is one year, the logical bounds for α are between $[1/10, 1/6]$. I set $\alpha = 1/6$ to match the legal exclusion from being able to declare bankruptcy since there is evidence Han and Li (2011) households regain

¹⁹The state policy parameters are summarized in Table A.1 in the appendix.

²⁰Note that the discussion relating parameters to data targets is heuristic in the sense that all parameters determine all endogenous variables jointly in the model. In the discussion I relate parameters with the moments that they affect the most quantitatively.

Table 1.1: Externally Calibrated Parameters

| Parameter | Value | Target |
|--|--------|---|
| <i>Income Process</i> | | |
| Persistence, ρ | 0.98 | |
| Std. of persistent shocks, σ_ν | 0.3 | Income process (Storesletten et al, 2004) |
| Std. of transitory shocks σ_ε | 0.245 | |
| <i>Legal Technology</i> | | |
| Foreclosure technology, γ | 0.78 | Foreclosure Sale Loss |
| Bankruptcy technology, ζ | 0.52 | Distributions to Creditors |
| Clean credit history, α | 0.167 | File for Chapter 7 every 6 years |
| <i>Interest Rates</i> | | |
| Risk-free rate, r_b | 0.01 | Risk-free rate |
| Cost of issuing debt, r_a | 11 BP | Bank administration cost |
| <i>Preferences</i> | | |
| Cobb-Douglas parameter, θ | 0.8590 | Housing share of consumption 14.1% |

access to credit while the bankruptcy notation still appears on their credit report. The parameter λ is then determined jointly to match the unsecured share of household debt. Data from the Flow of Funds Accounts of the U.S. published by the Federal Reserve (Table Z.1 D.3) indicate that consumer credit accounted for roughly 24% of household debt outstanding from 1983 to 2004. Over that same period, approximately 37% of consumer credit consisted of revolving credit, which is the closest analogue to unsecured debt in the model (non-revolving credit includes secured auto loans, student loans, etc). I target an aggregate share of unsecured credit of $0.24 \times 0.37 = 0.089$.²¹ I aggregate unsecured debt and total debt across the seven economies (weighted by households and income) and compute the unsecured share.

1.4.1 Preferences and Technology

Preferences: For the utility function I choose Cobb-Douglas preferences over consumption and housing services nested in a constant relative risk aversion (CRRA) function:

$$U(c, h) = \frac{(c^\theta h^{1-\theta})^{(1-\sigma)} - 1}{1 - \sigma}$$

Notice that this implies the solution to the intra-temporal consumption optimization problem is $p_s h = \frac{1-\theta}{\theta} c$, which allows me to independently calibrate θ to match the share of housing in total consumption. According to NIPA data, the housing share of total consumption has been relatively stable at 14.1% over the last forty years, thus I set $\theta = 0.8590$.

The CRRA parameter σ is calibrated jointly to match median net worth observed in the data. I use the 2004 Survey of Consumer Finances to compute the median net-worth of prime age households (head age ≤ 50). Median net-worth divided by median income is found to be 1.19. I restrict the analysis to households under age 50 because of strong life-cycle effects in housing and mortgage choice.²²

I calibrate the time discount factor β to match the aggregate bankruptcy rate from 1995-2004. The American Bankruptcy Institute publish aggregate annual bankruptcy filings, and I construct rates using data on the number of households from the Census. Chakravarty and Rhee (1999) report that 16.4% of respondents in the Panel Survey of Income Dynamics who filed for bankruptcy listed excessive health-care bills as the cause. Since I abstract from such expenditure shocks in the model, I target $100\% - 16.4\% = 83.6\%$ of the observed bankruptcy rate in the data.²³ Tables 1.1 and

²¹This number is nearly identical to the ratio of unsecured credit to unsecured credit plus mortgage debt measured in the 2004 Survey of Consumer Finances for prime age households.

²²Households in an infinite horizon model more closely correspond to prime age households in the data.

²³Himmelstein et al. 2009 attribute a much higher fraction of bankruptcies to health shocks because they include health related job loss and income changes. Since those shocks are captured in the calibration of the income process, I use the lower value.

1.2 summarize the model parameterization.

Endowment Process: Following Storesletten et al. 2004, I set persistence of the shock z , $\rho = 0.98$ and the variance to the innovations to $\sigma_\eta^2 = 0.09$. Estimates for the variance of log annual income range from 0.04 to 0.16 . I thus set $\sigma_\varepsilon^2 = 0.06$, generating a variance of log annual income of 0.15. Using the method of Tauchen and Hussey (1991), I approximate the persistent component with a two state Markov chain.

Foreclosure Technology: The foreclosure loss parameter, γ , is set to match the additional depreciation incurred in a foreclosure (e.g., it captures effects such as decreased maintenance by the occupants). The average loss was estimated by Pennington-Cross 2006 to be 22%. He estimates the loss by comparing revenue from foreclosed home sales to a market price constructed via the Office of Federal Housing Enterprise Oversight (OFHEO) repeat sales index. I therefore set $\gamma = 0.78$ for all states in the model.

Bankruptcy Technology: In order to map the bankruptcy recovery rate from the U.S. to the model, I must determine if 1) there is any loss in the forced sale of the home in bankruptcy; and 2) what fraction of assets recovered are actually distributed to creditors. First, note that if the house has been foreclosed the secured creditors seize it and there is nothing for unsecured creditors to collect (see Proposition 4). Campbell et al. 2011 estimate the discount due to bankruptcy in Massachusetts, and find it to be less than 5 percent. Thus, if a homeowner has positive equity in the home and declares bankruptcy, I assume that there is no loss in the sale of the house. The proceeds of the sale are first used to repay secured creditors. Next, the costs of administering the bankruptcy (including court costs, fees and administrative expenses) are paid. Finally, unsecured creditors are repaid from anything that re-

mains. The U.S. Department of Justice²⁴ reports of roughly \$10.5 billion collected in asset cases from 1994-2000, only 52 percent was dispersed creditors. Thus, I set the recovery parameter $\zeta = 0.52$. The remaining 48 percent is assumed to cover the unmodeled costs of administering bankruptcy.

The Depreciation Process: I calibrate the depreciation process to simultaneously match foreclosure rates and house depreciation moments from the data. Consistent with data from the Mortgage Banker’s Association on foreclosure rates from 1990-2003, I target an aggregate foreclosure rate of 0.55 percent. I also target the mean house depreciation, calculated at 1.48 percent annually, based on mean depreciation of residential housing reported by the Bureau of Economic Analysis. Using data on repeat home sales, the OFHEO estimates both aggregate and purely idiosyncratic components of house price risk.²⁵ Since there is only idiosyncratic risk in the model, I target the annual idiosyncratic house price volatility reported by the OFHEO of 10 percent.

I find that I need a fat tailed distribution to simultaneously match the price volatility and foreclosure rates. I assume that the depreciation shock follows a generalized Pareto distribution. The generalized Pareto distribution has three parameters, a shape parameter, k , a scale parameter, σ_δ , and a cutoff parameter $\underline{\delta}$. The upper bound for the support is set to 1, so that complete depreciation is possible. The cumulative distribution function is: $F(\delta) = 1 - \left(1 + \frac{k(\delta - \underline{\delta})}{\sigma_\delta}\right)^{\left(-\frac{1}{k} - 1\right)}$.

1.4.2 Model Fit

Aggregated statistics across the seven computed economies are listed in Table 1.3. The model performs well accounting for non-targeted moments in the data. The model slightly over-predicts average holdings of housing wealth. This result is not

²⁴“Preliminary Report on Chapter 7 Asset Cases 1994 to 2000.”

²⁵It models log house prices as a diffusion process consisting of a market price index and a house specific random walk. The technical details can be found in Calhoun (1996).

Table 1.2: Internally Calibrated Parameters

| Parameter | Value | Target | Data | Model |
|--|-----------------------|--|-------|-------|
| <i>Preferences</i> | | | | |
| Risk aversion, σ | 2.751 | Bankruptcy rate | 1.06% | 1.06% |
| Discount factor, β | 0.943 | Median net worth/income: | 1.19 | 1.19 |
| <i>Depreciation Process</i> | | | | |
| Shape parameter, k | 0.688 | Foreclosure rate | 0.55% | 0.55% |
| Scale parameter, σ_δ | 6.77×10^{-3} | Average depreciation | 1.48% | 1.48% |
| Cutoff parameter, $\underline{\delta}$ | 1.49×10^{-3} | House price variance | 0.01 | 0.01 |
| <i>Legal Technology</i> | | | | |
| Probability of deficiency judgment, ψ | 0.184 | Probability of bankruptcy conditional on foreclosure | 0.28 | 0.28 |
| Consumption penalty, λ | 5.68×10^{-3} | Revolving share of debt | 8.9% | 8.9% |

surprising since median net worth is targeted in the calibration, but housing and bonds are the only assets that households can hold in the model.²⁶ The model does successfully account for the fact that prime age households primarily allocate their wealth in risky assets, as indicated by the low levels of bond holdings. The high level of housing leads to an over-prediction of mortgage holdings and of unsecured debt holding (by construction since the ratio is targeted). The model does well in matching the fraction of households with zero or negative net-worth, the fraction of households who have unsecured debt, and the fraction of bankrupt households with positive home equity.

The presence of the housing asset allows the model to generate realistic interest rates. The mean interest rate paid on unsecured debt in the model is 11.2%, very close to the 12.3% reported in the SCF. The model is also able to successfully replicate the default premium on mortgages. The mean mortgage interest rate in the model is 1.24%, corresponding to a default premium of 24%. By comparison, the implied default premium for a 1-year-adjustable rate mortgage (MORTGAGE1US from St.

²⁶In the data, the median households have mainly housing wealth and not too much financial wealth (which is highly concentrated among the rich).

Table 1.3: Aggregate Results

| | Model | Data | Source |
|--|-------|-------|--------------------------------|
| Housing, H | 5.25 | 4.10 | Residential Property, SCF 2004 |
| Debt | -3.88 | -2.36 | SCF 2004 |
| Bonds, B_+ | 0.16 | 0.18 | Savings/Bonds, SCF 2004 |
| Unsecured debt, B_- | -0.34 | -0.21 | Unsecured Debt, SCF 2004 |
| Mortgages M | 3.54 | 1.93 | Mortgage Debt, SCF 2004 |
| Fraction of households with net worth ≤ 0 | 5.3% | 6.7% | SCF 2004 |
| Fraction of households with Unsecured Debt | 38% | 33% | SCF 2004 |
| Fraction of bankrupt households with positive home equity | 25% | 33% | SCF 2004 |
| Mean Interest Rate Paid on Unsecured Debt | 11.2% | 12.3% | SCF 2004 |
| Mortgage Default Premium | 24% | 22% | MORTGAGE1US, GS1 from FRED |

Louis FRED) over the 1-year Treasury constant maturity rate (GS1) during the inter-recession period March 1991-2001 was 22%.

1.5 Results

1.5.1 Accounting for State Differences in Bankruptcy Rates

By calibrating the model to aggregate bankruptcy and foreclosure rates, I do not directly target the effects that the homestead exemption and recourse laws have on default rates. Thus, I can evaluate to what extent the cross-state variation in bankruptcy rates in the data is predicted by the model. Further, the exercise provides an important source of model validation before proceeding to the policy analysis. It is important to note that, in the model, the variation in policies is given exogenously. Hynes, Malani, and Posner (2004) provide a detailed historical account of the origins of property exemptions in bankruptcy. They find that historical exemption levels have more predictive power in explaining current exemption levels than contemporaneous economic and political factors, and that historical exemptions were

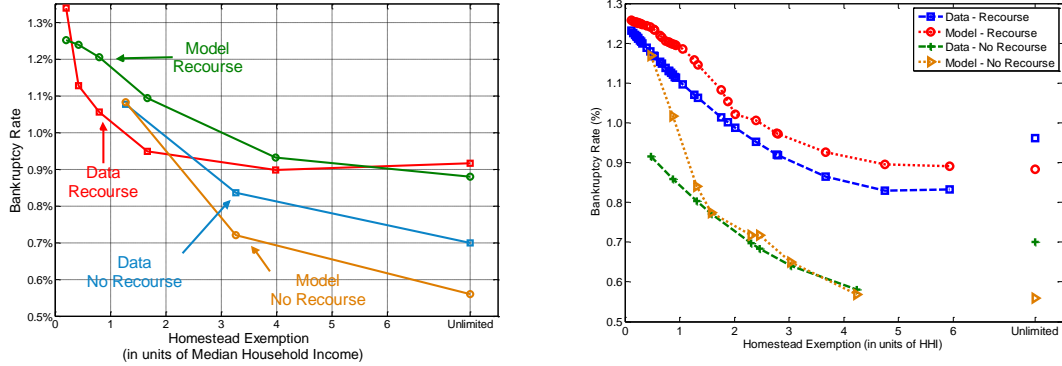
Table 1.4: Decomposing Bankruptcy Rates
$$bankrate_i = \beta_0 + \beta_L x_{L,i} + \beta_D x_{D,i} + \epsilon_i$$

| Variable | Coefficient | (Std. Err.) |
|---|-------------|-------------|
| <i>Demographic</i> | | |
| log(Median household income) | -0.0047 | (0.0027) |
| Average household size | 0.0099* | (0.0028) |
| Weak garnishment law | -0.0033* | (0.0008) |
| Judicial Foreclosure | -0.0018* | (0.0008) |
| <i>Bankruptcy & Foreclosure Law</i> | | |
| Recourse | 0.0029* | (0.0010) |
| Homestead Exemption | -0.0019* | (0.0009) |
| Square of Homestead Exemption | 0.0002 | (0.0002) |
| Unlimited Exemption | -0.0028* | (0.0014) |
| Constant | 0.0316 | (0.0271) |
| R ² | 0.58 | |
| * indicates significance at 5% level | | |

mainly driven by economic forces of the 19th and early 20th century. Thus, to the extent that current economic conditions are independent of the economy a century ago, I view treating state exemption levels as exogenous as defensible.

States vary in demographic and legal characteristics that are abstracted from in the model, but which may be relevant to state default rates. In order to partially control for that additional variation, in Figure 1.3(a), I plot mean model and data bankruptcy rates for states binned by exemption level and recourse policy. The model is able to capture the negative relationship between the homestead exemption and bankruptcy rates and the positive relationship between recourse laws and bankruptcy rates.

Figure 1.3(a) only presents conditional means. For a more careful accounting I control for additional observables and compute what fraction of the residual variation the model explains. First, I regress the state level bankruptcy rate on log median household income, the average household size, a dummy indicating lenient garnish-



(a) Bankruptcy rates in the data and model.

(b) Fitted data versus model generated data.

Figure 1.3: Accounting for the cross-state variation in bankruptcy rates.

ment law, a dummy for judicial foreclose, a dummy for recourse, the homestead exemption, the homestead exemption squared, a dummy for unlimited exemption, and a constant. The coefficients on the legal variables are significant and indicate that recourse increases bankruptcy rates and that more generous homestead exemptions lower bankruptcy rates. The full coefficients are in Table 1.4. To compare my model to the predictions from the regression, I compute the R^2 between the fitted bankruptcy rate using only the legal variables $x_{L,i}\hat{\beta}_L$ and the model predictions m_i . I find that an R^2 of 0.82, indicating that the model can explain more than 80 percent of the variation attributable to variations in homestead exemptions and recourse law. The predicted bankruptcy rates from the regression and from the model are plotted in Figure 1.3(b). The model quantitatively matches the cross-state correlation between policies and default rates. I find that the model can explain roughly 20 percent of the overall variation in bankruptcy rates (without controlling for state level characteristics).

To illustrate the importance of studying foreclosure and bankruptcy together in order to capture the cross-state variation in bankruptcy rate, I conduct the following thought experiment: would a modified model without mortgages and foreclosure capture the cross-state variation? To answer this question, I re-calibrate the model

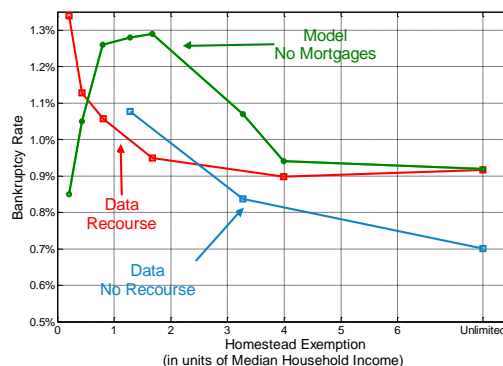


Figure 1.4: Data vs counterfactual model without mortgages and foreclosure.

without mortgages, dropping the targets related to mortgages and foreclosure. I plot the conditional means in Figure ???. This version of the model does not reproduce the observed negative relationship between bankruptcy rates and the homestead exemption. This counterfactual analysis highlights the importance of modeling secured and unsecured credit together.

1.5.2 The Household Default Decision

In order to understand how default policies lead to differences in default rates it is important to understand when households choose to default. In Figure 1.5 I consider a household in the Virginia economy (a recourse state with a \$10,000 homestead exemption), who had purchased a \$200,000 house, had an 80% leverage mortgage and took on \$12,500 of unsecured debt. I plot the bankruptcy and foreclosure decisions as a function of the realized home equity (after the price shock) and income realization. The graph illustrates the complementarity and substitutability of the two types of default. In the upper right quadrant, the household has positive home equity and high income, so it repays its debt. However, if its income is lower and has only non-exempt home equity it chooses to go bankrupt to discharge its unsecured debt, while preserving its home equity. Households with low income and negative home equity default on both their mortgages and unsecured debt. Whereas high income house-

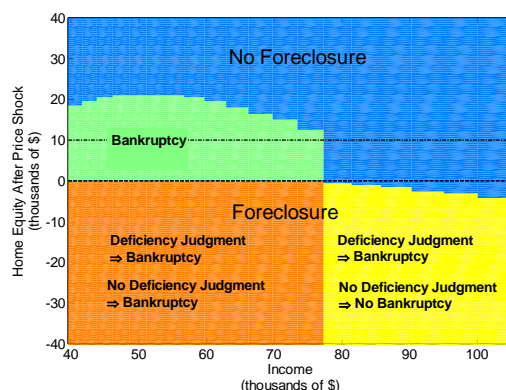


Figure 1.5: Household discrete choices with a house size equal to five times the median income and an 80% leveraged mortgage.

holds with negative home equity only file for bankruptcy if they receive a deficiency judgment.

Examining the household default problem alone cannot explain why bankruptcy rates are lower when homestead exemptions are higher, since, from the household perspective, more generous exemptions should lead to larger sets of income realizations for which the household will go bankrupt. Therefore the key mechanism must be coming through an interest rate effect, which causes households to select into different debt portfolios across the different states.

1.5.3 Effects of the Homestead Exemption

In this section I explore the general-equilibrium interest rate effects that arise from different homestead exemptions. In the theoretical results, I proved that households with less non-exempt home equity are more likely to go bankrupt. Since the prices of unsecured credit reflect the implied default probabilities, a household with less non-exempt home equity should face a higher cost of borrowing in unsecured credit than one with more non-exempt home equity.

To illustrate this effect, I choose two households, one in Virginia and one in Michigan (both recourse states) that have roughly median net worth and the high persistent

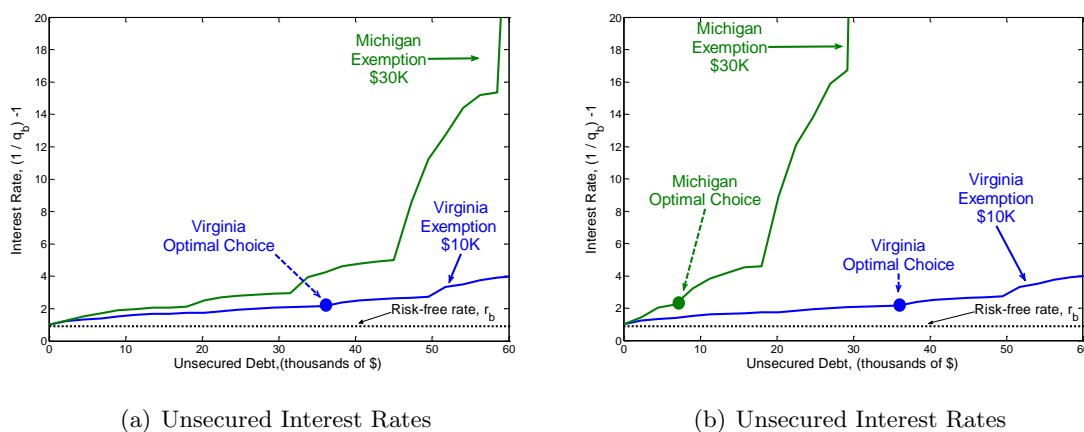


Figure 1.6: Interest rates on unsecured debt for households of identical net worth in Virginia and Michigan. The dots in both figures represent the optimal policy choices.

Notes: The household in Virginia optimally chooses a \$265K house, \$180K mortgage and \$36K of unsecured debt. The Michigan line in (a) represents the price schedule that the household would face if it chose the same size house and mortgage as the Virginia household. The Michigan line in (b) represents the price schedule given its optimal choice of housing and mortgage: \$210K house, \$155K mortgage and \$6K of unsecured debt.

income realization. Virginia has a \$10K homestead exemption as compared to Michigan's \$30K. The household in Virginia optimally chooses a portfolio consisting of a \$265K house, a \$180K mortgage and \$36K in unsecured credit. In Figure 1.6(a), I plot the unsecured interest rate for other hypothetical amounts of unsecured borrowing for the Virginia household. In addition, I plot the unsecured interest rate as a function of unsecured debt for the household in Michigan, assuming the same choice of housing and mortgage (note that the risk-free interest rate is the same in both states). Notice that the interest rate in Michigan is significantly higher at the Virginia optimal choice of \$36K. This is due to the fact that in Michigan the household has more exempt home equity and less non-exempt home equity. Both households would have \$85K in home equity. However, in Michigan \$30K of that equity is exempt as compared to \$10K in Virginia. Imagine that the value of the home fell by 15%. Both households would be left with slightly more than \$45K in equity. If the household in Virginia went bankrupt, it would have \$36K in unsecured debt discharged, but would lose \$35K in non-exempt equity - for a financial benefit of \$1K. The Michigan household,

however, would get the same discharge, but only forfeit \$15K, meaning a financial benefit of bankruptcy of \$21K. Thus, because of the difference in exemptions, the Michigan household is more likely to go bankrupt and would have to pay a higher interest rate on its unsecured debt.

At that interest rate, however, the Michigan household does not find it optimal to take on \$36K in debt. Since unsecured credit is more expensive, the overall cost of borrowing is higher for the Michigan household. As a result, it optimally takes on a lower level of debt. Since the household is borrowing less, it also optimally chooses a smaller sized house and mortgage. The Michigan household chooses a \$210K house and \$155K mortgage. In Figure 1.6(b), I plot the unsecured interest rates facing the Michigan household under the optimal housing and mortgage choice.²⁷ Since the household has only \$25K of non-exempt home equity, the interest rate rises rapidly as unsecured debt approaches that level. The household optimally chooses a much lower level of unsecured debt, about \$6K, but at a comparable interest rate to the Virginia household. Notice that in addition to the Michigan household taking on less overall debt (\$161K vs \$180K) the composition of the debt is also different. The Michigan household borrows almost exclusively in mortgage debt by taking on a more highly leveraged mortgage (74% vs 68%). By buying a smaller house, the Michigan household has less home equity, which further compounds the price effect of the higher homestead exemption. Thus, the household finds it optimal to increase its leverage, which only results in a small increase in the interest rate paid on the mortgage.²⁸

The above discussion sheds light on why household portfolios are different across states with different homestead exemptions, but does not directly answer why these differences lead to different default rates. In all states, there are very low net worth households that only borrow in unsecured credit, and have no housing or mortgage

²⁷It should be understood that the household is making its choice of housing, mortgage and unsecured credit simultaneously. The discussion of the choices as separate or sequential is merely to help illustrate the intuition for the mechanism at hand.

²⁸See Figure A.1 in the appendix for the mortgage interest rate schedule faced by the Michigan household conditional on its housing and unsecured debt choice

debt. The debt portfolios and default rates of these households are, to first order, unaffected by the exemption, since they hold no housing. The equilibrium price effects of the homestead exemption do, however, affect the fraction of households with housing that choose to take on unsecured debt. Households with non-exempt home equity are the ones that take advantage of cheap unsecured borrowing. As the homestead exemption rises, the fraction of households that have non-exempt home equity falls. As a result, some households stop borrowing unsecured and only take on mortgage debt. Thus, the fraction of households who borrow unsecured, and therefore *are at risk of going bankrupt* is smaller in high exemption states. This leads to lower bankruptcy rates.²⁹ The extensive margin choice of whether to take on unsecured debt drives the majority of the variation in bankruptcy rates. Further, differences in the extensive margin explain why states with higher interest rates also have lower default rates (even though interest rates reflect default probabilities). In states with high exemptions, *conditional on borrowing unsecured* households have a higher propensity to default, but since fewer households are borrowing, the state bankruptcy rate is lower. Foreclosure rates are higher in high exemption states because mortgage leverage is higher and the probability of foreclosure is increasing with leverage. These effects can be seen in the state level aggregates in Tables A.2 and A.3 in the Appendix.

Empirical Evidence for Unsecured Interest Rate Variation Across States

In the model, households in low exemption states pay on average lower interest rates on unsecured debt than households in high exemption states. To compare the prediction of the model to the data, I construct a measure of interest rate paid using the Consumer Expenditure Survey (CEX) from 1994-2003. For households that reported having unsecured debt, I compute the effective interest rate by dividing the expendi-

²⁹In recourse states even households that hold no unsecured debt but hold mortgages are at risk of bankruptcy because of the deficiency judgments in foreclosure. However, quantitatively, these households account for less than 1% of bankrupt households in recourse states.

Table 1.5: Unsecured Interest Rates

| | Data (CEX) | Model |
|----------------|-------------------|-------------------|
| Low Exemption | 23.49% (1.13%) | 7.93% (0.56%) |
| High Exemption | 27.64% (3.49%) | 13.07% (2.50%) |

Notes: Data constructed by dividing interest and finance charges by total debt and computing the mean across households. The model means are the averages of 100 simulations of a sample of size $N = 10,760$. Standard errors are reported across simulations

ture on interest and finance charges by the amount of unsecured debt. While a crude measure, to my knowledge the CEX is the only publicly available data source that provides information on unsecured debt, interest and state of residence. There are a total of 10,760 observations in my sample, so I simulate 100 samples of the same size from the model. I report the means and standard errors across the simulations from the model generated data. Because the CEX is not designed to be representative at the state level, I divide states into high and low exemption states and then compare the mean interest rates in Table 1.5. The interest rates are significantly higher in the CEX (and are high relative to the 12.3 percent average interest rate reported in the SCF), most likely due to the simplified measure being used and because the CEX also includes finance charges. However, the direction and magnitude of the difference in interest rates in the model is consistent with the data, providing additional evidence for the mechanism.

Empirical Evidence for Mortgage Leverage Variation Across States

As examined in the previous section, homestead exemptions change the price of unsecured debt. As a result households take on different portfolios of debt. The model predicts that households in high exemption states take on more highly leveraged mortgages than in low exemption states. To compare this prediction to the data, I construct household mortgage leverage from the 2000 Residential Finance Survey

Table 1.6: Mortgage Leverage

| | Data (RFS) | Model |
|----------------|-------------------|-------------------|
| Low Exemption | 67.03% (0.82%) | 68.27% (0.66%) |
| High Exemption | 74.50% (5.23%) | 74.10% (0.52%) |

Notes: Data constructed by dividing mortgage balances by current house value and computing the mean across households. The model means are the averages of 100 simulations of a sample of size $N = 4,315$. Standard errors are reported across simulations

(RFS). I compute the leverage by summing across the balance on all mortgages outstanding and dividing by the current value of the home for all prime-aged households. Since the RFS only includes state identifying information for twelve states (note that those twelve states include 65 percent of all households in the US³⁰) again I partition the states between high and low exemption states. The mean leverage of households with a mortgage and standard errors are reported in Table 1.6. I simulate households from the model of the same sample size ($N = 4,315$) and same states as the RFS 100 times and report the mean leverage and standard deviation across simulated means also in Table 1.6. The model does remarkably well in matching the level of leverage and its difference between high and low exemption states.

1.5.4 Effects of Recourse

Recourse has surprisingly little effect on foreclosure and mortgage interest rates. Recourse and no recourse states with the same homestead exemption have nearly identical foreclosure rates. This is because recourse only has significant effects on two groups of mortgage holders. The first are those with mortgages with very high leverage (90 percent). Those households have a large probability of being slightly underwater in the next period, and households are more likely to repay slightly underwater mortgages in recourse states (as shown in Figure 1.5). However, very few households take

³⁰The twelve states are: California, Florida, Illinois, Massachusetts, Michigan, New Jersey, New York, Ohio, Pennsylvania, Texas, Virginia, Washington.

on mortgages with leverage over 90 percent (median leverage in the data and model are both less than 70 percent), so in the aggregate this effect is marginal.

The other group of households affected by recourse are those with substantial savings in bonds. Those households are less likely to foreclose because they have the resources to repay an underwater mortgage and want to avoid a deficiency judgment.³¹ However, households that have substantial savings in bonds take on mortgages with low leverages and thus have low probabilities of going into foreclosure. Further, only a small fraction of households hold significant amounts of savings in bonds. Thus, the marginal change in their interest rate and foreclosure probability is negligible when aggregated at the state level.

In addition, the model predicts that recourse states will have higher bankruptcy rates than no-recourse states. The result is intuitive, since in recourse states foreclosing households face additional liability, which may trigger bankruptcy following foreclosure. In addition, in recourse states 10-20 percent more households go bankrupt conditional on foreclosure compared to no-recourse states. That number directly reflects the effect of the parameter ψ , the probability of a deficiency judgment. These results are consistent with recent research by Li and White (2009) (see their Table 5) that suggests that households are more likely to file for bankruptcy after foreclosure in recourse states than no-recourse states.

Having shown that the model is an appropriate laboratory for studying bankruptcy and foreclosure in the U.S., I proceed with policy analysis.

1.6 Policy Experiments

I now use the calibrated model to conduct two policy experiments. In the first policy experiment, I consider the effects of the 2005 Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA), the first major reform to bankruptcy in almost

³¹This is consistent with the interpretation of the effects of recourse found in Ghent and Kudlyak (2011).

30 years. The reform made it more difficult for households earning more than the median income in their state from filing for Chapter 7 bankruptcy. The analysis enables me to evaluate the hypothesis of Morgan, Iverson, and Botsch (2009) and Li, White, and Zhu (2010) that BAPCPA contributed to the subsequent observed rise in foreclosure rates. The second experiment is motivated by the ongoing debate in the U.S. Congress whether to standardize homestead exemption policy. To inform this policy debate, I use my calibrated model to quantitatively determine the optimal joint homestead exemption and recourse policy from a utilitarian welfare perspective.

1.6.1 BAPCPA

To simulate the effects of BAPCPA, in the model households above median income cannot file for bankruptcy, unless as a result they have non-positive consumption. I compute the transition from the original steady state to the new steady state equilibrium. I find that it takes several years for default, housing and debt to reach their new steady state levels. Taking into account the transitional dynamics will therefore be important for understanding the welfare implications of the policy.

Effects on Allocations

The aggregate implications of the reform are substantial, both in terms of default rates and total borrowing in the economy, as shown in Table 1.7. Unsecured debt increases 30 percent over approximately 10 years. The increase in unsecured debt is small, however, relative to the increased indebtedness of households. After reform, as more households take on unsecured debt, the fraction of households with non-positive net worth almost triples to more than 15 percent. The percentage of households that file for bankruptcy initially drops, and then rises rapidly and converges to a rate of 2.45 percent.³² Qualitatively, the initial drop and subsequent rise are consistent with

³²The transitional dynamics are illustrated in Figure A.2(a)-A.2(c) in the appendix.

Table 1.7: Aggregate Effects of BAPCPA

| | Baseline | BAPCPA |
|----------------------------------|----------|--------|
| Housing, H | 5.25 | 5.21 |
| Unsecured debt, B_- | -0.34 | -0.46 |
| Mortgages M | 3.54 | 3.64 |
| Fraction with net worth ≤ 0 | 5.3% | 15.1% |
| Bankruptcy Rate | 1.06% | 2.45% |
| Foreclosure Rate | 0.55% | 1.16% |

bankruptcy rates post-BAPCPA, however the model predicts a much faster increase in bankruptcy rates than observed. Foreclosure also more than doubles going from 0.55 percent to 1.15 percent of mortgages per year. How can a policy that is intended to make it more difficult for households to go bankrupt result in *higher* bankruptcy rates?

The reform significantly reduces the cost of unsecured borrowing. In Figure 1.7(a), I plot the unsecured interest rates for the same household in Michigan as in the previous section, one with roughly median net worth and high persistent income. The household optimally chooses a portfolio consisting of \$210K house, a \$155K mortgage and \$6K of unsecured credit. Also in the figure, I plot the unsecured interest rates that household would face if it chose the same size house and mortgage after the BAPCPA reform. The interest rate schedule shifts significantly to the right, meaning that the household faces lower interest rates. In addition, the interest rate schedule remains low even when the total amount of debt borrowed exceeds non-exempt home equity (the point at which the ex-ante financial gain from going bankrupt is positive). This is as a result of the fact that if the household earns above median income in the subsequent period it cannot go bankrupt even though there is a financial gain from doing so. Households are also less likely to go bankrupt in order to maintaining access to credit. Since interest rates are lower, access to credit is more valuable post-reform, implying that a greater direct financial benefit is required for a household to choose to go bankrupt.

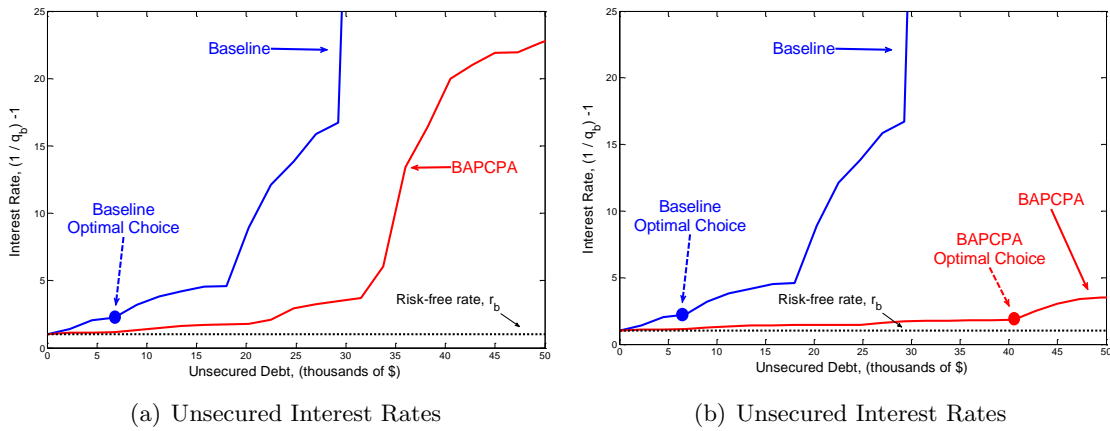


Figure 1.7: Interest rates on unsecured debt for a household in Michigan before and after the BAPCPA reform. The dots represent the optimal policy choices of the household.

Notes: Before the reform, the household optimally chooses a \$210K house, \$155K mortgage and \$6K of unsecured debt. The BAPCPA line in (a) represents the price schedule that the household would face if it chose the same size house and mortgage as before the reform. The BAPCPA line in (b) represents the price schedule given the household's optimal choice of housing and mortgage after the reform: \$280K house, \$190K mortgage and \$41K of unsecured debt.

Facing the lower cost of borrowing, the household in Michigan no longer finds it optimal to take on \$6K of unsecured credit. After the reform, the household takes on a bigger house and mortgage, \$280K and \$190K respectively. Based on those choices, the unsecured interest rates that the household faces are plotted in Figure 1.7(b). With the increased amount of home equity and the BAPCPA restrictions, the household faces significantly lower borrowing costs and optimally chooses \$41K of unsecured credit. This type of change in behavior can explain the large increases in unsecured debt taken on by households after the reform.

Increases in debt and lower interest rates alone do not fully account for the increase in bankruptcies. The composition of who is taking on unsecured debt changes as well. Before the reform, there were primarily two groups of households that took on unsecured debt: those with very low net worth and those with substantial non-exempt home equity. Households with only exempt home equity took on only small amounts unsecured debt or none at all. After the reform that distribution changes. The low net worth households continue to borrow only in unsecured debt. However,

households with high income and only exempt home equity take on more unsecured credit than before the reform. The persistence of income makes interest rates on unsecured debt low, even though the financial benefit of going bankrupt is high. If the household stays above median income, it simply repays or rolls over the debt. However, if the household falls below median income, it files for bankruptcy because the financial gain from doing so is large (since it keeps all of its home equity and discharges substantial unsecured debt). Unsecured borrowing coupled with exempt home equity essentially serves as insurance against below-median income realizations in the subsequent period. These results contrast with those of Chatterjee, Corbae, Nakajima, and Ríos-Rull (2007) who find a slight decline in the bankruptcy rate after imposing the income restriction for filing. The difference highlights the importance of considering exempt assets (mainly houses) as well as liabilities in any analysis of the effects of bankruptcy policy.

Effect of Homestead Exemption under BAPCPA

Before the reform, higher homestead exemptions lead to lower bankruptcy rates. After BAPCPA, the relationship is reversed - higher levels of the homestead exemption lead to higher levels of bankruptcy.³³

The income restriction imposed under BAPCPA significantly mitigates the price effect of higher exemptions because high income households are prevented from going bankrupt even when there is a financial benefit of doing so. As described in the previous section, unsecured credit and exempt home equity can mimic an insurance contract against low income realizations. The level of insurance provided is limited by the level of the exemption (the maximum amount households can keep after bankruptcy). Therefore, households in high exemption states take on unsecured debt and increase home equity, leading to increased bankruptcy rates.

³³The state by state default rates are presented in Table A.4 the Appendix.

Welfare Consequences of the Reform

Despite higher levels of bankruptcy and foreclosure, households on average are made strictly better off from the reform. Taking into account transitional dynamics, the average consumption equivalent welfare gain across households from adopting the policy is 1.4 percent of lifetime consumption (this is a utilitarian welfare measure). The reason why households benefit from the reform is that they are excluded from going bankrupt in states of the world where the gain is relatively small, but allowed to go bankrupt when the gain is large. Furthermore, with the exempt asset they are able to do better than just not having to repay the debt - they can also essentially transfer resources to the bankruptcy state through exempt housing. Since income is persistent, the cost of this “insurance” is fairly low for households above median income, so more households use it and end up going bankrupt more often, but are better off by doing so.

1.6.2 Optimal Homestead Exemption and Recourse Policy

In my second policy experiment, I ask how the government should optimally set the homestead exemption and recourse policy to maximize utilitarian welfare, taking into account the transitional effects of switching to a new policy. In the real world the federal government has the power to adopt a uniform bankruptcy law, but in the past has allowed states to opt-out of the federally mandated exemptions.

In order to solve for the optimal policy, I take as my initial condition the economy along the transition path induced by the passage of BAPCPA. I solve for the policy that maximizes current welfare taking into account the new transition path induced by the change in exemption and recourse law. I find that the optimal joint policy prescribes no recourse and a homestead exemption of roughly one quarter of median state income.

Eliminating recourse may at first seem counterintuitive. However, households in

this economy face two types of uncorrelated risk: house price risk and income risk. Having no recourse mortgages allows the two debt instruments to more effectively span the space of possible shocks. When there is recourse, housing risk could result in bankruptcy which reduces the ability of the household to use savings or unsecured debt to insure against income risk. A no-recourse mortgage policy is in some sense regressive, however, as the households that benefit the most are high income and high net worth households that have large homes and large mortgages. Lower net worth households get less insurance, but face the higher borrowing cost.

The intuition for why a positive homestead exemption is optimal relates to the discussion in the previous section on how unsecured debt can provide insurance against a drop in income. The trade-off between price and insurance is lower after BAPCPA, however, since default is costly, it is optimal to keep the exemption relatively low, yielding lower bankruptcy and foreclosure rates. In addition, the lower exemption disproportionately benefits households with low wealth, since their assets are mostly exempt. Since I have adopted a utilitarian welfare function, setting the exemption to benefit mostly low net worth households may represent a trade-off with no-recourse mortgages, which disproportionately benefit high net worth households.

The welfare gains from adopting the optimal exemption and recourse policy are non-negligible - on average households gain 0.4 percent of average lifetime consumption by the switching to the optimal policy. The gains are not uniform across states, as the states with recourse and high exemptions see the largest welfare gains. The welfare gains are also heterogeneous across households. For example, high net worth households benefit most from adopting no-recourse mortgages, and lower income households with unsecured debt and home equity benefit from the lower exemption.

1.7 Conclusions

The option to default provides an important channel for insurance for households in an incomplete markets world. In the wake of the 2005 reform and the financial crisis of 2008 there has been fierce debate over how the government should regulate consumer credit markets. In this paper, I have shown that household behavior fundamentally links secured and unsecured credit, and foreclosure and bankruptcy. From the perspective of these findings, researchers and policy makers, therefore, ought to take into account both channels of default when analyzing consumer credit; otherwise they risk misstating the overall effect on household behavior and welfare. I illustrated this by showing that the model can capture the cross state variation in bankruptcy rates *only* when foreclosure is incorporated. Moreover, the evaluation of the 2005 BAPCPA reform showed that it had the unintended consequence of raising both bankruptcy and foreclosure rates.

The framework I developed opens up exciting avenues for future research. First, aggregate house price risk could be incorporated into the model. The model with aggregate risk could be used to evaluate mortgage modification policies intended to mitigate the effects of large house price drops. In particular, the model provides the necessary framework to evaluate proposed reforms to bankruptcy that would allow bankruptcy judges to modify the principal balances on mortgages (commonly referred to as "cramdowns"). Second, one could use the model to explain aggregate house price changes. Moving from an endowment economy to a production economy with aggregate risk and frictions on housing would generate endogenous movements in house prices. I defer this to future work.

Chapter 2

Housing, Mortgage Bailout Guarantees and the Macroeconomy

A modified version of this chapter originally appeared as ? and is co-authored with Karsten Jeske and Dirk Krueger.

The United States displays one of the highest home ownership rates in the world at close to 70%, and owner-occupied houses constitute the most important asset for most U.S. households. Part of the attractiveness of owner-occupied housing stems from a variety of subsidies the government provides to homeowners. In addition to tax-deductible mortgage interest payments and the fact that implicit income from housing capital (i.e. the imputed rental-equivalent) is not taxable, a third subsidy arises from government intervention in the mortgage market. In the US close to 50% of residential mortgages are held by so-called Government-Sponsored Enterprises (GSE's), totaling more than \$5 trillion in value. In September 2008, the US Treasury took conservatorship of Fannie Mae and Freddie Mac after huge losses following the collapse of house prices. Since then, the US government has provided about \$180 billion (see FHFA, 2012) to help GSE's remain solvent. Policy makers are currently faced with deciding the future of GSE's and the role of the government in providing insurance in the mortgage market.

What are the macroeconomic and distributional consequences of government guar-

antees for GSE's, and what is the optimal degree of such bailout guarantees? We model the consequences of this bailout guarantee as a tax-financed mortgage interest rate subsidy. Prior to their bailout in 2008, the GSE's could borrow at interest rates close to that on U.S. government debt, despite the fact that they were heavily exposed to aggregate house price risk (as has become abundantly clear during the recent crisis). The absence of a significant risk premium for the GSE's debt can be attributed to the then implicit government bailout guarantee these institutions enjoyed. Currently the GSE's are explicitly backed by the US government and as a consequence enjoy lower borrowing costs than private companies. To the extent that part of the interest advantage of GSE's is passed through to homeowners, there exists a mortgage interest rate subsidy from the federal government to homeowners.

The aggregate and redistributive consequences of this subsidy are evaluated by constructing a heterogeneous agent general equilibrium model with incomplete markets in the tradition of Bewley (1986), Huggett (1993) and Aiyagari (1994). This model is augmented by a housing sector and we allow households to borrow against their real estate wealth positions through collateralized mortgages. In the model households can default on their mortgages, with the consequence of losing their homes. Competitive mortgage companies price the default risk into the mortgage interest rates they offer. The implicit (prior to 2008) or explicit (since 2008) support of GSE's is modeled as a tax-financed direct subsidy to mortgage interest rates. The stationary economy can be interpreted as a world in which the government taxes income every period and either saves the proceeds in an effort to smooth out the spending shock triggered by a potential insolvency of the GSE's, or alternatively, is able to buy insurance against that shock from the outside world via, say, a market for credit derivatives. Under this interpretation the tax revenues constitute the required funds to cover the necessary insurance premium.

In addition to addressing the applied policy question stated above, a second contri-

bution of the paper is the theoretical characterization of mortgage interest rates in the general equilibrium model with foreclosure. First, it is shown that mortgages are priced exclusively based on leverage, with more highly levered households paying higher interest rates. This result is important because it provides a concise characterization of the mortgage price function which allows to easily deal with the continuous choice by households of mortgage contracts with endogenous interest rates. It also facilitates the efficient computation of an equilibrium in the model. Second, a minimum down payment requirement arises endogenously in our model. Finally, a partial characterization of the household decision problem is provided that delivers insights into why households might simultaneously want to save in low interest bearing risk-free bonds and borrow in mortgages that carry higher interest rates. The model provides a useful and tractable framework for future analyses of the housing and mortgage market with collateralized default, and consequently might be of independent interest.

The quantitative results can be described as follows. First, comparing allocations in stationary equilibria with and without the policy, a tax-financed interest rate subsidy of 30 basis points¹ leads to a large increase in mortgage origination, but has little effect on investment in housing assets or in the equilibrium construction of real estate. The mortgage subsidy does *not* significantly change the share of households with positive holdings of real estate, because on one hand the subsidy makes real estate ownership more attractive, but on the other hand the higher required taxes lower after-tax income and thus discourage home ownership for low-income and low-asset households. However, the subsidy *does* significantly affect the distribution of leverage in the economy by increasing both the fraction of households that have positive mortgage debt and the level of leverage, conditional on holding a mortgage. This suggests that the government subsidy of the GSE's may have contributed to the increase in

¹Lucas and McDonald (2010) argue for a default premium of the GSE's and assumed by the government of 20 to 30 basis points. Thirty basis points is chosen, the high end of their range, but still lower than the estimates by the Congressional Budget Office (CBO, 2001) or those implied by Passmore (2005).

Several studies (e.g., Passmore, Sherlund and Burgess (2005) and Blinder, Flannery, and Kamihachi (2004)) have argued that a significant portion, if not all of the subsidy, is passed on to homeowners.

mortgage debt and household leverage prior to the housing bust, which in turn may have exacerbated the economic impact of the recent decline in house prices.

Second, using a steady state utilitarian social welfare function, the welfare implications of the subsidy are significantly negative, on the order of 0.5% of consumption equivalent variation. This aggregate statistic, however, masks substantial heterogeneity across households differing in income and wealth. Low-wealth households prefer to live in a world without the subsidy since they hold little housing and mortgages, and thus do not benefit from the interest rate subsidy, but bear part of the tax bill required to finance it. In contrast, wealthy households have larger homes and mortgages, and thus the benefits accruing to them outweigh the fiscal burden of the policy. Using the same social welfare function the *optimal* interest rate subsidy is found to be small but positive, at 9.375 basis points.

2.0.1 Related Literature

The paper aims at making two contributions, and thus is related to two broad strands of the literature. On the substantive side, it provides a quantitative, model-based analysis of the macroeconomic and distributional consequences of mortgage interest rate subsidies through government guarantees of the GSE's. It therefore complements empirical work that evaluates the importance of the GSE's and their government guarantee for the housing and mortgage market. Frame and Wall (2002a,b) and more recently Acharya et al. (2011) provide a thorough summary of the institutional details surrounding GSE's. The empirical estimates of Lucas and McDonald (2010) that quantified the borrowing interest rate advantage of GSE's to between 20 and 30 basis points are used to motivate the policy thought experiment.

More broadly, the paper contributes to the literature that studies the positive and normative implications of government housing subsidies on equilibrium allocations. Along this dimension, it is most closely related to the pioneering study by Gervais

(2002) who constructs a heterogeneous household general equilibrium life cycle model to evaluate the effects of the other two main government housing subsidies: the tax-deductibility of mortgage interest rates and the fact that the implicit income from owner-occupied housing capital is not subject to income taxation. Our contribution, relative to his, is to introduce mortgage default (foreclosure) into a dynamic general equilibrium model, and to use it to study a third, and hitherto perhaps somewhat overlooked government housing subsidy policy

A second, model-building and theoretical contribution of the paper is to develop an equilibrium model with mortgage debt and foreclosure in which mortgage interest rates are determined by competition of financial intermediaries, and fully reflect equilibrium default probabilities. In this regard, the model can be seen as a natural extension of the literature on uncollateralized debt and equilibrium default pioneered by Chatterjee et al. (2007) and Livshits et al. (2007). More broadly, our model shares many elements with the recent model-based quantitative housing literature.² For example, Chambers, Garriga and Schlagenhauf (2009), Ríos-Rull and Sánchez-Marcos (2008) and Favilukis, Ludvigson and van Nieuwerburgh (2012) incorporate a housing and mortgage choices into a general equilibrium framework. Similarly, Gruber and Martin (2003) also study the distributional effects of the inclusion of housing wealth in a general equilibrium model, but do not address the role of government housing subsidies.

Especially relevant for the purpose of our analysis are the three recent papers by Corbae and Quintin (2011), Chatterjee and Eyigungor (2011), and Garriga and Schlagenhauf (2009) that build general equilibrium models of housing that also feature equilibrium mortgage default, in order to evaluate the effects of the drop in house prices and a change in housing supply on equilibrium foreclosure rates. Their focus is mainly to understand the underlying reasons for, and consequences of the recent

²For a brief survey of this literature, see Fernandez-Villaverde and Krueger (2011).

foreclosure crisis³ in the U.S. whereas our purpose is to study the effects of a specific government housing market policy. Our paper is complementary to theirs in terms of focus, but also in terms of the details of how mortgages and foreclosure are modeled. In these papers mortgages are long term contracts whereas we permit households to costlessly refinance in every period. This modeling choice, in conjunction with perfect competition in the mortgage market allows us to obtain a sharp analytical characterization of equilibrium mortgage interest rates and default behavior in our model.⁴

The remainder of the paper is organized as follows. Section 2 introduces the model and defines equilibrium in an economy with a housing and mortgage market. Section 3 characterizes equilibria. Section 4 describes the calibration of our economy. Section 5 details the numerical results by comparing steady states in economies with and without a mortgage interest subsidy. Section 6 concludes the paper, and all proofs are relegated to the appendix.

2.1 The Model

The economy is populated by a continuum of measure one of infinitely lived households, a continuum of competitive banks and a continuum of housing construction companies. The analysis proceeds by immediately describing the economy recursively.

2.1.1 Households

Preferences: Households derive period utility $U(c, h)$ from nondurable consumption c and housing services h , which can be purchased at a price P_l (relative to the

³An important *empirically* oriented literature has recently studied the causes and consequences of the recent boom in foreclosures in the U.S. See e.g. Campbell et al. (2011), Gerardi et al. (2010) or Mian et al. (2011).

⁴Kraimer et al. (2009) construct a continuous time mortgage valuation model and also provide a partial analytical characterization of the interest rate and asset value of mortgages, as a function of mortgage leverage.

numeraire consumption good). Households discount the future with discount factor β and maximize expected utility.

Endowments: Households receive an idiosyncratic endowment of the perishable consumption good given by $y \in Y$. These endowments follow a finite state Markov chain with transition probabilities $\pi(y'|y)$ and unique invariant distribution $\Pi(y)$. Denote by $\bar{y} = \sum_{y \in Y} y\Pi(y)$ the average endowment. The terms endowment and (labor) income are used interchangeably throughout the remainder of the paper, and a law of large number is assumed to apply, so that π and Π also denote deterministic fractions of households receiving a particular income shock y .

The government levies a proportional tax τ on labor income to finance an interest rate subsidy, if such a policy is in place.

Assets: In addition to consumption and housing services the household spends income to purchase two types of assets, one-period bonds b' and perfectly divisible houses g' . The price of bonds is denoted by P_b and the price of houses by P_h . Houses are risky assets: they are subject to *idiosyncratic* house price shocks. Let $F(\delta')$ denote the continuously differentiable cumulative distribution function of the house price depreciation rate δ' tomorrow, which has support $D = [\underline{\delta}, 1]$ with $\underline{\delta} \leq 0$. A negative value of δ indicates positive house price appreciation. The realization of δ is independent across time for every household, and that a law of large number applies, so that $F(\cdot)$ is also the economy-wide distribution of house price shocks. One unit of the housing asset generates one unit of housing services. A house purchased in the current period can immediately be rented out to generate rental income in the same period as the purchase. By assumption households are prohibited from selling bonds and houses short.

Mortgages: Households can borrow against their real estate position using one-period mortgage debt.⁵ Let m' denote the size of the mortgage, and P_m the contemporaneous receipts of resources (that is, of the consumption good) for each unit of mortgage issued today and to be repaid in the subsequent period. The “price” P_m will be determined in equilibrium by competition of banks through a zero profit condition, and will in general depend on the characteristics of households as well as the size of the mortgage m' and size of the collateral g' against which the mortgage is issued. The gross mortgage interest rate is then simply given by $R_m = 1/P_m$.

Households that come into the next period with housing assets g' and a mortgage m' possess the option, after having observed the idiosyncratic house price appreciation shock δ' , of defaulting on their mortgages, at the cost of losing their entire housing collateral. There are no other costs associated with mortgage default. This assumption, together with modeling mortgages as short-term contracts, immediately implies that households will choose to default whenever the amount owed on the mortgage is greater than the value of the house after the realization of the price shock, that is, if and only if⁶ $m' > P_h(1 - \delta')g'$.

As a consequence, the ex-ante default probability of a household at mortgage origination, that is, prior to observing the shock, is simply a function of the size of the mortgage m' and today’s value of the collateral $g'P_h$. As argued below, this will imply that in equilibrium the price of a mortgage P_m today will only be a function of (m', g') , a fact we will already use when now specifying the household problem in recursive formulation.

⁵Our assumption abstracts from transaction costs of refinancing a mortgage or obtaining a home equity line of credit. Long-term mortgages in addition protect households from inflation risk and prevent banks from adjusting interest rates based on changing household characteristics (such as income), providing additional insurance to households. In our real model inflation risk is absent. In principle, financial intermediaries could condition interest rates of our one-period mortgages on income (and thus adjust them in response to income shocks), but in equilibrium (shown later) they will not. We therefore think that, in the context of our model, assuming short-term debt is a defensible assumption. As demonstrated below, the payoff is a sharp analytical characterization of equilibrium mortgage interest rates and foreclosure behavior.

⁶We make the assumption that a household indifferent between defaulting or not will choose not to default.

2.1.2 Recursive Formulation of the Household Problem

Let a denote cash at hand, that is, after tax income plus the value from all assets brought into the period, after the current income and house price shocks (y, δ) have materialized. The individual state of a household consists of $s = (a, y)$. The cross-sectional distribution over individual states is denoted by μ . Since the analysis is restricted to stationary equilibria in which μ is constant over time, in what follows the dependence of aggregate prices and quantities on μ is left implicit.

The dynamic programming problem of a household consists of choosing consumption c , housing services h and financial and housing assets (b', g') as well as mortgages m' to solve:

$$v(a, y) = \max_{c, h, b', m', g' \geq 0} \left\{ U(c, h) + \beta \sum_{y'} \pi(y'|y) \int_{\underline{\delta}}^1 v(a', y') dF(\delta') \right\} \quad s.t. \quad (2.1)$$

$$c + b'P_b + hP_l + g'P_h - m'P_m(g', m') = a + g'P_l \quad (2.2)$$

$$a'(\delta', y', m', g') = b' + \max\{0, P_h(1 - \delta')g' - m'\} + (1 - \tau)y' \quad (2.3)$$

Note that because of the assumption that newly purchased housing assets can immediately be rented out, rental income $g'P_l$ from newly purchased housing assets enters the current period budget constraint. Tomorrow's cash at hand a' is equal to the sum of after tax labor income $(1 - \tau)y'$, the amount of bonds b' brought into the period and the net value of real estate. If the household owes less than the realized value of her housing asset, she does not default and the net value of real estate equals $P_h(1 - \delta')g' - m'$. For bad realization of the house price shock δ' the mortgage is under water, the household defaults and is left with zero housing wealth.

2.1.3 The Real Estate Construction Sector

The representative firms in the perfectly competitive real estate construction sector face the linear technology $I = C_h$, where I is the output of newly build and perfectly divisible houses of a representative firm and C_h is the input of the consumption good. Note that we assume that this technology is reversible, that is, real estate companies can turn houses back into consumption goods using the same technology, although this does not happen in the equilibrium of our calibrated economies. Thus the problem of a representative firm reads as

$$\begin{aligned} \max_{I=C_h} \quad & P_h I - C_h \\ \text{s.t.} \quad & I=C_h \end{aligned} \tag{2.4}$$

and the equilibrium house price necessarily satisfies $P_h = 1$. In effect, ours is therefore a model with exogenous house prices normalized to $P_h = 1$, but endogenous rents (and thus endogenous house-price to rent ratios), and perfectly elastic supply of the housing asset from the real estate companies, at the exogenous house price $P_h = 1$.

2.1.4 The Banking Sector

Let r_b denote the risk free interest rate on one-period bonds, to be determined in general equilibrium. Competitive banks take their costs $P_b = \frac{1}{1+r_b}$ of re-financing as given. In addition, issuing mortgages is costly; let r_w be the percentage real resource cost, per unit of mortgage issued, to the bank. This cost captures screening costs, administrative costs as well as maintenance costs of the mortgage (such as preparing and mailing a quarterly mortgage balance).⁷ In addition, in order to insure mortgages against the (unmodeled) *aggregate component* of mortgage default risk, banks need to purchase insurance at a cost θ for each dollar of mortgage originated. This θ can be interpreted as a real resource cost that is transferred to an unmodeled insurance

⁷In addition to realism the cost $r_w > 0$ insures that the interest paid on a mortgage that is repaid with probability one is still higher than the risk-free rate on bonds, which avoids an indeterminacy in the household maximization problem (since with $r_w = 0$ bonds and zero-default mortgages are perfect substitutes).

company abroad. It will enter the aggregate resource constraint of the economy.

The government can subsidize mortgages using labor income taxes. The mortgage subsidy is modeled as an *interest rate* subsidy ϕ for each unit of mortgage issued. Thus the effective cost of the banking sector for financing one dollar of mortgage equals $(1 + r_b)(1 + r_w + \theta - \phi)$.

In the perfectly competitive banking sector, risk-neutral banks compete for customers *loan by loan*, as in Chatterjee et al. (2007), in the context of uncollateralized debt. Banks will only originate mortgages that yield non-negative profits in expectation. Banks, when making their origination decision, take into account the fact that a household may default on its mortgage. When a household does so, the bank seizes the housing collateral worth $(1 - \delta')g'$. However, the foreclosure technology is possibly inefficient, and therefore that the bank only recovers a fraction $\gamma \leq 1$ of the value of the collateral.

In order to define a typical banks' problem the optimal default choice of a household has to be characterized. As discussed in section 2.1.1 the household defaults if and only if her mortgage is under water. Thus for a household with housing assets g' and a mortgage m' there is a cutoff level for house price depreciation $\delta^*(m', g')$ at which a household is indifferent between defaulting and not defaulting on her mortgage. This cutoff is determined as $m' = (1 - \delta^*(m', g'))g'$, and thus explicitly, as

$$\delta^*(m', g') = \delta^*(\kappa') = 1 - \frac{m'}{g'} = 1 - \kappa' \quad (2.5)$$

where $\kappa' = \frac{m'}{g'}$ is defined as the leverage (for $g' > 0$) of a mortgage m' backed by real estate g' . Thus the household defaults for all house price depreciation realizations $\delta' > \delta^*(\kappa')$. Since the foreclosure decision of a household does not depend on bond holdings b' chosen today or current income y , in equilibrium the receipts P_m will not depend on these quantities either.

Using the characterization of the household default decision, the set of mortgage

contracts that the bank will originate can be characterized. A bank will originate a mortgage if and only if:

$$m'P_m(g', m') \leq \frac{\left\{ m'F(\delta^*(\kappa')) + \gamma g' \int_{\delta^*(\kappa')}^1 (1 - \delta') dF(\delta') \right\}}{(1 + r_b)(1 + r_w + \theta - \phi)} \quad (2.6)$$

$$= \frac{m'\Psi(\kappa')}{(1 + r_b)(1 + r_w + \theta - \phi)} \quad (2.7)$$

The left hand side $m'P_m(g', m')$ is the amount the bank pays out to a household that takes on a mortgage of size m' collateralized by g' housing assets. The term $m'\Psi(\kappa')$, the term in $\{\}$ -brackets in equation (2.6), denotes the receipts tomorrow for the bank from the mortgage. With probability $F(\delta^*(\kappa'))$ the household receives a house price shock δ' that makes default suboptimal in which case she repays the full face value of the mortgage m' . For all price shocks $\delta' > \delta^*(\kappa')$ the household defaults and the bank retrieves $\gamma(1 - \delta')g'$ by foreclosing and selling off the house. The term $\Psi(\kappa')$ measures the expected revenue for the bank tomorrow for each dollar of a mortgage with leverage κ' issued today. For each dollar of mortgage issued today the costs of funds to the bank are $1 + r_b$, the direct costs of maintaining one dollar worth of mortgage are r_w , the insurance costs per dollar of mortgage are θ and the subsidy per dollar is ϕ , so that the effective discount factor of the bank is given by $\frac{1}{(1+r_b)(1+r_w+\theta-\phi)}$. Perfect competition requires that for all mortgages offered in equilibrium the inequality in (2.6) holds as equality.

Notice that one direct and obvious consequence of equation (2.6) is that $P_m(g' = 0, m') = 0$ for all $m' > 0$, that is, a mortgage $m' > 0$ without collateral, i.e. with $g' = 0$, will not generate any funds for the household today. Without collateral ($g' = 0$) and $m' > 0$ the household will default on the mortgage for sure tomorrow and foreclosure will not generate any revenues for the bank. Therefore the right-hand side of equation (2.6) equals zero, and thus $P_m(g' = 0, m') = 0$.

A financial intermediary that issues a mortgage of size m' with leverage $\kappa' = m'/g'$ issues bonds of value $m'P_m(g', m')(1 + r_w + \theta - \phi)$ today, transfers $m'P_m(m', g')$ to the household, uses $r_w m'P_m$ resources for mortgage origination, transfers $\theta m'P_m$ to the international insurance agency and receives a transfer $\phi m'P_m$ from the government. Tomorrow it repays the bonds (including interest) with the expected receipts $m'\Psi(\kappa')$ from the mortgage to break even.

2.1.5 The Government

As stated above, the government levies income taxes at a flat rate τ on households to finance the mortgage interest rate subsidy. The tax revenues of the government are given by $\tau\bar{y}$. In the baseline economy, we model the bailout guarantee provided by the government as an interest rate subsidy equal to the cost of insurance $\phi = \theta$ per unit of mortgage issued. We interpret this as the government levying income taxes to provide insurance to banks against systemic (i.e. aggregate) mortgage risk. For a loan of type (m', g') the subsidy by the government is given by

$$sub(m', g') = \theta m'P_m(g', m'; \phi = \theta) \quad (2.8)$$

and the total economy-wide subsidy is

$$G = \int sub(m', g')d\mu \quad (2.9)$$

Note that G also measures the amount of resources expended on insurance against aggregate shocks, either by the households directly (in case of no bailout policy) or by the government.

2.1.6 Equilibrium

We are now ready to define a stationary recursive Competitive Equilibrium for the benchmark economy. Let $S = \mathbb{R}_+ \times Y$ denote the individual state space.

Definition Given a government subsidy policy ϕ a **Stationary Recursive Competitive Equilibrium** are value and policy functions for the households, $v, c, h, b', m', g' : S \rightarrow \mathbb{R}$, policies for the real estate construction sector I, C_h , prices P_l, P_b , a mortgage pricing function $P_m : \mathbb{R}_+ \times \mathbb{R}_+ \rightarrow \mathbb{R}$, a government tax rate τ and government spending G , as well as a stationary measure μ such that: (1) Given prices P_l, P_b, P_m and government policies the value function solves (2.1) and c, h, b', m', g' are the associated policy functions. (2) Policies I, C_h solve the maximization problem (2.4) of the real estate construction company. (3) Given P_b and P_m , (2.6) holds with equality for all m', g' . (4) The tax rate function τ satisfies $\tau = G/\bar{y}$ and government spending G satisfies (2.9), given the functions m', P_m . (5) The rental market clears:

$$\int g'(s)d\mu = \int h(s)d\mu. \quad (2.10)$$

(6) The bond market clears:

$$P_b \int b'(s)d\mu = (1 + r_w + \theta - \phi) \int P_m(g', m'; \phi)m'(s)d\mu. \quad (2.11)$$

(7) The goods market clears:

$$\int c(s)d\mu + C_h + (r_w + \theta - \phi) \int P_m(g', m'; \phi)m'd\mu + G = \bar{y}, \quad (2.12)$$

where

$$C_h = I = \int g'(s) \left[1 - \int_{\underline{\delta}}^{\delta^*(\kappa'(s))} (1 - \delta')dF(\delta') - \gamma \int_{\delta^*(\kappa'(s))}^1 (1 - \delta')dF(\delta') \right] d\mu \quad (2.13)$$

is gross investment in the housing stock. The measure μ is invariant with respect to the Markov process induced by the exogenous Markov process π and the policy functions m', g', b' .

For the policy experiments aggregate economy-wide welfare is measured via a Utilitarian social welfare function in the steady state, defined as

$$\mathcal{WEL} = \int v(s)\mu(ds) \quad (2.14)$$

where μ is the invariant measure over the state space for cash at hand and income, $s = (a, y)$.

2.2 Theoretical Results

In this section theoretical properties of our model are stated that provide insights into the forces that determine optimal household portfolio and leverage choices. In addition, the properties are useful in the computation of an equilibrium.

2.2.1 Mortgage Interest Rates

Recall that the implied net real interest rate from a mortgage m' with collateral g' and receipts $P_m(g', m')$ is $r_m(g', m') = 1/P_m(g', m') - 1$. From equation (2.6) and the fact that competition requires profits for all mortgages issued in equilibrium to be zero we immediately obtain a characterization of equilibrium mortgage interest rates:

Proposition 9. *In any steady-state equilibrium, mortgages originated with positive collateral $g' > 0$ have the following properties: (1) They are priced exclusively based on leverage $\kappa' = \frac{m'}{g'}$, that is $P_m(m', g') = P_m(\kappa')$ and $r_m(g', m') = r_m(\kappa')$; (2) $P_m(\kappa')$ is decreasing in κ' , and strictly decreasing if the household defaults with positive probability. Thus mortgage interest rates $r_m(\kappa')$ are increasing in leverage κ' ; and (3) Households that default with positive probability tomorrow receive $P_m(\kappa') < \frac{1}{(1+r_b)(1+r_w+\theta-\phi)}$*

today, that is, they borrow at a risk premium $1 + r_m(\kappa') > (1 + r_b)(1 + r_w + \theta - \phi)$ that is strictly increasing in leverage κ' .

This characterization of equilibrium mortgage interest rates now allows to obtain an endogenous upper bound for the leverage chosen by households.

2.2.2 Endogenous Down Payment Requirement

It is straightforward to show that it is never strictly beneficial for a household to purchase a mortgage with a leverage higher than the level that leads to subsequent default with probability one. Define the leverage that leads to certain default by $\bar{\kappa}$, which is equal to $1 - \underline{\delta}$, from equation (2.5). There exists a tighter *endogenous* upper bound on leverage $\kappa^* < \bar{\kappa}$ that households will never choose to exceed in equilibrium. This result also implies that it is never optimal for the household to lever up to the point in which default occurs with probability 1. Furthermore, at least with $\underline{\delta} = 0$, any mortgage chosen by households in equilibrium requires a positive down payment.

Proposition 10. *If $F(\delta)$ is \mathcal{C}^2 and log-concave with support $[\underline{\delta}, 1]$, $\underline{\delta} \leq 0$ and foreclosure is inefficient ($\gamma < 1$), there exists an endogenous borrowing limit κ^* . It is never optimal for a household to choose leverage $\kappa > \kappa^*$ at equilibrium mortgage prices P_m . Further, $\kappa^* < \bar{\kappa}$. In addition, if $\underline{\delta} = 0$, then $\kappa^* < 1$, that is, there is an endogenous minimum down payment $1 - \kappa^* > 0$.*

Log-concavity of the distribution guarantees that the resources received from a mortgage m' today, $m'P_m(\kappa')$, will be concave in m' . This fact, combined with the smoothness assumption on the distribution of the house price shocks $F(\cdot)$, guarantees that the leverage that maximizes resources today will be strictly less than the leverage that leads which to certain default. By increasing leverage beyond the level that maximizes resources today, the household receives strictly less resources today and has to repay weakly more resources tomorrow, implying that it can never be optimal

for the household to take on leverage above the level that maximizes contemporaneous resources received from the mortgage. Note that the (truncated) Pareto distribution used in our quantitative analysis for $F(\delta)$ is \mathcal{C}^2 and log-concave.

2.2.3 Existence of a Solution to the Household Problem

It is now shown that the recursive problem of the household has a unique solution. In order to do so it is helpful to split the household problem into a static problem that optimally allocates a given amount of resources between consumption and rental expenditures, and a dynamic consumption-saving and portfolio choice problem.⁸

As a function of the rental price P_l and total expenditures consumption c , define the indirect static utility function u as the solution to:

$$u(c; P_l) = \max_{\tilde{c}, h \geq 0} U(\tilde{c}, h) \text{ s.t.} \quad (2.15)$$

$$\tilde{c} + P_l h = c \quad (2.16)$$

Note that, in slight abuse of notation, c now denotes total expenditures $\tilde{c} + P_l h$ as opposed to just nondurable consumption (as it was defined in previous sections).

The dynamic household maximization problem can then be rewritten as:

$$v(s) = \max_{c, b', m', g' \geq 0} \left\{ u(c; P_l) + \beta \sum_{y'} \pi(y'|y) \int_{\underline{\delta}}^{\infty} v(s') dF(\delta') \right\} \quad (2.17)$$

$$\text{s.t.} \quad c + b' P_b + g' [1 - P_l] - m' P_m(\kappa') = a \quad (2.18)$$

$$a'(\delta', h', m', g') = b' + \max\{0, (1 - \delta')g' - m'\} + (1 - \tau)y' \quad (2.19)$$

In the appendix it is shown that the recursive problem of the household has a unique solution:

⁸Clearly this separation hinges crucially on the existence of frictionless housing and rental markets and the perfect substitutability of owner occupied housing and rentals in providing housing service flows.

Proposition 11. *Suppose that $u(\cdot; P_l)$ is unbounded from below and bounded from above. Then recursive problem of the household has a unique solution $v(a, y)$ that is strictly increasing in its first argument a .*

The fact that the utility function is bounded from above guarantees that even as the cash at hand of a household diverges, the value function will remain bounded. Therefore, since the utility function is unbounded from below, it will always be optimal to set consumption expenditures c strictly away from zero, since contemporaneous utility diverges to negative infinity as consumption goes to zero, but the continuation value is bounded for all levels of saving. Note that if the utility function U will be of CRRA form with risk aversion coefficient $\sigma > 1$ (with Cobb-Douglas aggregator between consumption and housing) as in our quantitative analysis, then the indirect utility function u satisfies the assumptions made in proposition 11.

2.2.4 Characterization of the Household Problem

A partial characterization of the household problem is now provided. Define as

$$P(\kappa') := 1 - P_l - \kappa' P_m(\kappa') \quad (2.20)$$

the net *per unit* resources required to purchase g' housing assets, partially financed by a mortgage with leverage $\kappa' = m'/g'$. Note that

$$g' P(\kappa') = (1 - P_l)g' - m' P_m(m'/g'). \quad (2.21)$$

Using this definition the following holds:

Proposition 12. *If $u(c; P_l)$ is differentiable in c , then for any state s for which it is optimal to choose an interior solution to the portfolio choice problem ($g', b', m' > 0$) in the current and subsequent period, the Euler equation governing for the household*

is given by:

$$[P_b + P'(\kappa')]u'(c(a, y); P_l) = [1 - F(1 - \kappa')] \beta \sum_{y' \in Y} \pi(y'|y)u'(c(b' + (1 - \tau)y', y'); P_l) \quad (2.22)$$

Further, at any such point the optimal leverage κ' chosen by the household is determined by:

$$P(\kappa') - (1 + \kappa') P'(\kappa') = 1 - P_l \quad (2.23)$$

This partial characterization helps illustrate why households might simultaneously choose to borrow and save. First, note from Proposition 1 that when the default probability is zero, in the benchmark case with subsidy, households can borrow at a rate $r_b + r_w$ and save in bonds at rate r_b . If r_w were to equal zero, there would be an indeterminacy between saving and borrowing, conditional on choosing mortgages with zero default probability. Having a positive cost of issuing a mortgage, $r_w > 0$, eliminates that indeterminacy and creates a wedge between the borrowing and saving rate, even in the absence of default. However, even when there is a wedge in the interest rates between borrowing and saving, it may be optimal for households to simultaneously save and hold mortgages (i.e. borrow).

Equation (2.22) emerges by inserting the first order condition for mortgages m' into the first order condition for risk-free bonds b' (and using the envelope condition). It equates the costs and benefits from a joint marginal increase in bond holdings b' and mortgages m' (holding housing g' constant). On the cost side, an extra bond costs P_b , and a simultaneous increase in mortgages by one unit brings revenue

$$P_m(\kappa') + \frac{m'}{g'} P'_m(\kappa') = -P'(\kappa') > 0 \quad (2.24)$$

and thus the net cost of this marginal variation is the left-hand side of equation (2.22), $P_b + P'(\kappa')$. In utility terms, the cost amounts to $[P_b + P'(\kappa')] u'(c)$. One can

interpret $P_b + P'(\kappa')$ as the *insurance premium* of borrowing in mortgages to save at the risk free rate. On the benefit side, in states δ' in which the household does not default, she has to pay back the extra unit of the mortgage, but receives the extra bond payoff, which nets out to zero. For states δ' in which the household defaults, however, she still receives the extra unit of consumption from the bond payoff (which the household values at $u'(c')$), but does not have to repay the extra unit of the mortgage. The risk-free bonds thus provide insurance against low consumption in default states. The default probability is given by

$$1 - F(\delta^*(\kappa')) = 1 - F(1 - \kappa'). \quad (2.25)$$

Thus the expected benefit, in utility terms, from the joint marginal variation in b', m' is given by the right hand side of equation (2.22). This equation therefore shows why a household would simultaneously save at a low risk-free rate and borrow (in defaultable mortgages) at a higher rate: this strategy, together with the default option, provides insurance against low consumption in high δ' states, for which the household is willing to pay an insurance premium.

Equation (2.23) then shows that conditional on wanting to “borrow to save” there is a unique optimal value κ' at which to do so. Thus the proposition predicts that the optimal policy function for leverage κ' is flat over that region of the state space for which the household finds it optimal to “borrow to save”. Our quantitative analysis below will demonstrate that this is indeed the optimal portfolio strategy for a significant part of the state space.

2.2.5 Bounds on the Equilibrium Rental Price of Housing

After having partially characterized the household problem an upper bound is derived on the rental price P_l , one of the two prices to be determined in general equilibrium.⁹

⁹The equilibrium bond price P_b satisfies $P_b < 1/\beta$, as in Aiyagari (1994).

For all feasible choices of the household it has to be the case that $P(\kappa') = 1 - P_l - \kappa' P_m(\kappa') \geq 0$, otherwise the household can obtain a positive cash flow today by buying a house with a mortgage; the default option on the mortgage guarantees that the cash flow from the house tomorrow is non-negative. Thus, the requirement of absence of this arbitrage opportunity in equilibrium requires $P(\kappa') \geq 0$ for all κ' , and, in particular, for $\kappa' = \bar{\kappa}$. Thus

$$P(\kappa' = \bar{\kappa}) = 1 - P_l - \bar{\kappa} P_m(\kappa' = \bar{\kappa}) \geq 0 \quad (2.26)$$

which implies

$$\begin{aligned} P(\bar{\kappa}) &= 1 - P_l - \bar{\kappa} P_m(\bar{\kappa}) = 1 - P_l - \left(\frac{1}{(1+r_b)(1+r_w)} \right) \gamma(1 - E(\delta')) \geq 0 \text{ or} \\ P_l &\leq 1 - \left(\frac{1}{(1+r_b)(1+r_w)} \right) \gamma(1 - E(\delta')) = \frac{r_b + r_w + r_b r_w + \gamma E(\delta') + 1}{(1+r_b)(1+r_w)} \quad (2.27) \end{aligned}$$

which places an upper bound on the equilibrium rental price.¹⁰

Appendix B.1.4 includes a discussion of why the riskiness of the housing asset puts also puts a lower bound on the expected return from housing, and thus a lower bound on the rental price P_l , which given in our quantitative applications by $P_l \geq \frac{r_b + E(\delta')}{1+r_b}$.

These bounds bracket the equilibrium rental price and are thus very useful for the computation of the model. Equipped with the theoretical characterization of household portfolio behavior, of the high-dimensional equilibrium mortgage interest rate function $r_m(\kappa')$ and the bounds for the equilibrium rental price P_l , we now proceed to the quantitative assessment of the aggregate and distributional consequences of the government interest rate subsidy.

¹⁰If $\gamma = 1$, this condition simply states that the rental price P_l cannot be larger than the user cost of housing, inclusive of the cost r_w of originating mortgages $\frac{r_b + r_w + r_b r_w + E(\delta')}{(1+r_b)(1+r_w)}$.

2.3 Calibration

The model is mapped to the US during the years 2000-2006, a period prior to when the implicit bailout guarantee turned explicit. Some parameters are selected exogenously; the remaining parameters are calibrated jointly in the model.

2.3.1 Technology and Endowments

Income process: For a continuous state $AR(1)$ process of the form

$$\log y' = \rho \log y + (1 - \rho^2)^{0.5} \varepsilon \quad (2.28)$$

with $E(\varepsilon) = 0$ and $E(\varepsilon^2) = \sigma_\varepsilon^2$, the unconditional standard deviation is σ_ε and the one-period autocorrelation (persistence) is ρ . Estimates for ρ in the literature center around values close to 1. Motivated by Storesletten et al. (2004) $\rho = 0.98$ is selected. Estimates for σ_ε range from 0.2 to 0.4 (see e.g. Aiyagari, 1994), and $\sigma_\varepsilon = 0.3$ is chosen. The $AR(1)$ process is approximated with a 5 state Markov chain using Tauchen and Hussey's (1991) procedure. B.2.2 gives the values for the income realizations, Markov transition matrix π and the invariant distribution Π .

Foreclosure technology: Two recent studies, Pennington-Cross (2006) and Campbell, Giglio and Pathak (2011), estimate the default loss parameter γ . Pennington-Cross studies liquidation sales revenue from foreclosed houses and compares it to market prices constructed via the OFHEO repeat sales index. Campbell, Giglio and Pathak have access to zip code level data in Massachusetts and compare foreclosed home sales to regional prices. Pennington-Cross finds that the average loss in foreclosure is 22% as opposed to 27% in Campbell, Giglio and Pathak. Since they use data from only one state, as compared to national estimates from Pennington-Cross (and their estimates are relatively close anyhow), the lower value is chosen, hence

$\gamma = 0.78$.

The depreciation process: The house value price depreciation process is calibrated to attain realistic levels of default in the model while at the same time generating the statistical properties of *idiosyncratic* house price appreciation and depreciation rates observed in the data. Since the analysis conducted is steady state, the aggregate component of house price fluctuations and secular aggregate house price growth are abstracted from.

According to the Mortgage Banker Association (MBA (2006)), the quarterly foreclosure rate has been about 0.4 percent in between 2000 and 2006. Abstracting from the possibility that one house may go in and out of foreclosure multiple times within one given year, this implies that on an annual basis, banks start foreclosure proceedings on about 1.6 percent of their mortgages. The ratio of mortgages in foreclosure that eventually end in liquidation was about 25 percent in 2005, according to MBA (2006). Most homeowners avoid liquidation by either selling their property, refinancing their mortgage or just paying off the arrears. Consequently, only about 0.4 percent of mortgages actually end up in liquidation, in the way our model envisions it. Given the unusually strong aggregate home price appreciation over the 2000-06 period this figure is viewed as a lower bound on the long-run foreclosure rate (that rate certainly increased strongly in subsequent years) and thus a default rate of 0.5 percent of all mortgages is targeted.

Two empirical moments of house price depreciation are targeted, the mean and the standard deviation. The mean depreciation for residential housing according to the Bureau of Economic Analysis was 1.48% between 1960 and 2002 (with standard deviation 0.05%), computed as consumption of fixed capital in the housing sector (Table 7.4.5) divided by the capital stock of residential housing. With respect to the standard deviation of idiosyncratic house price depreciation shocks, we utilize data from the Office of Federal Housing Enterprise Oversight (OFHEO). OFHEO models

house prices as a diffusion process and estimates within-state and within-region annual house price volatility. The technical details can be found in the paper by Calhoun (1996). The broad range for the eight census regions is an annual volatility of 9 – 10% in the years 1998-2004. The upper bound $\sigma_\delta = 0.10$ is used to account for the fact that nationwide house price volatility is slightly higher than the within-region volatility.

Using a log-normal distribution for house price appreciation of real estate in our model, with the mean and standard deviation as stated above, does not generate a sufficiently large share of foreclosures, since, at least within the context of our model, the right tail of the distribution appears to be too thin to reproduce the empirical foreclosure target. In order to obtain more empirically realistic levels of mortgage default a generalized Pareto distribution is used (which has a fatter right tail, relative to a log-normal distribution) whose probability distribution function is given by:

$$f(\delta) = \frac{1}{\sigma_\delta} \left(1 + \frac{k(\delta - \underline{\delta})}{\sigma_\delta} \right)^{\left(-\frac{1}{k} - 1\right)} \quad (2.29)$$

With this parametric form for the house price depreciation distribution there are three parameters $k, \sigma_\delta, \underline{\delta}$ to pin down three moments: the mean depreciation rate, its standard deviation and the equilibrium share of mortgages in default that the model generates endogenously.¹¹

2.3.2 Preferences

For the period utility function, a CRRA form with a Cobb-Douglas aggregator between nondurable consumption and housing services is assumed.

$$U(\tilde{c}, h) = \frac{(\tilde{c}^\alpha h^{1-\alpha})^{1-\sigma} - 1}{1 - \sigma} \quad (2.30)$$

¹¹It is understood that, strictly speaking, all parameters determine all endogenous variables jointly.

Note that this functional form implies an indirect utility function of

$$u(c; P_l) = \frac{\Phi(P_l)c^{1-\sigma} - 1}{1 - \sigma} \quad (2.31)$$

where $\Phi(P_l) = (\alpha^\alpha(1 - \alpha)^{1-\alpha}P_l^{\alpha-1})^{1-\sigma}$.

The parameter α is chosen such that the share of housing in total consumption expenditures matches NIPA data, according to which this share has been fairly steady at 14.1% over the last 40 years, with a standard deviation of only about 0.5%. This yields a value of $\alpha = 0.8590$.

The time discount parameter β and the CRRA parameter σ are endogenously calibrated to match an equilibrium risk free rate of 1% and a median household leverage of 61% in the benchmark economy. Data from the 2004 Survey of Consumer Finances is used and our attention is restricted to households with heads aged 50 and younger, in order to control for strong life-cycle trends in leverage. Household leverage is then computed using data on houses owned and mortgages owed on those homes. The median leverage is calculated to be 61% from these SCF data. The resulting preference parameters are $(\beta, \sigma) = (0.919, 3.912)$.

2.3.3 Mortgage Parameters

For the interest rate subsidy it is assumed that the pass-through of the subsidy is 100%, in order to make the case for the subsidies most favorable. The size of the subsidy is chosen to match the estimated implicit interest rate differential of 30 basis points that the GSE's enjoyed during the period of their implicit guarantee by the government, see Lucas and McDonald (2010). Finally a mortgage administration cost r_w of 10 basis points is chosen, equal one third of the mortgage subsidy. This choice corresponds to an annual cost of \$100 for servicing a \$100,000 mortgage. Tables 1 and 2 summarize our parameterization of the model.

2.4 Results

Before analyzing the effects of the bailout policy by comparing the equilibria with and without the policy in place it is instructive to explain household behavior in the baseline economy. In figures 2.1 and 2.2 the housing and leverage policy functions of households are plotted under both policy scenarios, as a function of cash at hand a , conditional on the lowest and highest realizations y_1 and y_5 of current labor income y . Note that by the definition of cash at hand, $a \geq y$, and thus the policy functions for $y = y_5$ starts to the right (along the x-axis) of that for $y = y_1$.

From figure 2.1 observe that, with the subsidy, purchases of housing assets are monotonically increasing in cash at hand. Figure 2.2 displays the fact that leverage is high (at close to 80%) for households with little wealth under this policy scenario. Leverage then drops quickly, as cash at hand increases, to around 61% and remains constant at that level. From the threshold for cash at hand for which a leverage of 61% is optimal onwards households no longer reduce leverage with increasing “wealth” a , but start purchasing *bonds*, as can be seen from the bond policy function for the subsidy case, displayed in figure 2.3. As cash at hand increases further leverage remains constant, and the holdings of bonds b' , the housing asset g' and mortgages m' rise.

This behavior is exactly what proposition 12 above predicts: households with high wealth both borrow through high-interest mortgages and save with low-interest bearing bonds. These households want to take advantage of the high return on housing, but would also like to insure consumption against adverse house price shocks. Positive bond holdings are essentially consumption insurance against bad δ' realizations that might trigger default and would thus reduce total wealth to zero, in the absence of positive bond holdings. If in addition labor income tomorrow is low, $y' = y_1$, then a portfolio mix without positive bond holdings would lead to very low consumption realization in bad idiosyncratic states of the world (e.g. $y' = y_1$ and high δ'). In order

to maintain a level of consumption above that of labor income it is therefore optimal to hold bonds as insurance. Note that equation (2.23) determines uniquely the constant (in cash at hand a) optimal leverage of these households, which is calculated to be 61% in the baseline model.¹²

2.4.1 Effects of Removing the Subsidy on Household Behavior

Now the bailout policy is evaluated, comparing steady state equilibria of economies with and without a tax-financed mortgage interest rates subsidy of 30 basis points. First the change in household behavior induced by the removal of the subsidy is analyzed, and then its aggregate, distributional and welfare implications are discussed.

The main economic impact on households from removing the subsidy is to make mortgages less attractive by increasing the effective interest rate. The most notable difference in household choices can thus be seen in the leverage and bond policy functions in figures 2.2 and 2.3 respectively, where each of the two panels plots the policy functions for both cases (subsidy, no subsidy) against cash at hand, for a given current income level $y \in \{y_1, y_5\}$. Observe that for households with low levels of cash at hand the change in behavior induced by the removal of the subsidy is modest: under both policy scenarios households with little wealth take on highly leveraged mortgages and hold no bonds. As households get wealthier, however, without the subsidy leverage decreases monotonically to zero. In the absence of the mortgage interest subsidy wealthy households do *not* simultaneously hold bonds and mortgages, since

¹²Note that since asset poor households do not buy any bonds, households allocate a larger share of their portfolios to bonds as cash at hand increases. This behavior of households may sound counterintuitive at first, but is consistent with results from the portfolio choice literature (see e.g. Cocco et al. (2005) or Haliassos and Michaelides (2001)). These papers argue that it should be households with high cash at hand that hold a higher share of their portfolio in the safe asset since these households have high financial relative to human wealth (the present discounted value of future labor income). Consequently, these households expect to finance their current and future consumption primarily with capital income, whereas low cash-at-hand people tend to rely mostly on their labor income. Thus it is relatively more important for the high cash at hand people not to be exposed to large financial asset return risk. In fact, since idiosyncratic labor income shocks and house depreciation shocks are uncorrelated in our model, housing is not a bad asset for hedging labor income risk (of course the bond is even better in this regard, but it has a lower expected return).

the wedge in the interest rate between saving and borrowing (even absent default risk) increases from 10 to 40 basis points. Thus the change in the policy induces a massive reduction in leverage for wealthier households, and thus a substantial reduction in mortgage debt held by these households.

As figure 2.1 shows, the effect on the housing choice is much smaller though. These two observations also imply that the removal subsidy causes a shift in the balance of the household portfolio away from *bonds* and towards *home equity* as seen in figure 2.4. As a consequence of this general shift in households' portfolio composition, the share of bonds in the net worth portfolio of the *median* household declines substantially: whereas this household holds 60.7% of its net worth in bonds with the mortgage subsidy, this share drops to 5.8% without the subsidy.

2.4.2 Aggregate Effects of Removing the Subsidy

How the change in household behavior translates into the main macroeconomic aggregates is summarized in table 2.3. Aggregate mortgages taken out by households decline sharply, by 91%. Despite this, the overall impact on aggregate investment into housing is actually slightly positive: the stock of housing properties increases by 2.38%. Household labor income net of taxes increases by 0.97%, exactly the amount required to finance the interest rate subsidy in equilibrium.

The behavioral changes induced by a change in the subsidy in turn have significant general equilibrium price effects. Since the supply of housing increases, the equilibrium rental price of housing decreases, by slightly more than one percent. The equilibrium risk-free interest rate r_b declines by a substantial 48 basis points in response to the removal of the subsidy since the demand for loans to finance house purchases collapses. Note that the effective equilibrium interest rate on borrowing, holding leverage constant, actually *decreases* by 18 basis points in the absence of the subsidy, since the 30 basis point increase due to the removal of the subsidy is more

than offset by the general equilibrium. This highlights that the key margin governing household asset and portfolio choice is not so much the absolute cost of borrowing or return on saving, but the *wedge between the borrowing and saving rate*. With the subsidy, and for a mortgage with zero default risk, the difference in interest rates on saving and borrowing was 10 basis points, equal to the per dollar cost r_w of originating and maintaining the mortgage. Without the subsidy, the effective interest rate on borrowing is 40 basis points higher than (and thus almost double) than that of saving. This massive reduction in the attractiveness of mortgage borrowing is also reflected in a decline in aggregate default rates which fall from 0.51% to 0.41% per year. Note that since foreclosure is costly in terms of resources (banks only recover a fraction γ of the value of the home), the reduction in foreclosure rates due to the removal of the subsidy will be a key factor in the welfare evaluation of the change of the government's policy.

Given that the subsidy only benefits home owners one would expect that removing it has important consequences for the distribution of home ownership, wealth and welfare. Since the only asset in positive net supply is real estate and, as was already documented, the stock of houses increases by 2.71% due to the removal of the subsidy, so does total wealth in the economy. However, median net worth falls, about 1.4%. This rising gap between average and median wealth suggests that the distribution of wealth becomes more dispersed without the subsidy, which is confirmed by a mild increase in the Gini coefficient for (net) wealth from 0.471 to 0.478. Figure 2.5 which displays the stationary wealth distributions with and without policy suggests that this is mainly due to a larger fraction of households at the borrowing constraint and a slightly fatter right tail of the wealth distribution in the scenario without the subsidy. Thus if wealth inequality is a direct concern of policy makers the removal of the subsidy is counterproductive along this dimension, although the effects of the subsidy policy on wealth inequality is quantitatively small.

Another potential rationale for (indirectly) subsidizing mortgage interest rates on the part of the government is to increase home ownership rates in the economy. Table 2.3 shows that if this is indeed the ultimate goal of the government, it is successful, according to our model. The fraction of households that own some real estate, $\mu(g' > 0)$, is slightly higher with than without the interest rate subsidy. The fraction of households that own at least as much real estate as they use for their own housing service consumption, $\mu(g' > h)$ increases more substantially, from 40% to 44% with the subsidy. Even though in our model owning real estate is not directly linked to using that same real estate as owner occupied housing¹³, the fraction of households with $g' \geq h$ is perhaps the best proxy of home ownership rates in our model, and it is negatively affected by the removal of the government subsidy.

2.4.3 Welfare and Distributional Implications of the Policy

The welfare consequences of the reform are now discussed. Removing the mortgage interest rate subsidy increases aggregate steady state welfare, as measured by consumption equivalent variation (CEV), by a non-negligible 0.5%. That is, household consumption (of both nondurables and housing services) in the steady state with the subsidy has to be increased by this percentage in all states of the world and for all households, such that a household is indifferent ex ante (that is, prior to knowing what part of the distribution he will be born into) between being born into the steady state with or without the subsidy.¹⁴

Figure 2.6 sheds some light which households which characteristics (a, y) benefit from the subsidy. The figure plots the steady state consumption equivalent gain

¹³In our model nothing links the housing stock g' a household owns to the housing services h she consumes, but it is convenient for the interpretation of our results to make that association.

¹⁴Steady state welfare comparisons can be problematic since they ignore the welfare consequences of the transition path towards the new steady state (and thus the cost of additional accumulation of physical capital or the stock of housing). In our model without capital the only transitional cost stems from building up the modest extra 2.4% of the housing stock. One therefore might expect the welfare gains from removing the policy to be somewhat smaller, but still positive in the aggregate, once the transitional costs are fully accounted for.

for households with different income realizations against cash at hand.¹⁵ This plot should be understood as a quantitative answer to the following hypothetical question: in which economy would someone with state (a, y) prefer to start her life, an economy with or without subsidy? Our results indicate that the welfare gains from the subsidy are monotonically increasing in wealth, with wealth-poor households preferring to start life in the economy without subsidy while households with high wealth benefit from the subsidy. Similarly, holding wealth fixed higher current income households view the mortgage interest rate subsidy more favorably than income-poor households.

The heterogeneity in the welfare assessment of the policy across households is due to the following factors. First, the subsidy keeps interest rates on the financial assets of wealthy households high (since the subsidy fuels a stronger mortgage demand), and second, it provides these households (which invest in bonds and leverage substantially in real estate) with a direct interest rate subsidy for this investment strategy. Poorer households, on the other hand, derive a larger share of their current resources from labor income which is subject to the income tax that finances the mortgage rate subsidy. Thus these households would prefer having the subsidy and the tax that comes with it removed. This is especially true if their wealth is so low that debt-financed investment into real estate becomes suboptimal for the household, and thus the subsidy does not apply to them.

We conclude (and view this as perhaps our most important normative finding) that masking the aggregate moderate welfare gains from removing the policy is a substantial heterogeneity in the welfare assessment of this policy across the population. The disagreement between households is quantitatively sizable: the poorest member of society would pay in excess of 1% of lifetime consumption to get rid off the policy, whereas households with wealth twice the average would lose more than 1% from the same policy reform.

¹⁵The same comments about ignoring the welfare effects along the transition apply, as before.

2.4.4 The Optimal Size of the Mortgage Interest Rate Subsidy

The previous discussion begs the question what size of a (potentially negative) subsidy is optimal, given the *utilitarian steady state social welfare function* employed above. The answer is not obvious in a model with incomplete markets and rich household heterogeneity, but is straightforward to derive computationally. A smaller (relative to the benchmark) but positive subsidy of 9 and 3/8 basis points maximizes social welfare. Table 2.4, column 3, displays the aggregate and distributional consequences of implementing the optimal subsidy. In order to understand why, in figure 2.6 consumption equivalent variation (CEV) for households with different characteristics is plotted and the optimal subsidy of 9 and 3/8 basis points, side by side with the CEV's from an elimination of the subsidy. Recall that the CEV's measure the welfare gains (or losses), relative to the benchmark case, a subsidy of 30 basis points. Notice that with the zero subsidy the CEV plots are steeper, relative to the $9\frac{3}{8}$ basis point subsidy. Low income, low CAH households benefit more from the complete removal of the subsidy, mainly because of the decrease in tax burden. However, examining the difference in household portfolio choices it becomes clear why a positive subsidy is optimal. In the baseline economy high CAH households take on large mortgages, subsidized by the government. However, as the value of the subsidy falls, these high CAH households no longer exhibit the "borrow-to-save" behavior. Essentially the lower subsidy disincentivizes wealthy households from trying to get "government financed" insurance. However, it still allows lower CAH households to engage in this strategy. The optimal subsidy imposes a small tax burden on the very low CAH, but still subsidizes "middle class" households for obtaining insurance against catastrophic house depreciation shocks. Using a utilitarian social welfare function to aggregate the welfare gains and losses then delivers the optimal subsidy rate. Of course it is important to note, in comparing the status quo, the optimal policy and the no-subsidy case, that neither policy *Pareto-dominates* another policy, and what we term "optimal" is

only socially optimal under our specific (but very commonly used in the literature) social welfare function.

2.5 Sensitivity Analysis

This subsection contains a discussion of two strong assumptions that have been made so far and to what extent they affect our substantive positive and normative conclusions. First, a production economy is introduced. Second, assets that allow for the diversification of house price risk are introduced.

2.5.1 Other Assets in Positive Supply: Introducing Capital

In the model discussed so far the only asset in *positive net supply* was risky housing. This assumption helped us to isolate the role of mortgages and foreclosure in hedging idiosyncratic house price risk. The analysis is extended to a production economy with physical capital as in Aiyagari (1994), but with risky real estate and housing services, as in the benchmark economy. Appendix B.3.1 discusses the details of the model and its calibration, and table 2.4, columns 4 and 5, summarize the results. In a nutshell, as the table shows, the introduction of physical capital leaves the results of the policy analysis qualitatively, and to a large extent quantitatively unchanged *if we re-calibrate the model* to be consistent with the same targets as was the model without capital.¹⁶ Note, though, that the risk free interest rate in the economy with capital is somewhat less sensitive to the removal of the subsidy due to the curvature in the production function.

The one quantitative exception are the welfare gains from the removal of the sub-

¹⁶Such re-calibration to match the same median leverage ratio and risk free interest rate requires increasing the risk aversion and prudence parameter σ from 3.9 to 7.5, and reducing the time discount factor β from 0.92 to 0.89. Under the *old calibration*, but in the model with capital, the appendix shows that since households save predominantly in riskless capital, the demand for riskless assets and mortgages completely collapses. It is our belief that this economy is not a useful laboratory to analysis the hypothetical policy reform since it results in the counterfactual absence of any meaningful mortgage market. And of course, if there are no mortgages traded in equilibrium, a policy that subsidizes these mortgages has no effect.

sidy, which are *significantly larger* in the economy with capital, thus *reinforcing* the normative point we wish to make. The key difference to the economy without capital is a larger value of the risk aversion (prudence) parameter σ , which induces households to save more in order to absorb the additional supply of assets (the physical capital stock), but also implies a larger curvature in the utility and thus value function of households. Thus a policy reform (such as the removal of the subsidy) that redistributes from rich (high income and cash at hand) to poor households constitutes larger aggregate welfare gains, under our utilitarian social welfare function.

2.5.2 Diversification of Idiosyncratic House Price Risk

In our model with idiosyncratic house price risk households have a strong incentive to pool that risk, something that the benchmark version of the model rules out, in the same way explicit insurance against the idiosyncratic income risk households face is ruled out, in line with the standard incomplete markets literature. Although it is empirically plausible to assume that *idiosyncratic* house price risk cannot be fully diversified through trading state-contingent claims that pay off contingent on individual house-specific price shocks, this importance assumption is now briefly explored in two ways. First, a version of the model with a housing mutual fund is analyzed. Second, sensitivity analysis is performed with respect to the variance of the house price shock, in effect assuming that a certain share of house price risk can be fully diversified.

First, consider an extended version of the model where a representative, competitively behaving mutual fund buys a portfolio of houses of positive measure, rents them out and sells the depreciated portfolio of houses tomorrow. Given that the mutual fund holds a positive measure of houses, the expected depreciation rate on its portfolio is risk-free and equal to $E(\delta)$. Households can purchase three assets, financial assets and mortgage-financed individual houses (exactly as in the benchmark model)

as well as the mutual fund. Given that the mutual fund has a risk-free investment strategy, the return on the mutual fund has to equal that of risk free bonds in equilibrium. This in turn implies an equilibrium rental rate of $P_l = \frac{r_b + E(\delta)}{1 + r_b}$, equal to the user cost of housing (see appendix B.3.2). Note that households are still permitted to buy individual houses financed by mortgages, and might do so given the option-like mortgage cum foreclosure contracts available to them.

However, as table 2.4, columns 8 and 9 show, in this version essentially the entire housing stock (more than 99.9%) is held by the mutual fund, the mortgage market shuts down, and thus the removal of the interest rate subsidy has no effect on the equilibrium (since no mortgages are traded with and without the subsidy). Also note that households would be willing to pay 1.7% of permanent consumption (as measured by the *CEV*) to be borne into the economy with the mutual fund, relative to the economy without it, signaling large welfare gains from completing markets with respect to idiosyncratic house price risk.

Second, a version of the model is computed in which the variance of the house price shocks was reduced to half its original size, $\hat{\sigma}_s^2 = 0.5\sigma_s^2 = 0.005$, assuming that the other half is perfectly diversifiable through financial assets we do not spell out explicitly. As table 2.4, columns 6 and 7, display, all qualitative findings remain intact under this specification, but the quantitative welfare effects shrink significantly. This is due to substantially the same reason as for the introduction of the housing mutual fund. With lower house price risk households, especially those with large housing positions and cash at hand, now tend to own real estate outright, rather than finance it with mortgages (since there is less housing risk to hedge, the foreclosure option is less attractive). As house price risk is reduced further, the economy converges to the housing mutual fund economy discussed above.

Thus, and in contrast to introducing capital and production, the assumed presence of significant undiversifiable house price risk is important, quantitatively but even

qualitatively, for our positive and welfare results. In light of the substantial welfare gains that could be achieved by such diversification an investigation of the causes for why markets diversifying this risk do not exist or are imperfect seems an important area of work; see Shiller (2008) for a discussion.

2.6 Conclusions

The future of the GSE's and the role of the government in mortgage market remains a key question facing policy makers. We have constructed an equilibrium model of mortgage debt and foreclosures and use it to evaluate the aggregate and distributional consequences of a stylized bailout guarantee for GSE's. This guarantee leads to excessive mortgage origination, higher leverage and larger foreclosure rates in equilibrium, compared to a world without such a policy. The steady state aggregate welfare gains from abolishing the guarantee are significantly positive, and poor households would strongly benefit from such a reform.

An extension to a nonstationary model with endogenous house prices would lend itself to a quantitative evaluation of how much of the run-up in household mortgage debt and house prices in the early 2000's can be attributed to the government's involvement with the GSE's. It could also be used to study the distributional consequences of the collapse in house prices in a world with high household leverage that is at least partially induced by this involvement. Such an analysis is deferred to future work.

Note: This table presents the parameters calibrated endogenously in the model via a moment matching procedure to match the relevant moments in US data.

Table 2.1: Endogenously Calibrated Parameters

| Parameter | Interpretation | Value | Target |
|----------------------|---------------------------|---------|----------------------------|
| σ | Risk Aversion | 3.912 | Median Leverage |
| β | Time Discount Factor | 0.919 | Risk-free Rate |
| k | Pareto shape parameter | 0.7302 | Foreclosure Rate |
| σ_δ | Pareto scale parameter | 0.0078 | House price volatility |
| $\underline{\delta}$ | Pareto threshold paramter | -0.0077 | Average price depreciation |

Table 2.2: Exogenously Calibrated Parameters

| Parameter | Interpretation | Value | Target |
|------------|--------------------------------------|--------|-----------------------------|
| A_h | Technology Const. in Housing Constr. | 1.0 | none (normalized) |
| ρ | Income Persistence | 0.98 | Storesletten et al (2004) |
| σ_e | Income Variance | 0.3 | Storesletten et al (2004) |
| γ | Foreclosure Technology | 0.78 | Pennington and Cross (2004) |
| α | Share Parameter on Nondur. Cons. | 0.8590 | Exp. Share in BEA |
| ϕ | Implicit Interest Rate Subsidy | 30 BP | Lucas and McDonald (2010) |
| r_w | Mortgage administration fee | 10 BP | |

Note: This table presents the parameters calibrated exogenously (taken from the relevant literature).

Table 2.3: Quantitative Results: Consequences of Removing the Subsidy

| Variable | Subsidy | No Subsidy | Difference |
|-----------------------------|---------|------------|------------|
| % Sub | 30bp | 0bp | -100% |
| Sub/\bar{y} | 0.97% | 0% | -100% |
| P_l | 0.0281 | 0.0278 | -1.1% |
| r_b | 1.0% | 0.518% | -0.482% |
| H | 5.327 | 5.454 | 2.38% |
| M | 3.231 | 0.319 | -91.3% |
| Default share | 0.51% | 0.41% | -19.6% |
| Mean Net Worth | 5.327 | 5.454 | 2.38% |
| Median Bond Portfolio Share | 60.7% | 5.8% | -90.4% |
| Wealth Gini | 0.471 | 0.478 | 1.49% |
| $\mu(g' > 0)$ | 96.74% | 96.66 | -0.08% |
| $\mu(g' > h)$ | 43.51% | 39.77% | -8.60% |
| CEV | -0.6297 | -0.6206 | 0.5%* |

*Computed as consumption equivalent variation, that is

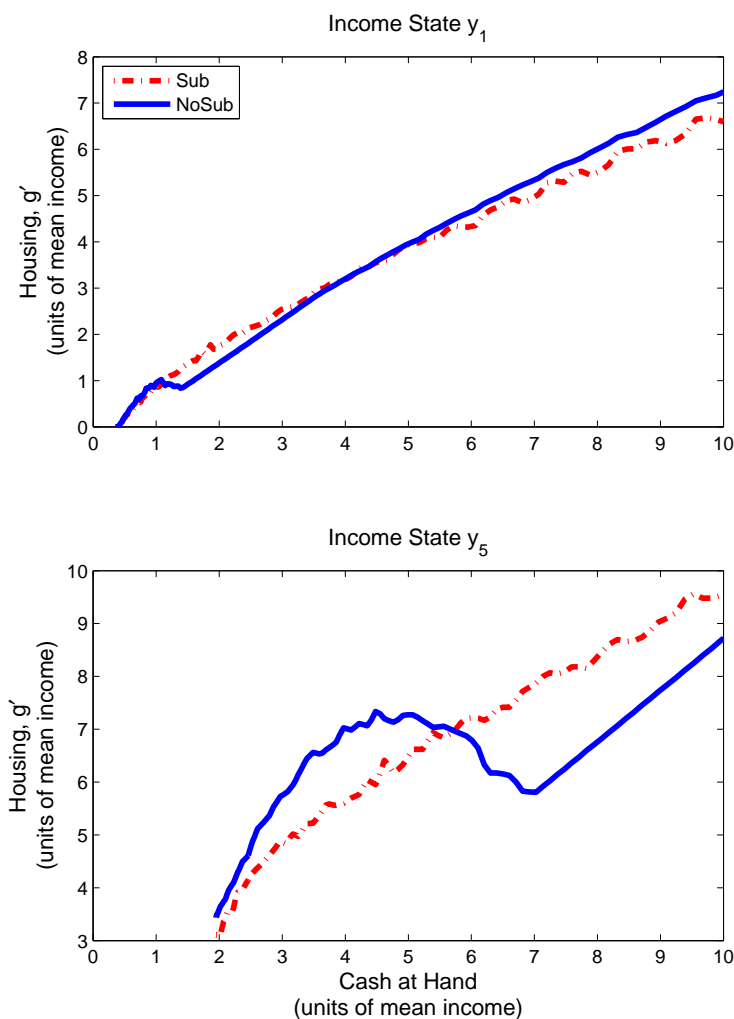
$$(EV_{no\ subs}/EV_{subs})^{1/(1-\sigma)}$$

Note: This table presents relevant aggregate statistics from the baseline economy with the mortgage subsidy and compares it to the economy with the subsidy removed. The welfare comparison is presented in consumption equivalent variation.

Table 2.4: Quantitative Results: Optimal Subsidy and Sensitivity Analysis

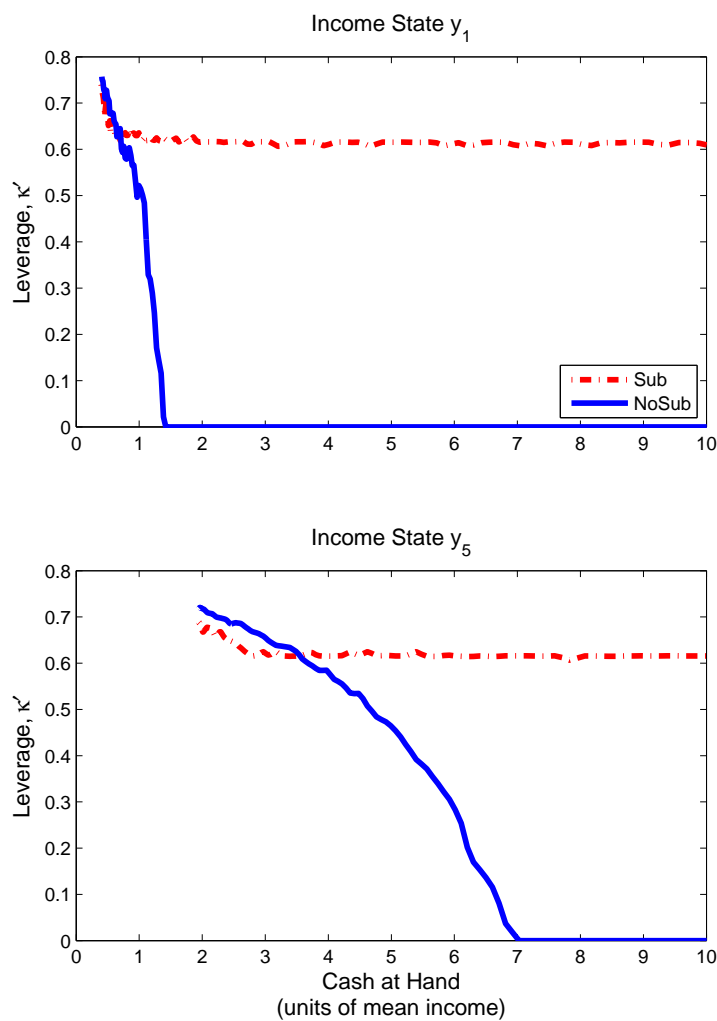
| Variable | Baseline | | | With Capital | | | Var/2 | | | H Mutual Fund | | |
|------------------|----------|--------|---------|--------------|--------|--|--------|--------|--|---------------|--------|--|
| | 30bp | 0bp | 9.375bp | 30bp | 0bp | | 30bp | 0bp | | 30bp | 0bp | |
| % Sub | 61.5% | 0.0% | 0.0% | 61.5% | 0.0% | | 0.7% | 0.0% | | 0.0% | 0.0% | |
| Median Leverage | 1.0% | 0.518% | 0.597% | 1.0% | 0.676% | | 1.043% | 0.783% | | 1.456% | 1.456% | |
| r_b | 0.97% | 0% | 0.04% | 0.96% | 0% | | 0.2% | 0% | | 0% | 0% | |
| $S_{ub/\bar{y}}$ | 0.0281 | 0.0278 | 0.0279 | 0.0296 | 0.0294 | | 0.0281 | 0.0279 | | 0.029 | 0.029 | |
| GDP | 1.15 | 1.151 | 1.152 | 1.585 | 1.587 | | 1.152 | 1.152 | | 1.153 | 1.153 | |
| H/GDP | 4.633 | 4.737 | 4.720 | 3.332 | 3.404 | | 4.683 | 4.723 | | 4.565 | 4.565 | |
| M/GDP | 2.81 | 0.269 | 0.382 | 2.018 | 0.003 | | 0.604 | 0.080 | | 0 | 0 | |
| K/GDP | 0 | 0 | 0 | 2.702 | 2.83 | | 0 | 0 | | 0 | 0 | |
| w | 1 | 1 | 1 | 1 | 1.014 | | 1 | 1 | | 1 | 1 | |
| Default share | 0.51% | 0.41% | 0.49% | 0.49% | 0.3% | | 0.28% | 0.14% | | 0% | 0% | |
| Net Worth/GDP | 4.633 | 4.737 | 5.436 | 6.034 | 6.234 | | 5.393 | 5.44 | | 5.262 | 5.262 | |
| Median b Share | 60.7% | 7.2% | 8.1% | 72.2% | 47.8% | | 12.9% | 1.7% | | 0% | 0% | |
| $\mu(g' > 0)$ | 96.79% | 96.66% | 96.68% | 100% | 100% | | 96.78% | 96.66% | | 14.45% | 14.45% | |
| $\mu(g' > h)$ | 43.00% | 39.77% | 40.71% | 45.7% | 45.9% | | 41.20% | 38.78% | | 0% | 0% | |
| CEV | 0 | 0.81% | 0.85% | 0% | 2.17% | | 0% | 0.13% | | 0% | 0% | |

Figure 2.1: Housing Policy Function With and Without Subsidy



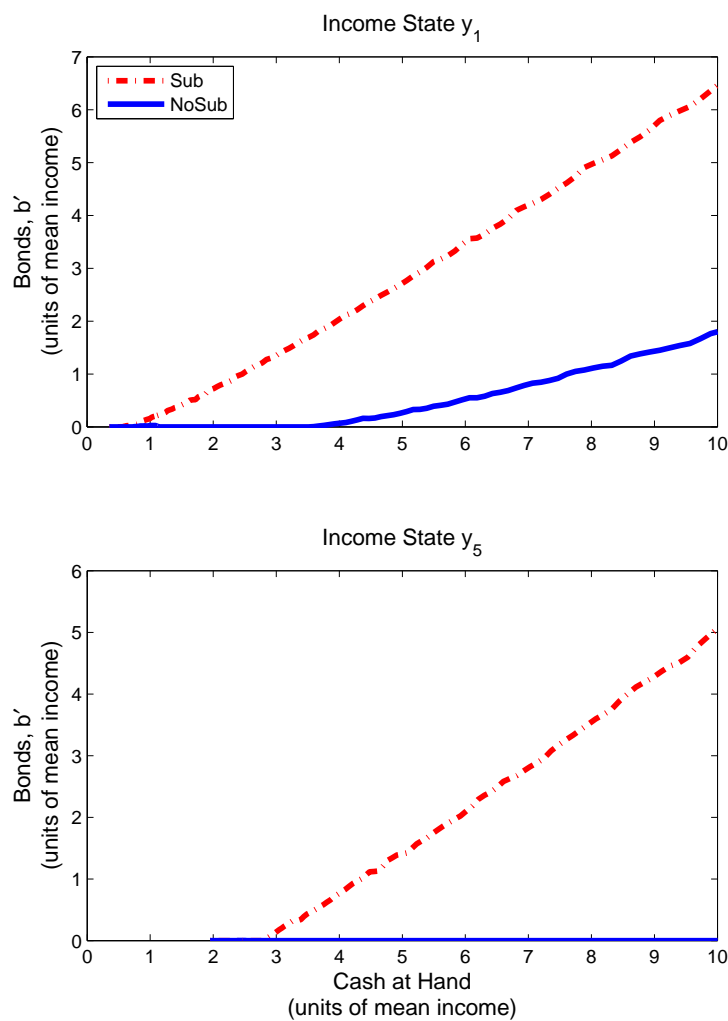
Note: This figure compares the optimal housing choice for a household in the baseline economy and the economy without the subsidy for different levels of cash at hand for the highest and lowest persistent income states.

Figure 2.2: Leverage Policy Function With and Without Subsidy



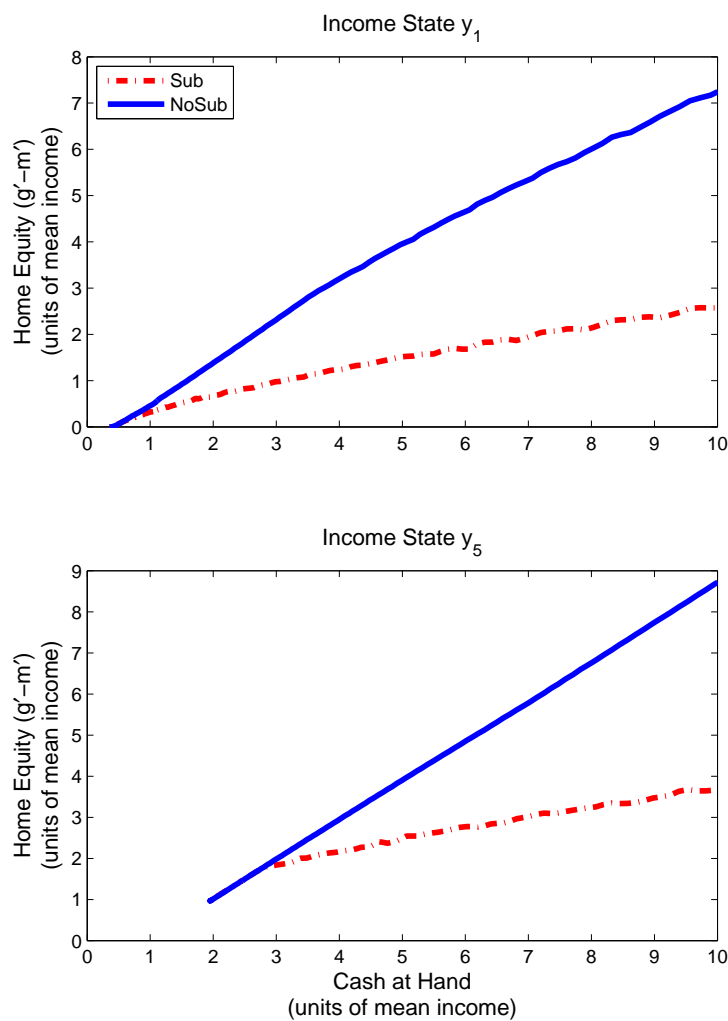
Note: This figure compares the optimal leverage choice for a household in the baseline economy and the economy without the subsidy for different levels of cash at hand for the highest and lowest persistent income states.

Figure 2.3: Bonds Policy Function With and Without Subsidy

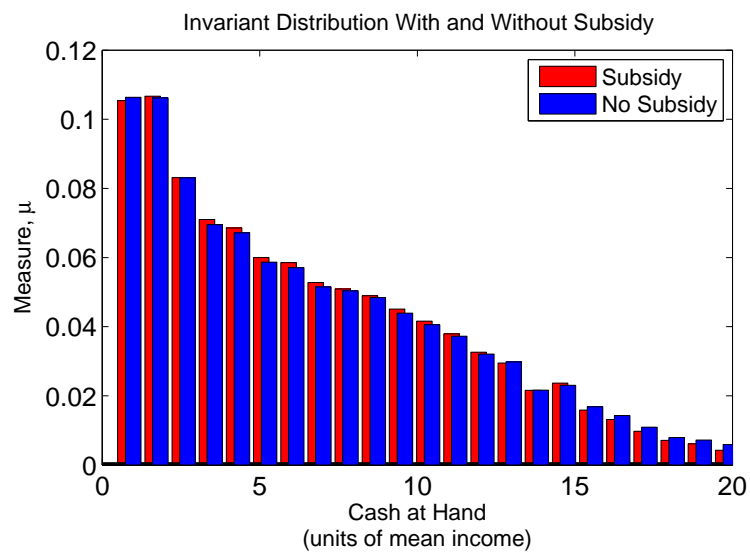


Note: This figure compares the optimal bond choice for a household in the baseline economy and the economy without the subsidy for different levels of cash at hand for the highest and lowest persistent income states.

Figure 2.4: Home Equity Policy Function With and Without Subsidy

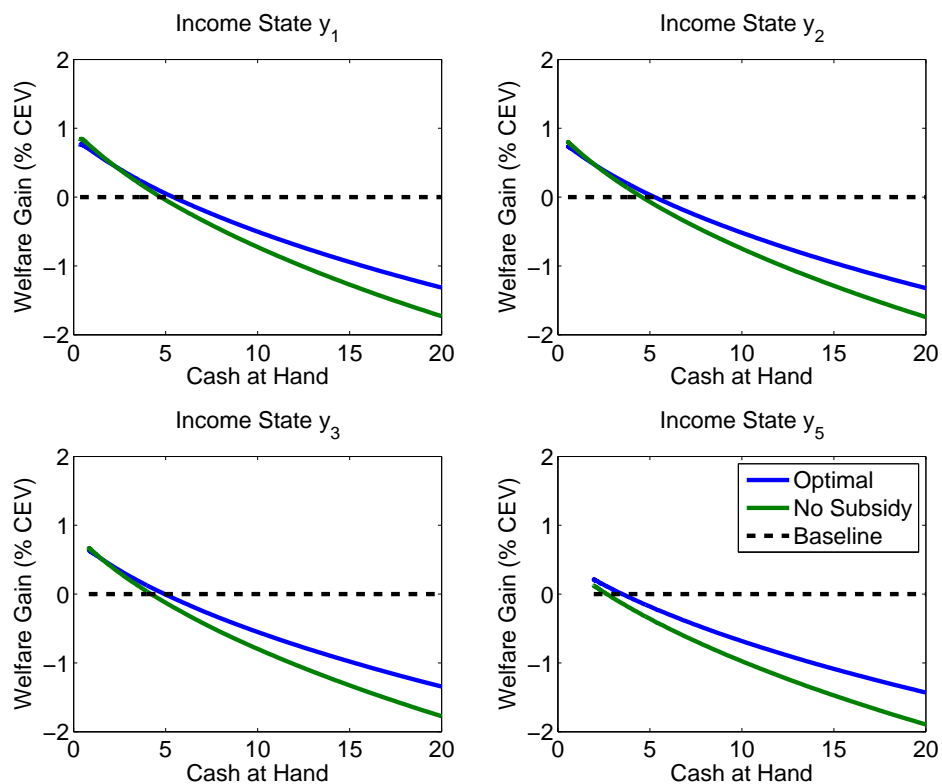


Note: This figure compares the home equity held by a household in the baseline economy and the economy without the subsidy for different levels of cash at hand for the highest and lowest persistent income states.

Figure 2.5: Distribution over Cash at Hand with and without Subsidy

Note: This figure compares the steady state distributions over cash at hand in the baseline economy and the economy without the subsidy.

Figure 2.6: Welfare Comparison



Note: This figure compares welfare in consumption equivalent variation terms between households in the baseline economy, the economy without the subsidy and the economy with optimal subsidy, for different levels of cash at hand for the four of the five persistent income states.

Chapter 3

Unemployment Benefits and Unemployment in the Great Recession: The Role of Macro Effects

A modified version of this chapter originally appeared as Hagedorn, Karahan, Mitman, and Manovskii (2013) and is co-authored with Marcus Hagedorn, Fatih Karahan and Iouri Manovskii.

Unemployment in the U.S. rose dramatically during the Great Recession and has remained at an unusually high level for a long time. The policy response involved an unprecedented extension of unemployment benefits with benefit duration rising from the usual 26 weeks to as long as 99 weeks. The motivation for this policy was to provide “income support for a vulnerable group after they have lost their jobs through no fault of their own” as well as “needed support for the fragile economy.”¹

The effectiveness of this policy response was questioned by Barro (2010) and Mulligan (2012), among others. Because unemployment benefit extensions represent an implicit tax on market work, they subsidize unemployment and discourage labor supply. This may offset some of the stimulative effect ascribed to such policies and explain the persistently high unemployment since the end of the Great Recession. Yet, careful microeconomic studies, reviewed below, have found only very small effects of

¹“Unemployment Insurance Extensions and Reforms in the American Jobs Act,” the report by the President’s Council of Economic Advisers, the National Economic Council, the Domestic Policy Council, and the Department of Labor, December 2011.

unemployment benefit extensions on labor supply.

These studies, however, did not assess the possibility that extensions of unemployment benefits have a large impact on labor demand. Consider the following stylized decomposition:

$$\text{Job finding rate}_{it} = \underbrace{s_{it}}_{\text{search intensity}} \times \underbrace{f(\theta_t)}_{\text{finding rate per unit of } s} \quad (3.1)$$

In other words, the probability that an individual i finds a job in a given time period t depends on how hard that individual searches and how selective he is in his acceptance decisions, which is captured by the “search effort” component s_{it} . It also depends on the aggregate labor market conditions θ_t that determine how easy it is to locate jobs by expending a unit of search effort. To use an extreme example, if there are no job vacancies created by employers, $f(\theta_t) = 0$, no amount of search effort by an unemployed worker would yield a positive probability of obtaining a job.

Changes in unemployment benefit policies affect both the search intensity of unemployed workers and the aggregate job finding rate per unit of search effort through general equilibrium effects. Indeed, in the classic equilibrium search framework of Mortensen and Pissarides (1994), the primary analytical device used by economists to study the determination of unemployment, the response of unemployment to changes in benefits is mainly driven by the response of employers’ decisions of whether and how many jobs to create and not by the impact on workers’ job search and acceptance decisions. The logic of the model is simple. Everything else equal, extending unemployment benefits exerts an upward pressure on the equilibrium wage. This lowers the profits employers receive from filled jobs, leading to a decline in vacancy creation. Lower vacancies imply a lower job finding rate for workers, which leads to an increase in unemployment. Surprisingly, there is little direct empirical evidence on the quantitative magnitude of these effects available in the literature. We attempt

to fill this gap in the literature in this paper.

Our empirical strategy exploits a policy discontinuity at state borders to identify the effects of unemployment insurance policies on unemployment. While we discuss the institutional features of the U.S. unemployment insurance system in detail below, its key property is that unemployment insurance policies are determined at the state level and apply to all locations within a state. One cannot infer the effects of benefit extensions by simply relating benefit duration to unemployment in a panel of states because of the potential policy endogeneity: it might be the states that have a large increase in unemployment that expand benefit eligibility as opposed to raises in benefits leading to higher unemployment. We show, however, that the endogeneity problem can be overcome by comparing the evolution of unemployment in counties that border each other but belong to different states.² Locations separated by a state border are expected to have similar labor markets due to the same geography, climate, access to transportation, agglomeration benefits, access to specialized labor and supplies, etc. Indeed, we provide direct evidence that economic shocks do not stop at the state border but evolve smoothly across borders. The key feature that sets these locations apart is the difference in policies on the two sides of the border. This policy discontinuity allows to identify its labor market implications. A fundamentally similar identification strategy was used, among others, by Holmes (1998) to identify the impact of right-to-work laws on location of manufacturing industry and by Dube, Lester, and Reich (2010) to identify the effect of minimum wage laws on earnings and employment of low-wage workers. We explicitly control for the effects of other policy changes at the state level (that could be correlated with the expansion of unemployment benefit durations) to ensure that our estimates isolate the effects of unemployment benefit extensions.

In Section 3.1 of the paper we extend this empirical strategy to accommodate

²A Map of U.S. state and county borders can be found in Appendix Figure C.2.

features of the policies that we are interested in evaluating (and verify the successful performance of these extensions in the data generated by an estimated equilibrium search model in Section 3.4) as follows:

1. The decisions of firms to create jobs are forward looking. Thus, they might be affected not only by the existing policy but also by the expectation of possible future policy changes. We derive a quasi-difference estimator of the effect of UI policies on variables such as vacancies and unemployment that controls for the effect of expectations. Among other things, this allows us to generalize our findings and estimate the effect of a temporary or permanent change in unemployment benefit duration.
2. Our estimation is based on a panel of border counties over the period of the Great Recession. Numerous shocks and policy changes have affected the aggregate economy but their impact was likely heterogeneous across county pairs. For example, shocks to and changing regulations of the financial system, while aggregate in nature, might have had a particularly strong impact on the counties on the border of New York and New Jersey, while the auto industry bailout likely had a larger impact on counties surrounding the border between Michigan and Indiana or Ohio. Similarly, the aggregate financial crisis potentially had different impact on the states depending on their different foreclosure laws. To obtain consistent estimates of unemployment benefit extensions despite heterogeneous impacts of the aggregate shocks we follow Bai (2009) and use a flexible interactive effects model.
3. An analysis based on a comparison of border counties belonging to states with different policy regimes must account for the possibility that residents of both counties may direct their job search efforts to the county with better labor market prospects. In Section 3.5 we will show that these mobility decisions can be

measured in the data from the observed labor market flows. The estimates reported in that section imply that individuals do not systematically change their location of employment in response to changes in unemployment benefits across states during the Great Recession. This is perhaps not surprising. Residents of the border counties face a trade-off between receiving higher wages with lower job finding probability in a county belonging to the state with higher benefit eligibility and receiving lower wages with higher job finding probability in the state with lower benefits (note that benefits depend on state of employment, and not on the state of residence). Moreover, the difference in the available duration of benefits across border counties is relatively small and may not justify larger commuting expenses. Thus, while we fully control for the response of the location of employment to changes in benefits in Section 3.5, this modification of the analysis turns out to be inconsequential. This leads us to work with a simpler and more transparent specification that ignores mobility decisions in the early parts of the paper.

Following the description of the main data sources we use, in Section 3.3 we measure the effects of unemployment benefit extensions on unemployment. We find that unemployment rises dramatically in the border counties belonging to the states that expanded unemployment benefit duration as compared to the counties just across the state border. The quantitative magnitude of this effect is so large that our estimates imply that benefit extensions can quantitatively account for much of the unemployment dynamics following the Great Recession.

In Section 3.4 we assess whether the mechanisms embedded in the standard equilibrium labor market search model can provide a coherent rationalization of the large effect of unemployment benefit extensions on unemployment that we document. The data suggest an affirmative answer. Consistent with implications of the equilibrium search model, we find that border counties with longer benefit extensions have sig-

nificantly higher wages, lower vacancy rates, and lower employment. The estimated magnitudes of these changes are also quantitatively consistent with the model.

Our estimate of the effect of unemployment benefit extensions on employment is based on the difference across border counties. It is desirable to be able to use the resulting coefficient to predict the effect of a nation-wide extension. A potential concern is that when some states extend benefits more than others, economic activity may reallocate to states with, say, lower benefits. This reallocation is picked up by our estimates but will be absent when the policy is changed everywhere. Our results in Sections 3.4 and 3.5 provide evidence against such a concern. First we find large negative effect of unemployment benefit extensions on employment in sectors commonly considered non-tradable and thus not subject to reallocation. Second, we find that unemployed workers do not change the strategy of which county to look for work in response to changes in benefits.

Finally, in Section 3.6 we briefly consider the implications of our findings for macroeconomic time-series. In particular, we summarize the results in Mitman and Rabinovich (2013), who introduced unemployment benefit extensions into the Mortensen and Pissarides (1994) model calibrated to match the effect of unemployment benefit extensions on unemployment documented in this paper. The model matches nearly perfectly the dynamics of unemployment over the last 60 years. Moreover, the extensions of unemployment benefits generate the apparent shift in the Beveridge curve after the Great Recession that was widely interpreted in the literature as a sign of increased mismatch in the labor market, see Diamond (2013) for a review.

3.0.1 Brief Overview of the Related Literature

We organize the discussion of the related literature on the effects of unemployment benefit extensions on unemployment around the illustrative decomposition in Equation (3.1). As is customary in the literature, we label the impact of benefits on the

search intensity of an unemployed worker, holding aggregate conditions fixed, the “micro” effect. In contrast, the “macro” effect measures the effect of benefits on the job finding rate per unit of search effort.

Seminal Empirical Contributions

The empirical literature on the effects of unemployment benefit extensions is based on the seminal contributions by Moffitt (1985a), Katz and Meyer (1990a), Meyer (1990a), and Card and Levine (2000).³ These authors used administrative data on unemployment benefit recipients and exploited the cross-state variation in unemployment benefit extensions to measure the effect of the extensions on the hazard rate of leaving compensated unemployment.⁴ These estimates were interpreted using a partial equilibrium search model as measuring how individual search efforts respond to changes in benefits holding labor market conditions constant. As these studies focused on a relatively small subsample of unemployed workers who collect benefits, and the authors could not measure the impact of benefit extensions on the search effort of those who do not receive benefits, they could not assess the impact of benefit extensions on overall unemployment.

Micro Effects

In recent, innovative work, Rothstein (2011a) estimates the partial equilibrium effects of the unemployment benefit extensions on labor market outcomes during the Great Recession. Using data from the Current Population Survey (CPS) on individual unemployment duration, he exploits the cross-state variation in unemployment benefit extensions to identify how unemployment benefit durations impact individual search behavior. Importantly, Rothstein (2011a) goes to great lengths to “absorb labor de-

³Krueger and Meyer (2002a) provide a survey of other important contributions to this literature.

⁴While this hazard was originally interpreted as measuring transitions from unemployment into employment, such an interpretation was recently questioned by Card, Chetty, and Weber (2007).

mand conditions” – that is, he controls for any changes in job creation to isolate solely the effect on worker search. For example, in one specification he uses unemployed workers who are ineligible for UI benefits as a control group. If unemployment benefits have a large effect on job creation, the job finding rate of all unemployed workers would drop significantly, but comparing ineligible to eligible would only capture the difference in behavioral response of search effort between workers, not the possibly much larger macro effect. Rothstein (2011a) concludes that the micro elasticity of unemployment duration to unemployment benefits is relatively small, with the estimates implying that only a small fraction of the persistent increase in unemployment after the Great Recession can be attributed to a decline in worker search effort.

In this paper, we aim to exploit the same heterogeneity in policy as in Rothstein (2011a), but with the goal of identifying the labor demand or macro elasticity of unemployment benefits that was beyond the scope of his analysis. We see our work as highly complementary and helping provide the complete picture on the effect of benefit extensions.

Another recent paper, Schmieder, Von Wachter, and Bender (2012) estimates the disincentive effect of unemployment benefits over the business cycle. Using detailed administrative data from Germany they exploit a policy discontinuity based on the age of workers on the day they become unemployed. The months of unemployment benefits a worker is eligible for changes discontinuously at two age cutoffs. Using a regression discontinuity design they are able to estimate the change in the behavioral response due to increased benefit eligibility, and how this response varies with business cycle conditions. They find a small disincentive effect overall that does not vary much with business cycle conditions. However, it is important to note that they also hold constant all market-level factors, and identify only the micro elasticity.

Macro Effects

Starting with the pioneering work of Millard and Mortensen (1997), the evidence on the magnitude of the macro effect is predominantly based on the estimation of structural models.⁵ Clearly, the firm's vacancy creation decision is based on comparing the cost of creating a job to the profits the firm expects to obtain from hiring the worker. The profit is the difference between a worker's productivity and the wage. Hagedorn and Manovskii (2008a) have shown that the fluctuations in aggregate labor productivity of the magnitude observed in the data can account for the observed business cycle fluctuations of aggregate unemployment and vacancies using the Mortensen and Pissarides (1994) model. This implies that the amount of job vacancies is highly responsive to the relatively small business cycle frequency changes in productivity. The flip side of this argument is that changes in unemployment benefit policies that affect wages can have a similar impact on profits also implying a large response of vacancies, and, as a consequence, of unemployment. The persuasiveness of these arguments depends, however, on whether one agrees with the parameter values estimated by these authors. Key among them is the flow utility obtained by unemployed workers. This parameter is difficult to measure directly but its value is crucial for the amount of amplification delivered by the search model. Our objective in this paper is to directly measure the impact of unemployment benefits on the labor market variables of interest without having to rely on the estimates of the flow utility of the unemployed and without having to fully specify the model. Our empirical strategy is, however, consistent with a fully specified model.

⁵One line of research, reviewed in e.g., Costain and Reiter (2008), has studied the effects of unemployment benefits on unemployment using cross-country regressions. While this literature typically finds much larger effects than those implied by the micro studies, these estimates are relatively hard to interpret given the endogeneity problems and heterogeneity across countries that is difficult to control for.

3.1 Empirical Methodology

3.1.1 Identification via Border Counties: Controlling for Expectations

To estimate the macroeconomic effects of unemployment insurance on a variable x_t such as vacancies or unemployment, we first estimate the effect on labor market tightness, θ_t , defined as the ratio of vacancies to unemployment, and therefore look at firms' job creation decision. In the standard Pissarides (2000) model, firms' period t profits from employing a worker are given by the difference between workers' marginal product and the wage. The wage, in turn, is affected by the generosity of unemployment benefits available to the worker. Thus, up to a log-linear approximation with respect to the two state variables of the model, firms' profits from employing a worker are given by:

$$\log(\pi_t) = \gamma_z \log(z_t) - \gamma_b \log(b_t), \quad (3.2)$$

where z_t is workers' productivity and b_t are benefits. γ_z and γ_b are unknown coefficients which the standard theory implies should both be positive, although we do not impose such a restriction. The value of a filled job for the firm is:

$$J_t = \pi_t + \beta(1 - s_t)E_t J_{t+1}, \quad (3.3)$$

where β is the discount factor, s_t is the exogenous probability that the job ends and E_t is the expectation operator using information available at time t . Free entry into vacancy posting implies that the expected cost of posting a vacancy is equal to the value of a filled job. The job creation decision is then

$$q(\theta_t)J_t = c, \quad (3.4)$$

where $q(\theta_t)$ is the probability to fill a vacancy and c is the the cost of maintaining a vacancy. This approximately yields

$$\log(\theta_t) = \tilde{\kappa} \log(J_t). \quad (3.5)$$

We now approximate $\log(J_t)$ as a function of $\log(\pi_t)$, $\log(J_{t+1})$ and an expectational error $\log(\eta_t)$ around the steady state with a constant $\pi = J(1 - \beta(1 - s))$, so that the previous equation reads

$$\log(\theta_t) = \tilde{\kappa} \frac{\pi}{J} \log(\pi_t) + \tilde{\kappa} \beta(1 - s_t) \log(J_{t+1}) + \log(\eta_t). \quad (3.6)$$

Using $\pi/J = (1 - \beta(1 - s))$ and the job creation decision for $t + 1$, $\log(\theta_{t+1}) = \tilde{\kappa} \log(J_{t+1})$, yields

$$\log(\theta_t) = \tilde{\kappa}(1 - \beta(1 - s)) \log(\pi_t) + \beta(1 - s_t) \log(\theta_{t+1}) + \log(\eta_t). \quad (3.7)$$

In quarterly data variables such as unemployment are well approximated by a linear function of $\log(\theta)$:⁶

$$\log(x_t) = \lambda_x \log(\theta_t), \quad (3.8)$$

so that we obtain the quasi-difference

$$\tilde{x}_t := \log(x_t) - \beta(1 - s_t) \log(x_{t+1}) = \tilde{\kappa} \lambda_x (1 - \beta(1 - s)) \log(\pi_t) + \lambda_x \log(\eta_t). \quad (3.9)$$

Now, denote by p the border-county pair. Then, substituting Equation (3.2) into

⁶See, e.g., Hall (2005), Shimer (2007). Below we verify that this approximation also performs well in a calibrated equilibrium search model with unemployment benefit extensions.

Equation (3.9) and differencing between border counties within a pair yields:

$$\Delta \tilde{x}_{p,t} = \alpha \Delta b_{p,t} + \Delta \epsilon_{p,t}, \quad (3.10)$$

where Δ the difference operator over counties in the same pair. More specifically, if counties i and j are in the same border-county pair p , then $\Delta \tilde{x}_{p,t} = \tilde{x}_{p,i,t} - \tilde{x}_{p,j,t}$, and, with a slight abuse of notation, $\Delta b_{p,t} = \log(b_{p,i,t}) - \log(b_{p,j,t})$.

After we describe the structure of the error term $\Delta \epsilon_{p,t}$ in Section 3.1.2, Equation (3.10) can be estimated in the data to recover the coefficient of interest α , which equals, using equations (3.2) and (3.9),

$$-\gamma_b \lambda_x \tilde{\kappa} (1 - \beta(1 - s)). \quad (3.11)$$

Dividing this coefficient by the measurable factor $(1 - \beta(1 - s))$ yields the permanent percentage change of a variable x in response to a permanent one percentage change in the policy variable b , $-\gamma_b \lambda_x \tilde{\kappa}$. More generally, the effect of increasing benefit duration from ω_1 to ω_2 weeks for n time periods is given by

$$\hat{\alpha} \times \frac{1 - (\beta(1 - s))^n}{1 - \beta(1 - s)} \times (\log(\omega_2) - \log(\omega_1)). \quad (3.12)$$

Equation (3.10), which will form the basis of our empirical strategy, differs from the standard specification in the literature in that the left-hand-side variable is the quasi-difference $\tilde{x}_{p,t}$ as opposed to simply $x_{p,t}$. This is essential in our application because vacancy posting decisions by employers are forward looking and are affected by the expectations of future changes in benefits. Moreover, the expectations of the future path of benefits might depend on the benefit level today. For example, suppose raising benefit levels leads to a rise in unemployment. If the benefit level and the duration are increasing in state unemployment, an increase in benefits today makes it then more likely that benefits would be increased further in the future. Since vacancy

creation and, consequently, unemployment respond to this change in expectations, it is clear that the coefficient α in a regression with $x_{p,t}$ on the left-hand side will be a biased estimator of the effect of the current benefit structure on the current variable of interest, such as unemployment.

To clarify how our estimation strategy controls for expectations, recall that our quasi-difference is defined as $\tilde{x}_t := \log(x_t) - \beta(1 - s_t)\log(x_{t+1})$. This works because market tightness in period t , θ_t , depends on expected profits J_t and thus on the whole expected sequence of future benefit levels in $t, t + 1, t + 2, \dots$. Shifting by one period, market tightness θ_{t+1} depends on expected profits in period $t + 1$, J_{t+1} , and thus on the expected sequence of benefit levels in $t + 1, t + 2, \dots$. Since profits in periods t and $t + 1$ are related by the simple accounting identity, $J_t = \pi_t + \beta(1 - s_t)E_t J_{t+1}$, market tightness θ_t depends on current profits π_t (affected by b_t) and on market tightness θ_{t+1} which is linearly related to $E_t J_{t+1}$ and depends on the sequence of benefits (b_{t+1}, b_{t+2}, \dots). As a result, a change in current benefits b_t affects current profits, current vacancy creation and thus the quasi-differenced market tightness. In contrast, changes in future benefits, say b_{t+1} , affect both θ_t and θ_{t+1} . The effect of b_{t+1} on θ_t is discounted by $\beta(1 - s_t)$. The effect of b_{t+1} on θ_{t+1} is not discounted, but is multiplied by $\beta(1 - s_t)$ when constructing the quasi-difference. Thus, the effect of a change in b_{t+1} cancels out in the quasi-difference. By the same logic, the quasi-difference eliminates the effect of a change in b_{t+2}, b_{t+3}, \dots . Thus, our specification allows us to obtain an unbiased estimate of the coefficient α - the effect of a current change in benefits on current profits and current market tightness - despite a forward looking nature of the job creation decision.⁷

In order to ascertain the accuracy of our specification, In Section 3.4.4 we will compare the predicted permanent effect estimated using the proposed method to the actual permanent effect in a calibrated Mortensen and Pissarides (1994) model. We

⁷Obviously, this issue cannot be resolved by including future values of benefits into the regression because they represent a realized path and will bias all the coefficients due to their correlation with today's expectation error.

find that our empirical specification is very accurate in model generated data.

3.1.2 Interactive Effects

The term $\Delta\epsilon_{p,t}$ in Equation (3.10) contains the expectation error and the permanent differences in \tilde{x} across border counties caused by, e.g., permanent differences in tax policies across states they belong to. Moreover, as we mentioned in the Introduction, various shocks have affected the aggregate economy during the Great Recession. But the same aggregate shocks are likely to have a heterogeneous impact on different border county pairs. In this case, estimating the panel regression in Equation (3.10), perhaps with a set of county pair and time fixed effects, might be problematic for inference (see Andrews (2005) for the discussion of this problem in a cross-sectional regression). Fortunately, Bai (2009) has shown that consistency and proper inference can be obtained in a panel data context, such as ours, through the use of an interactive-effects estimator. In particular, we decompose the error term in Equation (3.10) as

$$\Delta\epsilon_{p,t} = \lambda_p' F_t + \nu_{p,t}, \quad (3.13)$$

where λ_p ($r \times 1$) is a vector of pair-specific factor loadings and F_t ($r \times 1$) is a vector of time-specific common factors. Our baseline specification can then be written as

$$\Delta\tilde{x}_{p,t} = \alpha\Delta b_{p,t} + \lambda_p' F_t + \nu_{p,t}. \quad (3.14)$$

As is shown in Bai (2009), this model incorporates additive time and county pair fixed effects as special cases. It is, however, much more general and allows for a very flexible model of the heterogeneous time trends at the county pair level. The key to estimating α consistently is to treat the unobserved factors and factor loadings as parameters to be estimated. Our implementation is based on an iterative two-stage estimator described in Appendix C.1.

Estimating the Number of Factors

To implement this estimator, we need to specify the number of factors. Bai and Ng (2002) have shown that the number of factors in pure factor models can be consistently estimated based on the information criterion approach. Bai (2009) shows that their argument can be adapted to panel data models with interactive fixed effects. Thus, we define our criterion CP as a function of the number of factors k as:

$$CP(k) = \hat{\sigma}^2(k) + \hat{\sigma}^2(\bar{k}) [k(N + T) - k^2] \frac{\log(NT)}{NT},$$

where $\bar{k} \geq r$ is the maximum number of factors, N is the number of pairs, T is the number of time observations, $\hat{\sigma}^2(k)$ is the mean squared error, defined as

$$\hat{\sigma}^2(k) = \frac{1}{NT} \sum_{i=1}^N \sum_{t=1}^T \left(\Delta \tilde{x}_{p,t} - a \Delta b_{p,t} - \lambda'_i(k) F_t(k) \right)^2,$$

and $F_t(k)$ and $\lambda'_i(k)$ are the estimated factors and their loadings, respectively, when k factors are estimated. To avoid collinearity, we set \bar{k} to the minimum of seven and $T - 1$, one less than the total number of time observations. Our estimator for the number of factors is then given by

$$\hat{k} = \arg \min_{k \leq \bar{k}} CP(k).$$

Standard Errors

To properly compute standard errors, we need to take into account potential correlation in the residuals across counties and over time. There are two possible sources of correlation. First, the outcomes that we are interested in (unemployment, vacancies, wages, etc.) are highly serially correlated. This aspect of the data may cause serial correlation in the errors. Second, the fact that some counties appear in multiple county-pairs results in an almost mechanical correlation across county pairs. To

account for these sources of correlation in the residuals, we follow Bertrand, Duflo, and Mullainathan (2004) and use the block-bootstrap to compute standard errors.

3.2 Data

Data on unemployment among the residents in each county are from the Local Area Unemployment Statistics (LAUS) provided by the Bureau of Labor Statistics.⁸ County-level data on private sector employment (the number of jobs located in a county) and wages are from the Quarterly Workforce Indicators (QWI).⁹ QWI is derived from the Local Employment Dynamics, which is a partnership between state labor market information agencies and the Census Bureau. QWI supplies data for all counties except those in Massachusetts. Data availability varies substantially across states until 2004 Q4. Thus, for our main empirical analysis we will restrict attention to quarters beginning with 2005 Q1.¹⁰

To identify the role of unemployment benefit extensions on labor market outcomes, we focus our analysis on a sample of county pairs that are in different states and share a border.¹¹ There are 1,107 such pairs for which we have complete data.

Data on unemployment benefit durations in each state is based on trigger reports provided by the Department of Labor. These reports contain detailed information for each of the states regarding the eligibility and adoption of the two unemployment insurance programs over our primary sample period: Extended Benefits program (EB) and Emergency Unemployment Compensation (EUC08).¹²

The EB program allows for 13 or 20 weeks of extra benefits in states with elevated unemployment rates. The EB program is a joint state and federal program.

⁸<ftp://ftp.bls.gov/pub/time.series/la/>

⁹<http://lehd.ces.census.gov/datatools/qwiapp.html>

¹⁰There are some implausible high frequency changes in county-level employment in QWI data. Thus, when using these data, we restrict the sample to observations where employment changes by no more than 15% from one quarter to the next. All results are robust to the choice of this cut-off.

¹¹Data on county pairs are provided by Arindrajit Dube and were used in Dube, Lester, and Reich (2010).

¹²See <http://ows.doleta.gov/unemploy/trigger/> for trigger reports on the EB program and <http://ows.doleta.gov/unemploy/euc.trigger/> for reports on the EUC08 program.

The federal government pays for half of the cost, and determines a set of "triggers" related to the insured and total unemployment state rates that the states can adopt to qualify for extended benefits. At the onset of the recession, many states chose to opt out of the program or only adopt high triggers.¹³ The American Recovery and Reinvestment Act of 2009 turned this into a federally funded program (with 100% Federal funding currently scheduled to expire on December 31, 2013). Following this, many states joined the program and several states adopted lower triggers to qualify for the program.

The EUC08 program enacted in June 2008, on the other hand, has been a federal program since its onset. The program started by allowing for an extra 13 weeks of benefits to all states and was gradually expanded to have 4 tiers, providing potentially 53 weeks of federally financed additional benefits. The availability of each tier is dependent on state unemployment rates.¹⁴ The trigger reports contain the specifics of when each state was eligible and activated the EB program and different tiers of the EUC08 program. We have constructed the data through December 2012.

There is a substantial heterogeneity in the actual unemployment benefit durations across time and across the U.S. states. Appendix Figure C.3 presents some snapshots that illustrate the extent of this variation. Among 1,107 border county pairs used in our analysis, 1,079 have different benefits for at least one quarter. The median county pair has different benefit durations for 11 quarters during 2008-2012. The difference in available benefit duration within a county-pair ranges from 0 to 17 quarters.

Some of the data series used in the analysis are available at a monthly frequency while others are quarterly. Therefore, we aggregate all monthly data to obtain quarterly frequency. Logs are taken after aggregation. When constructing the quasi-differences at the quarterly frequency, we set $\beta = 0.99$ and use the separation rate measured from JOLTS data.¹⁵

¹³Wright (1986) studies unemployment benefit extensions in a voting equilibrium.

¹⁴This discussion is based on Rothstein (2011a).

¹⁵<http://www.bls.gov/jlt/>

Table 3.1: Unemployment Benefit Extensions and Unemployment

| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|----------------------|--------------------------|--------------------------|--------------------------|---------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Weeks of Benefits | 0.0602 (0.000) | 0.0592 (0.000) | 0.1528 (0.000) | 0.1193 (0.000) | 0.0638 (0.000) | 0.0629 (0.000) | 0.0635 (0.000) | 0.0579 (0.000) |
| State GDP per Worker | | 0.0039 (0.690) | | -0.0740 (0.000) | | | | |
| N. factors | 2 | 2 | 2 | 3 | 2 | 4 | 2 | 3 |
| Observations | 30,988 | 30,988 | 30,988 | 30,988 | 17,312 | 2,352 | 30,988 | 48,611 |
| R-squared | 0.4598 | 0.4601 | 0.565 | 0.642 | 0.490 | 0.642 | 0.473 | 0.405 |

Note - p -values (in parentheses) calculated via bootstrap. Bold font indicates $p < 0.01$.

Column (1) - Baseline sample,

Column (2) - Baseline sample controlling for State GDP per worker,

Column (3) - Scrambled border county pairs sample,

Column (4) - Scrambled border county pairs sample controlling for State GDP per worker,

Column (5) - Sample of border counties with similar industrial composition,

Column (6) - Sample of border counties within the same Core Based Statistical Areas,

Column (7) - Baseline sample with perfect foresight measure of available benefits,

Column (8) - Baseline results using data from 2001 recession only.

3.3 Unemployment Benefit Extensions and Unemployment

3.3.1 Baseline Empirical Results

Column (1) of Table 3.1 contains the results of the estimation of the effect of unemployment benefit duration on unemployment using the baseline specification in Equation (3.14). We find that changes in unemployment benefits have large and statistically significant short-run effect on unemployment: a 1% rise in benefit duration for only one quarter increases unemployment rate by 0.06 log points. Equation (3.12) helps us extrapolate these effects and estimate the effect of a permanent increase in benefit durations. Using the average quarterly separation rate of 10% in JOLTS data, we find that the effect of permanently ($n = \infty$) increasing benefits from $\omega_1 = 26$ to $\omega_2 = 99$ weeks is quite sizable: The effect on unemployment is 110%, meaning that such a permanent increase would increase the long-run average unemployment rate from 5% to 10.5%.

During the Great Recession, unemployment benefits have been on average at 82.5 weeks for approximately 16 quarters. Evaluating Equation (3.12) at $\omega_1 = 26$, $\omega_2 = 82.5$, and $n = 16$ yields 0.62. Translating this to rates, would predict a rise in unemployment from 5% to 8.6%.¹⁶

When comparing the magnitude of this effect to the experience in the data, it is important to keep in mind that it is based on the difference across pairs of border counties. Thus, the effects of various other shocks or policies that affect these counties symmetrically are differenced out. For example, the 2% reduction to an employee's share of Social Security payroll taxes implemented in all states in 2011 and 2012 might have had a substantial negative impact on unemployment, counteracting some of the effects of unemployment benefit extensions.

3.3.2 Testing for Endogeneity

In this section we formalize the potential endogeneity problem as well as develop and implement a test to detect its presence. We begin, however, by outlining the origin of the problem informally using an intuitive example. To help fix ideas, the example is stark and imposes stronger conditions than those actually required for identification.

Imagine a border county pair consisting of county a belonging to state A and county b belonging to state B . State A also has some geographic area \mathcal{A} that excludes county a . We now consider two cases.

Case 1. Continuous economic conditions at the state border.

Suppose there is a large shock affecting the economy of \mathcal{A} . The economic effects of this shock might spread geographically to reach county a . However, there is no particular reason for them to stop upon reaching the state border. Thus, they will continue spreading and would affect county b similarly to their effect on county a . If this is the case, there is no endogeneity problem in our baseline specification (3.14) as the

¹⁶ $\log(0.05) + 0.62 = \log(0.086)$.

difference in unemployment between counties a and b is due solely to the difference in benefit policies, perhaps triggered by the developments in \mathcal{A} . With geographically continuous economic fundamentals, shocks directly to counties a and b also do not create an endogeneity problem even if either one or both counties are large enough to trigger a changes in policies in the corresponding states.

Case 2. Discontinuous economic conditions at the state border.

The endogeneity problem can arise only if shocks to e.g., productivity, stop when reaching a state border. In this case, a shock to \mathcal{A} may affect, say, productivity in county a and trigger a change in unemployment benefit policy in state A . In contrast, this shock stops when reaching the state border so that neither b 's productivity nor B 's benefit policy is affected. In this case, the difference in unemployment between counties a and b is driven by both the difference in productivities and the difference in benefits, with the latter at least partially induced by the difference in productivities. In this case, the estimate of the effect of benefits would be biased if the difference in state productivities is not controlled for.

As we mentioned, this stark intuitive example helps fix ideas at the cost of imposing stronger conditions than those actually required for identification. For example, an endogeneity problem would not arise even if there are discontinuous idiosyncratic shocks to counties a or b as long as these shocks do not affect the state average conditions and do not trigger changes in benefit policy at the state level. This is not a very strong restriction as the median border county has only one half of one percent of its state's employment.

We now turn to a more formal exposition. The identifying assumption of our empirical strategy is that the error term $\nu_{p,t}$ in estimation equation (3.14) is uncorrelated with benefits $\Delta b_{p,t}$. The variable x at the county level is driven by benefits b , the time varying factors F and county-specific factors such as county-productivity and demand which are unobserved and are part of the term $\nu_{p,t}$. The assumption that $\nu_{p,t}$ is not

correlated with benefits then means that the differences in productivity, demand, etc. across border counties are not correlated with the benefits across the same counties. Since benefits are a function of state level variables, for this assumption to be valid, the difference in county level productivity, demand, etc. has to be uncorrelated with the corresponding differences at the state level, i.e.

$$\text{Corr}(\nu_{p,t}, \Delta z_p) = 0, \quad (3.15)$$

where z is state level productivity and Δz_p is the difference in productivity across states. To test this assumption, we can decompose the term $\nu_{p,t}$ into a part that depends on the state, Δz_p , and another part that depends on county-specific factors only, $\tilde{\nu}_{p,t}$,

$$\nu_{p,t} = \chi \Delta z_p + \tilde{\nu}_{p,t}, \quad (3.16)$$

so that we rewrite the empirical specification as

$$\Delta \tilde{x}_{p,t} = \alpha \Delta b_{p,t} + \lambda'_p F_t + \chi \Delta z_p + \tilde{\nu}_{p,t} \quad (3.17)$$

for a (possibly) nonzero coefficient χ .

The economics behind this specification should by now be clear. Unemployment benefit extensions are determined at the state level and thus depend on a state's economic conditions such as state level productivity z . Thus, a negative state-level shock to z can cause unemployment to increase in all the counties in the state and simultaneously lead to an extension of benefits. When we do not control for z and $\chi \neq 0$, the estimated coefficient α would be biased in specification (3.17). One way to ensure that $\chi = 0$ would be to assume that the two counties in a pair are identical so that $\nu_{p,t}$ is pure measurement error. Our identifying assumption (3.15) is weaker than this as we allow counties to be different but only in terms of county-specific

factors. State-related factors cancel when we take differences, that is $\chi = 0$. In other words, we allow for county-specific shocks but require that state-shocks affect the two counties symmetrically so that the difference in state-shocks does not affect the difference of x across the two counties.

To test for this type of endogeneity, we implement specification (3.17). If our empirical methodology suffers from this bias, we would expect the coefficient on Δz_p to be statistically different from zero, $\chi \neq 0$, and, more importantly, the coefficient α on benefit duration to change drastically and perhaps lose its statistical significance.¹⁷ We define state productivity as real gross state product per worker. We obtain data on state real GDP at an annual frequency from the Regional Economic Accounts at the Bureau of Economic Analysis¹⁸ and interpolate it at quarterly frequency. We then divide quarterly state GDP by quarterly state employment. The results are provided in Column (2) of Table 3.1. Note that including the difference in state productivity has almost no effect on the estimate of the effect of benefit duration on unemployment. These results provide clear evidence that our findings are not driven by a mechanical relationship between the economic conditions at the state level and the duration of unemployment benefits.

One may also consider whether the difference in state-level unemployment rates can be used in place of Δz_p when testing for endogeneity. We explain in Appendix C.2 why this would not constitute a valid test.

3.3.3 Scrambled Border County Pairs

In the previous section we tested for endogeneity by implementing equation (3.17) and found a negligible effect on the estimated effect of benefit extensions, α and that the effect on difference in state productivities, χ , is not statistically different

¹⁷We can expect to see some impact on the estimate as there might be at least some correlation between the measured productivities of the county and of the state it belongs to since the number of counties in a state may be too small for the Law of Large Numbers to apply.

¹⁸http://www.bea.gov/iTable/index_regional.cfm

from zero. The results lent empirical support to our identification assumption (3.15), implying that our benchmark sample is well described by Case 1 from the example in the preceding section.

Suppose, instead, that we randomly assign counties to pairs. That is, instead of pairing neighboring counties from different states, pairs are formed by randomly matching counties from the original set of the border counties. This mechanically introduces a discontinuity in economic conditions across the constructed “border” county pairs, so that Case 2 described in the preceding section applies with the associated endogeneity bias. Consider again the example of county a from state A being matched to county b from state B . With randomly assigned pairs, however, counties a and b do not border each other so that shocks to, say productivity of area \mathcal{A} of state A affect productivity in county a but not in county b . If these shocks also affect economic conditions in state A , they would also be correlated with the difference in policies between States A and B . This invalidates our identification assumption (3.15).

Consequently, estimating our benchmark specification (3.14) on a scrambled border county sample would yield a biased coefficient of interest α because $\nu_{p,t}$ is correlated with $\Delta b_{p,t}$ since both are correlated with Δz_p . The empirical results of the estimation are in Column (3) of Table 3.1 and show that the estimate of α is indeed substantially upward biased on a sample of randomly paired counties.

Next, we add the difference in state-level productivities to this regression as in specification (3.17). We expect to find a negative χ because the endogeneity problem induced by the random pairing of counties. Adding state level productivity however alleviates the endogeneity problem and diminishes the bias in estimating α . The bias is not expected to fully disappear when we add state level productivity since we do not control for other state variables, such as state demand, which are also correlated with $\nu_{p,t}$ leading to a bias, albeit a smaller one. Results in Column (4) of Table 3.1

confirm this logic.

3.3.4 Border Counties with Similar Industrial Composition

As pointed out by Holmes (1998), the density of manufacturing industry employment varies systematically across counties within border pairs that belong to states with different right-to-work legislation. Manufacturing industries and thus states with a large manufacturing sector have more cyclical unemployment. They may also have a more cyclical unemployment benefit policy, potentially giving rise to the endogeneity problem. If this cyclical heterogeneity across states is sufficiently empirically important, however, our interactive effects estimator picks it up through assigning a higher loading on the cyclical aggregate factor for more cyclical states.

As an additional and more general check, we now investigate whether differences in industrial composition affect our results. To this aim, we repeat the benchmark analysis on a subset of border counties with similar industrial composition. If the industrial composition affected our results, we would expect a different result in the subsample than in the full sample. We obtain data on county employment by industry from the Bureau of Economic Analysis, Regional Economic Information System.¹⁹ Using sample average industry employment shares within each county, we construct the l^2 -distance between border counties within each pair. The results, presented in Column (5) of Table 3.1, are based on the sample of 50% of county pairs with the most similar industrial composition out of all border county pairs. The effect of unemployment benefit extensions on unemployment on this subsample is similar to the one found in our full sample.

¹⁹<http://www.bea.gov/regional/>

3.3.5 Border Counties within the same CBSAs

The degree of economic integration varies across county border pairs. This is relevant for the following reason. If two border counties have a fully integrated labor market with perfect mobility of workers, the residence and employment decisions are separated. In other words, the decision in which of the two counties to (look for) work is independent of the decision in which of the counties to live. Thus, in response to a change in benefits, say, in one of the states, residents of both counties adopt the same strategy of which county to work in. As unemployment is measured by the place of residence, it will be the same in both counties. Thus, our estimate of the effect of unemployment benefit extensions on unemployment would be severely biased toward zero.

In Section 3.5 we will present evidence that workers do not change the location of employment in response to changes in benefits and that labor markets in border counties are well approximated as closed economies. Here we explore whether the potential bias is large by restricting attention to a subset of border counties with most integrated labor markets. To do so, we repeat the analysis on a restricted sample of border counties that belong to the same Core Based Statistical Areas (CBSAs). CBSAs represent a geographic entity associated with at least one core of 10,000 or more population, plus adjacent counties that have a high degree of social and economic integration with the core (see Office of Management and Budget (2010) for detailed criteria). The results, presented in Column (6) of Table 3.1, imply similar effect of unemployment benefit extensions on unemployment to the one found in our full sample.

3.3.6 Alternative Benefit Duration Measure

Our baseline measure of weeks of benefits available corresponds to the number of weeks a newly unemployed worker can expect to receive if current policies and ag-

gregate conditions remained in force for the duration of the unemployment spell. An alternative, albeit extreme, assumption is that individuals have a perfect foresight of the future path of benefits.

To construct the perfect foresight measure of available benefits, for a worker who becomes unemployed in a given week, we compute the realized maximum number of weeks available to him during the course of his unemployment spell (this takes into account extensions that are enacted after the spell begins).

The following example illustrates the construction of the two measures of benefit duration. Consider October 2009 in California. At the time, up to 26 regular weeks were available, in addition to 20 weeks in Tier 1 and 13 weeks in Tier 2 of EUC08 and 20 weeks in EB. Thus, under our baseline specification the measure of weeks available would be $26+20+13+20=79$ weeks. In November of 2009, the weeks available were expanded up to 99 total (two additional tiers were added) and the program continued to be extended at those benefit levels through September of 2012. So the perfect foresight measure would assign 99 weeks available to a worker that became unemployed in 2009.

The results based on the perfect foresight measure of available benefit duration are reported in Columns (7) of Table 3.1. Similar to the results based on the baseline measure of benefit availability, they continue to imply a quantitatively large impact of unemployment benefit duration on unemployment.

3.3.7 The 2001 Recession

The Great Recession was unusually severe and accompanied by a financial crisis. This suggests that our findings of the large effect of unemployment benefit extensions on unemployment might be specific to this recession. To assess this hypothesis, we repeated the analysis using the data on benefit extensions during the much milder 2001 recession (using the 1996-2004 sample). In order to extend our analysis to

the 2001 recession we need to quantify the difference in benefits during that time period. In addition to EB, the federal government enacted the Temporary Emergency Unemployment Compensation Program (TEUC), which provided up to 26 weeks of additional benefits depending on state conditions. We obtain data on weeks available from BLS trigger reports.²⁰ As JOLTS data are only available beginning in December 2000, prior to that we set the separation rate equal to its average value in the available JOLTS data. The results of this experiment, reported in Column (8) of Table 3.1, imply that the effect of unemployment benefit extensions on unemployment is the same in both recessions.

3.3.8 Controlling for Other State-Level Policies

In this section we control for government tax and transfer policies that might be correlated with unemployment and unemployment benefit extensions at the county or state levels.

Controlling for the Expansion of Food-Stamps Programs

Mulligan (2012) has argued that in addition to unemployment benefit extensions, the Department of Agriculture's food-stamp program, now known as the Supplemental Nutrition Assistance Program, or SNAP, was also expanded considerably following the Great Recession. It is possible that the expansion of this program at the state level was correlated with unemployment benefit extensions so that the results reported above combine the effects of these programs. We now isolate their impacts.

Food-stamps were originally designed as a means-tested program for the poor. During the Great Recession the Federal government has allowed states to adopt broad eligibility criteria that effectively eliminated the asset test and states received waivers from work requirements for the participants in the program. As a result, the par-

²⁰<http://www.ows.doleta.gov/unemploy/teuc/>

Table 3.2: Unemployment Benefit Extensions and Unemployment:
Controlling for State SNAP and Foreclosure Policies

| VARIABLES | (1) | (2) | (3) | (4) |
|------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Weeks of Benefits | 0.0607 (0.000) | 0.0542 (0.000) | 0.0586 (0.000) | 0.0627 (0.000) |
| SNAP Broad Eligibility | | 0.0100 (0.000) | | |
| SNAP Spending | | | 0.0056 (0.190) | |
| Foreclosure Policy | | | | 0.0025 (0.470) |
| Number of Factors | 2 | 2 | 2 | 2 |
| Observations | 30,988 | 30,988 | 30,988 | 30,988 |
| R-squared | 0.460 | 0.464 | 0.463 | 0.465 |

Note - p -values (in parentheses) calculated via bootstrap.

Bold font indicates $p < 0.01$.

ticipation in the program increased dramatically so that by 2010 half of non-elderly households with an unemployed head or spouse were receiving food stamps, with substantial variation across states.

To assess the extent to which the effects of unemployment benefit extensions documented above are affected by the expansion of food-stamps program eligibility, we obtained USDA's SNAP Policy Database which documents policy choices of each state at monthly frequency.²¹ We construct a dummy variable equal to one during all periods when states use broad-based categorical eligibility to increase or eliminate the asset test and/or to increase the gross income limit for virtually all SNAP applicants. The variable is zero otherwise. We include this variable in our baseline regression and report the results in Column (2) of Table 3.2. The results confirm the argument in Mulligan (2012) that the expansion of food-stamps eligibility repre-

²¹<http://www.ers.usda.gov/data-products/snap-policy-database.aspx>

sents a marginal tax on working and thus leads to an increase in unemployment. It is, however, only weakly correlated with unemployment benefit extensions and thus does not significantly affect our estimate of their impact.

In addition, we control for the actual state-level spending on SNAP benefits that we obtained from the Regional accounts of the BEA. The results reported in Column (3) of Table 3.2 confirm our findings in Column (2) of Table 3.2 which were based on statutory rule changes.

Controlling for Variation in State Foreclosure Policies

The Great Recession has begun with a sharp but heterogeneous across states decline in house prices. The government has responded by introducing various mortgage modification programs with the objective of helping underwater mortgagors. Various of these programs were either asset-tested or designed to write down mortgage principle to ensure that housing costs do not exceed a certain proportion of household income. In a series of papers, Mulligan (2008, 2009, 2010) has noted that this represents an implicit subsidy to unemployed workers. Moreover, Herkenhoff and Ohanian (2013) have argued that the duration of the foreclosure process has been extended considerably following the Great Recession and that unemployed mortgagors use their ability to skip payments without being foreclosed upon as an implicit loan subsidy negatively affecting their job search and acceptance decisions.

Cordell, Geng, Goodman, and Yang (2013) use proprietary data to measure the heterogeneity in foreclosure delay following the Great Recession across states. They find that in judicial states, in which state law requires a court action to foreclose, the delay is much larger than in statutory foreclosure states that do not require judicial intervention. Our use of the interactive effects estimator was specifically motivated by the concerns that aggregate shocks, such as shocks to house prices, may have heterogeneous impacts across border-county pairs depending, in part, on their state

foreclosure law. To verify the performance of the estimator, we define a dummy variable taking the value of one for border counties belonging to states with judicial foreclosure laws and zero otherwise. We then include in the benchmark specification the difference of the value of this dummy between border counties i and j in pair p . The results reported in Column (4) of Table 3.2 indicate that this variable (the difference of the two dummies) is not statistically significant and does not affect the estimate of the effect of unemployment benefit extensions. This finding does not imply that foreclosure delay was not an important determinant of unemployment. It only means that our interactive effects estimator accounted for some of this aspect of heterogeneity across states and it did not impart a bias on our estimate of the effect of unemployment benefit extensions.

Controlling for the Effect of Stimulus Spending

In the specification of Column (2) of Table 3.3 we control for the effects of stimulus spending. We use data on actual county level spending arising from the American Recovery and Reinvestment Act (ARRA) - commonly referred to as the “stimulus package.” We obtain an accounting of all stimulus spending at the zip code level under the ARRA.²² We then match counties to zip codes. We run our specification both in levels and by dividing the spending by the population in the county, obtained from the Census. We find that that controlling for ARRA spending does not affect our estimate of the effect of unemployment benefit extensions.²³

Table 3.3: Unemployment Benefit Extensions and Unemployment: Controlling for State Tax and Spending Policies

| VARIABLE | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|--------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Weeks of Benefits | 0.0607 (0.000) | 0.0610 (0.000) | 0.0552 (0.000) | 0.0590 (0.000) | 0.0599 (0.000) | 0.0613 (0.000) | 0.0609 (0.000) | 0.0591 (0.000) | 0.0606 (0.000) |
| | Variable in Levels | | | | | Variable Relative to GDP | | | |
| Stimulus Spending | | 0.0008 (0.000) | | | | 0.0007* (0.210) | | | |
| Total Tax Revenue | | | 0.0035 (0.005) | | | | -0.0047 (0.140) | | |
| Sales Tax Revenue | | | | 0.0004 (0.245) | | | | 0.0005 (0.720) | |
| Income Tax Revenue | | | | | 0.0002 (0.360) | | | | -0.0044 (0.095) |
| # Factors | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Obs. | 30,988 | 30,988 | 30,988 | 30,988 | 30,988 | 30,988 | 30,988 | 30,988 | 30,988 |
| R-squared | 0.460 | 0.463 | 0.464 | 0.465 | 0.461 | 0.465 | 0.461 | 0.465 | 0.460 |

Note - p -values (in parentheses) calculated via bootstrap. Bold font indicates $p < 0.01$.

*-Relative to county population

Controlling for State Tax Policies

To control for the variation in state-level tax policies we obtained detailed Census Bureau data on quarterly tax revenues for each state.²⁴ We consider whether effective total or sales tax rates have co-moved systematically with unemployment benefit durations. We find no support for this hypothesis. The results reported in Table 3.3 imply that directly controlling for these effective tax rates has virtually no impact on our estimates of the effect of unemployment benefit extensions on unemployment.

Our analysis was based on effective tax rates for two reasons. First, the statutory rates have not changed systematically over our sample period. Despite many states having balanced budget laws, expansions of unemployment benefits have not required

²²www.recovery.gov.

²³The coefficient on spending however has to be interpreted with caution. It is conceivable, in contrast to unemployment benefits which depend on economic conditions at the state level, that spending at the county level depends on the economic conditions at the county level. In this case the coefficient on spending will be biased.

²⁴<http://www.census.gov/govs/ntax/>

changes in tax rates as extensions were mostly federally financed. Second, there are numerous state programs targeted to attract businesses that offer tax deductions to individual firms. For competitive reasons details of such policies are rarely disclosed. We can effectively measure them, however, by focusing on actual tax receipts.

Controlling for Other State Policies

While we found no evidence that the effects of unemployment benefit extensions on unemployment are a proxy for changes in other tax policies, we now consider whether they could be driven by other state policies, such as changes in regulatory or litigation environment. For this purpose we obtain data from three prominent indexes of state policies - U.S. State Business Policy Index (SBSI), State Business Tax Climate Index (SBTCI), and BHI State Competitiveness Index (BHI).²⁵ The construction of these indexes is based on a well-documented methodology, the data is available annually over our sample period, and can be made consistent over time. A more detailed description of these indexes, the analysis of their predictive performance for state economic outcomes, and references to other academic evaluations can be found in Kolko, Neumark, and Mejia (2013).

The motivation for using these broad policy indexes was provided in Holmes (1998), who found that controlling for a similar (but no longer available) index of state policies accounted for the positive relationship between right-to-work laws and manufacturing employment. This suggests that the conclusion about the effects of one policy may be misleading without taking into account other state policies reflected in a broad index. In contrast, the results reported in Table 3.4 imply that controlling for such indexes does not affect the measured impact of unemployment benefit extensions on unemployment.

²⁵www.sbecouncil.org, www.taxfoundation.org, www.beaconhill.org, respectively.

Table 3.4: Unemployment Benefit Extensions and Unemployment:
Controlling for Other State Policies

| VARIABLES | (1) | (2) | (3) | (4) |
|-------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Weeks of Benefits | 0.0602 (0.000) | 0.0602 (0.000) | 0.0615 (0.000) | 0.0588 (0.000) |
| SBSI | | -0.0059 (0.105) | | |
| SBTCI | | | -0.0024 (0.260) | |
| BHI | | | | -0.0039 (0.175) |
| Number of Factors | 2 | 2 | 2 | 2 |
| Observations | 30,988 | 30,988 | 30,988 | 30,988 |
| R-squared | 0.460 | 0.462 | 0.464 | 0.462 |

Note - p -values (in parentheses) calculated via bootstrap.

Bold font indicates $p < 0.01$.

3.4 The Role of Macro Effects

In equilibrium labor market search models, the dynamics of unemployment over the business cycle and the response of unemployment to changes in policies are primarily driven by employers' vacancy creation decisions. Consider, for example, an increase in unemployment benefit duration. Having access to longer spells of benefits improves the outside option of workers and leads to an increase in the equilibrium wage. This lowers the accounting profits of firms and reduces vacancy posting to restore the equilibrium relationship between the cost of firm entry and the expected profits. Lower vacancy creation leads to a decline in labor market tightness, defined as the ratio of vacancies to unemployment. This lowers the job finding rate of workers and results in an increase in unemployment.

In this section, we present evidence on the empirical relevance of these macro effects. In particular, we document the effect of unemployment benefit extensions

Table 3.5: Unemployment Benefit Extensions and Job Creation

| VARIABLES | Vacancies (1) | Tightness (2) | Employment (3) | Wages (4) |
|----------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| Weeks of Benefits | -0.0631 (0.000) | -0.1067 (0.000) | -0.0051 (0.030) | 0.0128 (0.025) |
| N. factors | 2 | 2 | 2 | 2 |
| Observations | 29,492 | 29,492 | 29,600 | 29,549 |
| R-squared | 0.175 | 0.178 | 0.933 | 0.457 |

Note - p -values (in parentheses) calculated via bootstrap.
 Bold font indicates $p < 0.05$.

on vacancy creation, employment, and wages in the data. We also compare the magnitude of these empirical findings to those in a calibrated equilibrium search model.

3.4.1 Unemployment Benefit Extensions and Vacancy Creation

We begin by considering the effect of unemployment benefit extensions on vacancy posting by employers and on labor market tightness using the basic specification in Equation (3.14). We obtain vacancy data from the Help Wanted OnLine (HWOL) dataset provided by The Conference Board (TCB). This dataset is a monthly series that covers the universe of vacancies advertised on around 16,000 online job boards and online newspaper editions. The HWOL database started in May 2005 and replaced the Help-Wanted Advertising Index of print advertising also collected by TCB.²⁶ For a more detailed description of the data, some of the measurement issues, and a comparison with the well-known JOLTS data, see Sahin, Song, Topa, and Violante (2012).

The results are reported in Columns (1) and (2) of Table 3.5. We find that changes in unemployment benefits have a large and statistically significant short-run effect on

²⁶For detailed information on survey methodology, coverage, and concepts see the Technical Notes at <http://www.conference-board.org/data/helpwantedonline.cfm>.

vacancy creation: a 1% rise in benefit duration for only one quarter lowers the number of vacancies by 0.063 log points and labor market tightness by 0.107 log points.

In the standard equilibrium search model, the matching function implies a tight relationship between changes in unemployment, vacancies, and tightness. As we have obtained independent estimates of the effects of benefit extensions on these variables, it is of interest whether their magnitudes are mutually consistent. The following calculation establishes that this is indeed the case.

Assuming that the matching function is of the commonly used Cobb-Douglas type,

$$M(u, v) = \mu v^{1-\gamma} u^\gamma,$$

allows us to relate the change in tightness to the change in unemployment. Since the job finding rate is given by

$$f = \mu \theta^{1-\gamma},$$

the implied change in f induced by a change in benefits equals $-(1 - \gamma) \times 0.1067$. Since the elasticity of the steady-state unemployment rate u w.r.t f equals $1 - u$, the implied change in u (due to the change in tightness induced by the change in benefits) equals

$$(1 - u)(1 - \gamma) \times 0.1067.$$

For standard values of $\gamma = 0.4, 0.5$, assuming $u = 0.05$, the implied change equals 0.06 ($\gamma = 0.4$) and 0.05 ($\gamma = 0.5$) respectively, values close to the actual change in unemployment reported in Table 3.1.

3.4.2 Unemployment Benefit Extensions and Employment

In Column (3) of Table 3.5 we report the effect of unemployment benefit extensions on employment. We find a large negative effect implying that a rise in unemployment associated with an extension of unemployment benefits is similar in magnitude to the

decline in employment. This finding challenges the wisdom of relying on unemployment benefit extensions as a policy to stimulate aggregate demand. The large decline in employment associated with such policies is likely to substantially dampen any potential stimulative effects.

A hypothesis often mentioned in the literature, see, e.g., Solon (1979) and Rothstein (2011a), is that the rise in unemployment in response to unemployment benefit extensions might be driven by measurement issues. In particular, workers who collect benefits claim to be actively searching for a job in response to surveys used to determine the unemployment rate, while in reality they are not. In other words, had benefits not been extended, these workers would have reported themselves as being out of the labor force. The decline in the vacancy rates and employment documented here provides evidence against this hypothesis. In fact, if we consider the same calculation as in Section 4.1, we can compute the effect on employment of extending benefits to 82.5 weeks for 16 quarters as:

$$-0.0051 \times \frac{1 - (\beta(1 - s))^{16}}{1 - \beta(1 - s)} \times (\log(82.5) - \log(26)) = 0.62.$$

Translating this into levels, this would predict a drop in the employment rate from 95% to 90.8%. This 4.2 percentage point decrease is slightly larger, but of a comparable magnitude to the 3.6 percentage point increase in the unemployment rate found above.

Note that our estimate of the effect of unemployment benefit extensions on employment is based on the difference across border counties. We then use the resulting coefficient to predict the effect of a nation-wide extension. A potential concern with such a procedure is that when some states extend benefits more than others, economic activity and, thus, employment may reallocate to states with lower benefits. This reallocation is picked up by our estimates but would be absent if the policy was changed nation-wide. We find no empirical justification for such a concern. In partic-

ular, we apply our empirical methodology to measure the change in employment in sectors producing output that is plausibly non-tradable across states, such as retail or food services. If the change in employment is driven to an important degree by reallocation, we would not expect benefit extensions to have a large effect on these sectors. Instead, we find that a 1% rise in benefit duration for one quarter leads to a decline of employment by 0.013 and 0.015 log points in retail and food services sectors, respectively. Both effects are statistically significant at 1%.

3.4.3 Unemployment Benefit Extensions and Wages

We have established that extensions of unemployment benefits lead to a decline in job creation by employers. In a standard equilibrium search model such a response is induced by the fact that longer expected benefit eligibility improves the outside option of workers and leads to an increase in the equilibrium wage. We now assess whether this equilibrium effect is consistent with the data.

Consider the wage of a worker i in county a in pair p which depends on county productivity z^a , county market tightness θ^a , benefits b^a and idiosyncratic productivity ϕ^i :

$$\log(w_t^i) = \beta_0 + \beta_z \log(z_t^a) + \beta_\theta \log(\theta_t^a) + \beta_b \log(b_t^a) + \log(\phi_t^i) + \eta_t^i, \quad (3.18)$$

where η is a measurement error. Theory predicts that the equilibrium wage, conditional on county productivity, demand, etc, increases when UI becomes more generous. It is important to emphasize that we are referring to the response of the equilibrium wage, which is also negatively affected by a drop in market tightness caused by a negative response of job creation to the policy change. The fact that the equilibrium wage combines the positive direct effect of benefit extensions and the negative effect induced by the equilibrium response of job creation, makes the identification of the net equilibrium effect on wages more demanding on the data.

The crucial issue in studying the dynamics of wages is selection. The idiosyncratic productivity of workers moving from non-employment to employment or from job to job depend on business cycle conditions (Gertler and Trigari (2009), Haefke, Sonntag, and van Rens (2012) and Hagedorn and Manovskii (2013)). Idiosyncratic productivity can be decomposed into permanent ability μ^i , job specific productivity κ^i and a stochastic component ϵ^i :

$$\log(\phi_t^i) = \log(\mu_t^i) + \log(\kappa_t^i) + \log(\epsilon_t^i). \quad (3.19)$$

The decision of a non-employed to accept a job depends on z_t , μ_t^i , the job-specific productivity $\hat{\kappa}$ as well as on benefits b . The decision of a worker to switch jobs depends on the worker's current job specific productivity κ_t^i and the job-specific productivity in the new job $\hat{\kappa}$. Productivity $\hat{\kappa}$ is a random draw of a distribution F . A worker who has received N offers during a period accepts the highest draw κ , which is distributed according to F^N . Since the F^N are ordered by first-order stochastic dominance, the expected value of κ is increasing in N and is thus increasing in the number of vacancies. A more generous unemployment insurance system leads to a drop in vacancy posting and therefore to fewer offers and a lower expected value of κ . By the Law of Large Numbers, workers starting a new job in a recession or when benefits are high then have a lower average value of κ than workers starting a job when many offers are available such as in a boom or when benefits are low. Thus, if we regress wages on benefits we also pick up the impact of benefits on the average value of κ .²⁷ To deal with this issue, we follow Hagedorn and Manovskii (2013) and consider job stayers, defined as workers who have the same job in period t and $t + 1$ and thus also

²⁷Benefits may also affect κ by making liquidity constrained workers more selective in the jobs they accept.

the same value of κ . Taking differences across time for a job stayer yields

$$\begin{aligned} & \log(w_{t+1}^i) - \log(w_t^i) \\ = & \beta_z(\log(z_{t+1}^a) - \log(z_t^a)) + \beta_\theta(\log(\theta_{t+1}^a) - \log(\theta_t^a)) + \beta_b(\log(b_{t+1}^a) - \log(b_t^a)) \\ & + \log(\epsilon_{t+1}^i) - \log(\epsilon_t^i) + \eta_{t+1}^i - \eta_t^i, \end{aligned}$$

that is the terms μ^i and κ^i drop out. We therefore consider a group of workers who worked in period t and $t + 1$ for the same employer with average wages $w_{t,t}^a$ in period t and $w_{t,t+1}^a$ in period $t + 1$. Theory then predicts that regressing the difference in wages $\log(w_{t,t+1}^a) - \log(w_{t,t}^a)$ on the difference in benefits, $\log(b_{t+1}^a) - \log(b_t^a)$, yields a positive coefficient. We again have to control for the endogeneity of policy and to this end we again invoke assumption (3.15) and consider the difference across paired border counties. Taking differences across counties a and b in the same pair p of $\log(w_{t,t+1}^a) - \log(w_{t,t}^a)$ and $\log(w_{t,t+1}^b) - \log(w_{t,t}^b)$ yields

$$\begin{aligned} & (\log(w_{t,t+1}^a) - \log(w_{t,t}^a)) - (\log(w_{t,t+1}^b) - \log(w_{t,t}^b)) \\ = & \beta_\theta((\log(\theta_{t+1}^a) - \log(\theta_t^a)) - (\log(\theta_{t+1}^b) - \log(\theta_t^b))) \\ & + \beta_b(\log(b_{t+1}^a) - \log(b_t^a)) - (\log(b_{t+1}^b) - \log(b_t^b)) + \vartheta_t, \end{aligned} \tag{3.21}$$

where ϑ_t collects all error terms and stochastic components unrelated to policy. We then regress this double difference of wages on the double difference in benefits. This captures the equilibrium wage response since benefits b are correlated with θ and regressing wages on benefits only captures both the direct effect of benefits on wages as well as the indirect effect of benefits on market tightness θ . We obtain not only the direct effect β_b but the equilibrium response which is a linear combination of β_b and β_θ .

To implement this procedure, we obtain wage data from the QWI that allows us to measure wages of job stayers. The QWI provides a measure of full quarter

employment - workers who remained employed at the same firm for the entire quarter - and average wage earnings of full quarter employees. However, in quarter t the measure of full quarter employment also includes workers who will separate in $t + 1$, and in quarter t the measure includes new hires from quarter t . Thus, to isolate the wages of stayers we difference out the average wages of $t + 1$ separators (also available from QWI) from the average wages in t and difference out the average t new hire wages from the average wages in $t + 1$. This yields the true average wages of stayers in quarters t and $t + 1$.

Column (4) of Table 3.5 shows the result. We find that wages statistically significantly increase in response to an increase in benefits. Note that the increase in wages that we document provides strong evidence for the general equilibrium effects. Indeed, if higher unemployment was not caused by unemployment benefit extensions, one would expect wages to be *lower* in counties with higher unemployment.

To assess the quantitative magnitude of this estimate consider a typical county pair in the Great Recession. The estimate implies that a county with 70 weeks of benefits has a 0.3% higher level of wages than a county with 50 weeks of benefits, everything else equal.

3.4.4 Validation using Model-Generated Data

In this Section we evaluate the performance of our empirical method on data generated by a calibrated equilibrium search model. The model is an extension of Mortensen and Pissarides (1994) to allow for unemployment benefit expiration.

To address the border county design, the model features a nested state-county structure. In particular, there is a stochastic process for state's productivity.²⁸ The

²⁸The literature based on the Mortensen and Pissarides (1994) model typically uses aggregate productivity as the standard stochastic process inducing aggregate fluctuations. Richer stochastic structures can be considered and identified in a more fully specified DSGE model. This can be necessary, depending on the purpose of the analysis. The associated complications, however, appear inessential for our purpose here, which is to assess the performance of our estimator.

unemployment benefit policy depends on the endogenous unemployment level in the state economy. The county economy takes the endogenously induced joint stochastic process for state unemployment, productivity and benefits as exogenous. The assumption is that counties are "small" relative to the state of which they are apart.

Preferences, technology and frictions are the same across the state and county economies.

Agents. In any given period, a worker can be either employed (matched with a firm) or unemployed. Risk-neutral workers maximize expected lifetime utility

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t c_t,$$

where \mathbb{E}_0 is the period-0 expectation operator, $\beta \in (0, 1)$ is the discount factor, c_t denotes consumption in period t . An unemployed worker produces h , which stands for the combined value of leisure and home production. In addition, unemployed workers may be eligible for benefits b . Unemployed workers who are eligible for benefits lose eligibility stochastically at rate $e_t(\cdot)$, which depends on the state unemployment rate as specified below.

Firms are risk-neutral and maximize profits. Workers and firms have the same discount factor β . A firm can be either matched to a worker or vacant. A firm posting a vacancy incurs a flow cost k .

Matching. The number of new matches in period t is given by $M(u_t, v_t)$, where u_t is the number of unemployed in period t , and v_t is the number of vacancies. The matching function is assumed to be constant returns to scale, and strictly increasing and strictly concave in both arguments. We define $\theta_t = v_t/u_t$ as the market tightness in period t . We then define the job-finding probability as $f(\theta_t) = M(u_t, v_t)/u_t = M(1, \theta_t)$ and the probability of filling a vacancy as $q(\theta_t) = M(u_t, v_t)/v_t = M(1/\theta_t, 1)$. By the assumptions on M made above, the function $f(\theta_t)$ is increasing in θ_t and $q(\theta_t)$

is decreasing in θ_t . Existing matches are destroyed with exogenous job separation probability δ .

Production. A matched worker-firm pair produces output z_t , which follows a first order Markov process. Firms pay workers a wage w_t , determined through Nash bargaining with workers' bargaining power ξ . Thus, the period profit of a matched firm is given by $\pi_t = z_t - w_t$.

State Economy

In the state economy the benefit expiration policy depends on the state unemployment rate, $e_t(u_t^S)$. We assume ineligible workers regain eligibility as soon as they are matched with a firm. The relevant state variables for the state economy are thus the exogenous state productivity z_t^S and the endogenous unemployment rate u_t^S . Let $\Omega_t^S = (z_t^S, u_t^S)$. The state law of motion for employment is therefore:

$$L_{t+1}^S(\Omega_t^S) = (1 - \delta)L_t^S + f(\theta_t^S) (1 - L_t^S) \quad (3.22)$$

and $u_t^S = 1 - L_t^S$.

Value Functions. The flow value for a firm employing a worker is

$$J_t^S(\Omega_t^S) = z_t^S - w_t^S + \beta (1 - \delta) \mathbb{E}J_{t+1}^S(\Omega_{t+1}^S) \quad (3.23)$$

and the flow value of a vacant firm is:

$$V_t^S(\Omega_t^S) = -k + \beta q (\theta_t^S) \mathbb{E}J_{t+1}^S(\Omega_{t+1}^S), \quad (3.24)$$

where k is the flow cost of maintaining a vacancy. The surplus for a firm employing a worker is thus $J_t^S - V_t^S$.

The value functions for workers can be written as:

$$\begin{aligned} W_t^S(\Omega_t^S) &= w_t^S + \beta(1-\delta)\mathbb{E}W_{t+1}^S + \beta\delta(1-e_t(\Omega_t^S))\mathbb{E}U_{t+1}^{S,E}(\Omega_{t+1}^S) \\ &\quad + \beta\delta e_t(\Omega_t^S)\mathbb{E}U_{t+1}^{S,I}(\Omega_{t+1}^S), \end{aligned} \quad (3.25)$$

$$\begin{aligned} U_t^{S,E}(\Omega_t^S) &= h + b + \beta f(\theta_t^S)\mathbb{E}W_{t+1}^S(\Omega_{t+1}^S) + \beta(1-f(\theta_t^S))(1-e_t(\Omega_t^S))\mathbb{E}U_{t+1}^{S,E}(\Omega_{t+1}^S) \\ &\quad + \beta(1-f(\theta_t^S))e_t(\Omega_t^S)\mathbb{E}U_{t+1}^{S,I}(\Omega_{t+1}^S), \end{aligned} \quad (3.26)$$

$$U_t^{S,I}(\Omega_t^S) = h + \beta f(\theta_t^S)\mathbb{E}W_{t+1}^S(\Omega_{t+1}^S) + \beta(1-f(\theta_t^S))\mathbb{E}U_{t+1}^{S,I}(\Omega_{t+1}^S), \quad (3.27)$$

where W_t^S is the value of a job for a worker, $U_t^{S,E}$ is the value of unemployment for an agent eligible for benefits and $U_t^{S,I}$ is the value of unemployment for a non-eligible agent. Define the surplus of being employed as $\Delta_t^{S,E} = W_t^S - U_t^{S,E}$. Also define the surplus for an unemployed worker of being eligible: $\Phi_t^S = U_t^{S,E} - U_t^{S,I}$. The laws of motion for these quantities are:

$$\begin{aligned} \Delta_t^{S,E}(\Omega_t^S) &= w_t^S - h - b + \beta(1-\delta-f(\theta_t^S))\mathbb{E}\Delta_{t+1}^{S,E}(\Omega_{t+1}^S) \\ &\quad + \beta(1-\delta-f(\theta_t^S))e_t(\Omega_t^S)\mathbb{E}\Phi_{t+1}^S(\Omega_{t+1}^S), \end{aligned} \quad (3.28)$$

$$\Phi_t^S(\Omega_t^S) = b + \beta(1-f(\theta_t^S))(1-e_t(\Omega_t^S))\mathbb{E}\Phi_{t+1}^S(\Omega_{t+1}^S). \quad (3.29)$$

The wage is chosen to maximize:

$$\left(\Delta_t^{S,E}(\Omega_t^S)\right)^\xi \left(J_t^S(\Omega_t^S) - V_t^S(\Omega_t^S)\right)^{1-\xi}. \quad (3.30)$$

State Equilibrium Definition. Given a policy $(b, e_t(\cdot))$ and an initial condition Ω_0^S an equilibrium is a sequence of Ω_t^S -measurable functions for wages w_t , market tightness θ_t^S , employment L_t^S , and value functions

$$\left\{ W_t^S, U_t^{S,E}, U_t^{S,I}, J_t^S, V_t^S, \Delta_t^S \right\}$$

such that:

1. The value functions satisfy the worker and firm Bellman equations (3.23), (3.24), (3.25), (3.26), (3.27),
2. Free entry: The value V_t^S of a vacant firm is zero for all Ω_t^S ,
3. Nash bargaining: The wage satisfies equation (3.30),
4. Law of motion for employment: The employment process satisfies (5.2).

County Economy

The county is assumed to be small with respect to the state of which it is a member. That is, the county unemployment rate is not assumed to affect the state unemployment rate and the county productivity process is orthogonal to the state one. The benefit expiration policy for the county, however, depends on the state unemployment rate. Thus, in addition to exogenous county productivity, z^C , the state productivity and the state unemployment rate will be state variables (since they are jointly sufficient to forecast benefit policy). Thus, denote the vector of states for the county $\Omega_t^C = (z_t^C; z_t^S, u_t^S)$. All of the equations governing workers and firms are the same as in the state's economy with the appropriately adjusted state variable. The definition of equilibrium is modified to add an additional condition, namely that the joint process for (z_t^S, u_t^S) is consistent with the state equilibrium. The full equations and definition of the county equilibrium can be found in Appendix C.3.

Calibration

The calibration strategy we employ is to require the state economy to be consistent with key labor market statistics and to match the effect of unemployment benefit extensions on unemployment estimated in Section 3.3.1. The model period is taken to be one week. We match the average labor market tightness, the average job finding rate, and the regression coefficient of quasi-differenced unemployment on benefit duration.

Table 3.6: Internally Calibrated Parameters

| Parameter | Value | Target | Data | Model |
|--------------------------------------|--------|------------------------|--------|--------|
| h Value of non-market activity | 0.6246 | Regression Coefficient | 0.0602 | 0.0602 |
| ξ Bargaining power | 0.0662 | Mean tightness | 0.634 | 0.634 |
| γ Matching function parameter | 0.3995 | Mean job finding rate | 0.139 | 0.139 |

Note - The permanent effect is the average increase in unemployment from increasing unemployment benefit duration by 13 weeks in all states of the world.

The calibrated parameters are summarized in Table 5.1. In order to be consistent with the existing EB program, in the calibration we set benefit expiration policy at 26 weeks when state unemployment is less than 6.5%, 39 weeks when unemployment is between 6.5% and 8% and 46 weeks when greater than 8%. The remainder of the parameters are calibrated externally, using the same values and parametric forms for the matching function as Hagedorn and Manovskii (2008a).

Quantitative Evaluation

The goal of the simulation exercise is to generate synthetic data at the county level comparable to the actual data. We simulate two states and one county in each of them. The two states and the two counties each have the same process for productivity. The counties, consistent with our border county assumption, have the same *realized sequence of shocks*. The two states, however, have different realized sequences of productivity shocks. Consequently, the realized exogenous sequences of state unemployment will be different. Thus, the two counties will have a different time series of unemployment benefits.

We simulate the two states and the two counties for 100 years and throw out the first 15 years of data as "burn-in." We then estimate the same regression (with quasi-differenced unemployment on the left-hand side) as we do on the data from the Great Recession. Recall that our calibration strategy ensures that coefficient on the difference in benefits in this regression is the same in the data and in the simulations of the model. Then, we calculate the effect of a permanent 13-week increase in

Table 3.7: Estimated Permanent Effect of a 13 Week Benefit Extension from Regressions Coefficients in Model Generated Data

| VARIABLES | Unemp. (1) | Tightness (2) | Vacancies (3) |
|-----------|---------------|------------------|------------------|
| Data | 0.227 | -0.378 | -0.231 |
| Model | 0.226 | -0.388 | -0.225 |

benefits on unemployment, vacancies and tightness. We then compare these true permanent effects from the model to the calculated permanent effects from the data. The results and relevant comparisons are displayed in Table 3.7. The model generated data confirms the empirical validity of our specification, as our model, calibrated to generate the same regression coefficient on unemployment benefit duration from the data delivers near identical permanent effects on unemployment, vacancies and tightness.

Note that the model does not include endogenous search intensity decisions by unemployed workers. Thus, the micro elasticity is zero, similar to the empirical estimates discussed above. The total response of unemployment is instead driven by the macro effect of benefit extensions on employers' vacancy creation decisions.

3.5 Change in Location of Employment in Response to Changes in Benefits

A potential concern arises from the observation that households may live in different states than where they work. This would bias our estimates if the households systematically change their job search behavior in response to changes in unemployment benefits. For example, if households search in states with less generous benefits to take advantage of a higher job-finding rate, our estimate of the effect of benefit extensions on unemployment would be biased *downwards*, since those households would

face a higher job-finding rate, which would translate into a lower unemployment rate in that county. In this section, we use two different methods to show that our analysis is not affected by such a bias. First, we develop an imputation procedure that allows to estimate the effects of unemployment benefit extensions while fully accounting for mobility. Second, we provide direct empirical evidence of job search behavior. Both approaches confirm that search behavior does not vary systematically with changes in benefits, validating our use of a simple and transparent specification that ignores mobility decisions.

Because integrated labor markets generally contain multiple neighboring counties, instead of focusing on the county pair as the unit of analysis for search behavior we aggregate all counties on both sides of a border segment and perform the imputation on that "border segment" pair. To impute what fraction of workers search in the state where they live, consider the following model. We consider the local economy to consist of a pair of state border segments A , B . The segments are populated by labor forces of size n_t^A and n_t^B (taken as the sum of all the county labor forces in each state on the respective side of the border) and populations p_t^A and p_t^B .

In any given period, a worker can be either employed (matched with a firm), unemployed or not in the labor force. In period t , firms in state A post vacancies in state A , v_t^A . An unemployed worker in state A searches either in state A or in state B . We assume that a fraction ζ of non-labor force participants (observed in the LAUS data) enter the labor force and search for jobs. The number of new matches in state A in period t equals

$$M(\tilde{u}_t^A, v_t^A),$$

where \tilde{u}_t^A is the measure of individuals in period t searching in state A . The number of matches is the same for state B *mutatis mutandis*. We assume a constant returns to scale matching function M that is strictly increasing and strictly concave in both

arguments. We define

$$\tilde{\theta}_t^A = \frac{u_t^A}{\tilde{u}_t^A}$$

to be the market tightness in state A in period t . We define the job-finding and vacancy-filling probabilities as in Section 3.4.4.

The law of motion for the unemployed who live in states A and B is:

$$u_{t+1}^A = \delta_t (n_A - u_t^A) + u_t^A (1 - x_t^A f(\theta_t^A) - (1 - x_t^A) f(\theta_t^B)), \quad (3.31)$$

$$u_{t+1}^B = \delta_t (n_B - u_t^B) + u_t^B (1 - x_t^B f(\theta_t^B) - (1 - x_t^B) f(\theta_t^A)), \quad (3.32)$$

where u_t^i is the number of unemployed who live in state i , x_t^i is the fraction of the unemployed in state i that searches in state i , and δ_t is the separation probability into unemployment, calculated from the Current Population Survey (CPS) following Shimer (2007).

We can thus write for the number of unemployed searching in state A and B respectively:

$$\tilde{u}_t^A = (u_t^A + \zeta(p_t^A - n_t^A))x_t^A + (1 - x_t^B)(u_t^B + \zeta(p_t^B - n_t^B)), \quad (3.33)$$

$$\tilde{u}_t^B = (u_t^B + \zeta(p_t^B - n_t^B))x_t^B + (1 - x_t^A)(u_t^A + \zeta(p_t^A - n_t^A)), \quad (3.34)$$

where we follow Hall (2013) and set ζ to $5/27$ to match the ratio of the job-finding rates of non-participants to the unemployed in the CPS.

We can measure the probabilities for an unemployed worker from states A and B to find a job, ϕ_t^A and ϕ_t^B , in the data:

$$\phi_t^A = \frac{u_t^A - u_{t+1}^A + \delta_t (n_t^A - u_t^A)}{u_t^A}, \quad (3.35)$$

$$\phi_t^B = \frac{u_t^B - u_{t+1}^B + \delta_t (n_t^B - u_t^B)}{u_t^B}, \quad (3.36)$$

as all right-hand variables are measurable in the data. Using (3.31), we can then relate the measurable ϕ_t^A and ϕ_t^B to the unobservable variables $x_t^A, x_t^B, f(\theta_t^A), f(\theta_t^B)$:

$$\phi_t^A = x_t^A f(\theta_t^A) - (1 - x_t^A) f(\theta_t^B), \quad (3.37)$$

$$\phi_t^B = x_t^B f(\theta_t^B) - (1 - x_t^B) f(\theta_t^A). \quad (3.38)$$

The four equations (3.33), (3.34), (3.37) and (3.38) have 4 unknowns, $x_t^A, x_t^B, f(\theta_t^A), f(\theta_t^B)$.²⁹ These equations are not linearly independent and thus do not allow us to recover these 4 unknowns. Instead they give us a set of solutions S .

In order to proceed to identify x_t^A, x_t^B we assume that the matching function is Cobb-Douglas, $\mu u^\gamma v^{1-\gamma}$. Note, however, that we do not necessarily see the true level of vacancies. However, if we assume that we see the same *fraction*, ψ , of total vacancies for both counties in a pair, we can still estimate the effective matching function given our observed vacancies. If we observe $\tilde{v} = \psi v$, then the total number of matches is $\tilde{\mu} u^\gamma \tilde{v}^{1-\gamma}$, where $\tilde{\mu} = \psi^{\gamma-1} \mu$. Thus, we propose to identify $\tilde{\mu}$ and γ in addition to the x 's.

We allow $\tilde{\mu}$ to change over time, to capture any possible time trends in the adoption of online vacancies. The algorithm consists of selecting $\alpha, \{\mu_t, x_t^A, x_t^B\}_{t=1}^T$ to minimize the error in the equations (3.37), (3.38) and:

$$\frac{q(\theta_t^A)}{q(\theta_t^B)} = \left(\frac{\theta_t^B}{\theta_t^A} \right)^\alpha, \quad (3.39)$$

where we observe all left hand side variables for all t .³⁰

We measure the effect of benefits on search behavior by examining the difference between the imputed fraction of workers searching away from their home states $(1 - x_t^A) - (1 - x_t^B)$. Further, we construct imputed tightness by dividing county level

²⁹We do not directly observe x_t^A , and thus we don't observe \tilde{u}_t^A and θ_t^A , nor the matching function.

³⁰The probability to fill a vacancy $q_t = 1 - \frac{v_{t+1} - v_{t+1}^{new}}{v_t}$, where v_t is the stock of vacancies at t and v_t^{new} are newly posted vacancies at t , so that $v_{t+1} - v_{t+1}^{new}$ are not filled vacancies from period t . Both v_t and v_t^{new} are observable in the data.

Table 3.8: Effect of UI Benefits on Imputed Labor Market Variables

| VARIABLES | Out of State Work | Imputed Tightness | Imputed Job-finding |
|-------------------|-------------------|---------------------------|---------------------------|
| Weeks of Benefits | 0.0002 (0.510) | -0.1154 (0.000) | -0.0524 (0.000) |
| Factors | 2 | 2 | 2 |
| Observations | 29,492 | 29,492 | 29,492 |
| R-squared | 0.066 | 0.2816 | 0.2996 |

Note - p -values (in parentheses) calculated via bootstrap.

Bold font indicates $p < 0.01$.

vacancies by the imputed measure of unemployed workers searching in that county (v_t^A/\bar{u}_t^A), corrected for the search behavior along that border segment (we impose the same x 's for all counties within a state for each border segment). Then, the job finding rate is constructed using the imputed tightness and the estimated parameters of the matching function. Table 3.8 Column (1) shows, using the difference-in-difference estimator, that there is only a very small and statistically insignificant response of search behavior, to changes in benefits, so that mobility does not bias our estimates. Further, the effect on imputed tightness, which now fully accounts for changes in mobility in response to changes in benefits, is not statistically significantly different from the baseline estimate. The effect of extending benefits to 82.5 weeks for approximately 16 quarters (the average during the Great Recession) on the quarterly job finding rate would predict a drop from 77.6% to 48.6%.

Next, we look for direct empirical evidence on where people work relative to where they live. We use data from the American Community Survey (ACS) from 2005-2011. The ACS is an annual 1% survey of households in the United States conducted by the Census Bureau. The survey contains information on the county of residence of households and the state of employment. The survey is representative at the Public Use Micro Area level - a statistical area that has roughly 100,000 residents (and thus also for counties with more than 100,000 residents). We compute the share

Table 3.9: Regression Estimates of Out of State Employment

| VARIABLES | Out of state work | |
|--------------------|-------------------------|---------------------|
| | Quasi-Difference (1) | Diff-in-Diff (2) |
| Weeks of Benefits | -0.3560 (1.125) | 0.1737 (1.267) |
| Pair Fixed Effects | Yes | No |
| Observations | 76 | 76 |
| R-squared | 0.770 | 0.115 |

Note - Standard errors in parentheses.

Bold font indicates $p < 0.1$.

of households in border counties who work in the neighboring state. We can then examine how this share of border state workers responds to changes in benefits across states. We perform our analysis using the quasi-difference estimator derived in the empirical methodology section and using a difference-in-difference estimator:

$$\text{Quasi-difference: } \Delta \tilde{e}_{p,t} = \phi_p + \alpha_e \Delta b_{p,t} + \Delta \nu_{p,t}$$

$$\text{Diff-in-diff: } \Delta e_{p,t} = \phi_p + \alpha_e \Delta b_{p,t} + \Delta \nu_{p,t}$$

where $e_{p,t}$ is the fraction of workers at time t that live in county i and work in the state associated with county j (also in pair p). The results of the regressions are in Table 3.9. Using both the quasi-difference and difference-in-difference specification the coefficient on weeks of benefits available is statistically insignificant. This direct evidence once again implies that worker search behavior does not respond significantly to changes in unemployment benefits.

3.6 Implications for Macro Models

Throughout the paper our analysis was motivated by equilibrium search models, such as Mortensen and Pissarides (1994). We found empirical support for the key

mechanisms in the model. In particular, extending unemployment benefits puts an upward pressure on equilibrium wages, which induces lower vacancy posting by firms and consequently an increase in unemployment. Using a simple calibrated version of the model we found that these effects are quantitatively consistent with the data.

In this section we briefly comment on the implications of our findings for the business cycle analysis using this class of models. This analysis was carried out in Mitman and Rabinovich (2013), who used a version of the model in Section 3.4.4, calibrated to match the effect of unemployment benefit extensions on unemployment documented in this paper. They carefully model the history of unemployment benefit extensions in the US. In addition to changing unemployment benefit eligibility over time, the dynamics are driven by fluctuations in aggregate productivity. The endogenously determined dynamics of the unemployment rate in the model together with its evolution in the data are plotted in Figure 3.1.

The results indicate that the effect of unemployment benefit extensions on unemployment, vacancies, and wages documented in this paper is consistent with the effect of business cycle movements in aggregate productivity on these variables. Interestingly, Mitman and Rabinovich (2013) find that the automatic and discretionary benefit extensions in the recent recessions have substantially amplified the response of unemployment and served as the root cause of the widely documented phenomenon of the jobless recoveries (benefit extensions are triggered when unemployment reached a sufficiently high level so that they effectively kick in after productivity is already recovering, inducing a delayed recovery of employment). This is evident in Figure 3.1.

An important line of research, reviewed in Diamond (2013), that also aims to explain the persistently high unemployment following the great recession focused on the behavior of the Beveridge curve. As the dotted green line in Figure 3.2 illustrates, the curve appears to have shifted out following the Great Recession. This was interpreted

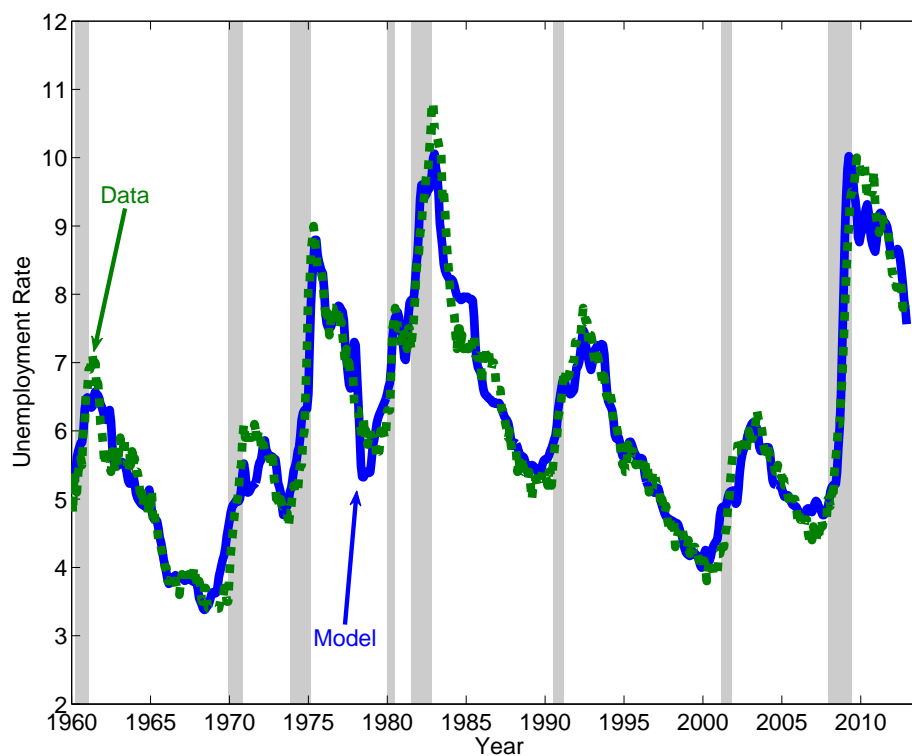


Figure 3.1: The evolution of the U.S. unemployment rate: data and the prediction of the search model with unemployment benefit extensions in Mitman and Rabinovich (2013).

as implying an increase in the “structural” or “mismatch” unemployment because of the apparently high level of vacancies coexisting with high unemployment. As the solid blue line in the same figure illustrates, this behavior of the Beveridge curve arises naturally in the productivity-driven equilibrium search model with the extensions of unemployment benefits as observed in the data during the Great Recession.

3.7 Conclusion

In this paper we employed a state-of-the-art empirical methodology to measure the total effect of unemployment benefit extensions on unemployment. In particular, we exploited the discontinuity of unemployment insurance policies at state borders to

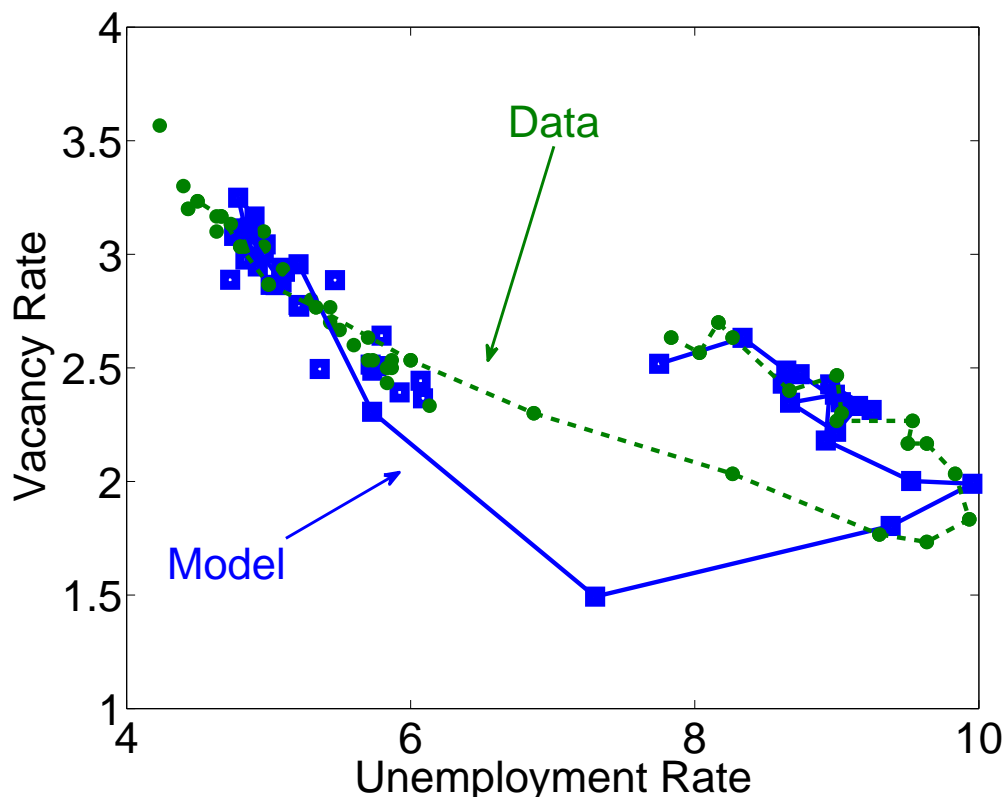


Figure 3.2: The Beveridge Curve in the Great Recession: data and the prediction of the search model with unemployment benefit extensions in Mitman and Rabinovich (2013).

identify their impact. Our estimator controls for the effect of expectations of future changes in benefits and has a simple economic interpretation. It is also robust to the heterogeneous impacts of aggregate shocks on local labor markets.

We found that unemployment benefit extensions have a large effect on total unemployment. In particular, our estimates imply that unemployment benefit extensions can account for most of the persistently high unemployment after the Great Recession. Coupled with the robust finding in the recent literature that the "micro" effect of unemployment benefit extensions on worker search effort and job acceptance decisions is small, this finding implies that the "macro" elasticity is quantitatively large, much larger than the micro elasticity. We found direct support for this conclusion by documenting a large negative response of vacancy creation and employment to

unemployment benefit extensions.

One motivation for increasing unemployment benefit durations during the Great Recession, in addition to helping unemployed workers smooth their consumption, is to increase employment through its stimulative effect on local demand. Although we cannot do full justice to evaluating this effect given the methodology on which our analysis relies, our results nevertheless offer some insights. To the extent that the unemployed spend a significant fraction of their income in their home counties (in a form of e.g., rent payments or service purchases), the corresponding part of the stimulative effect is fully captured by our analysis. Indeed, we find that border counties with longer benefit durations have much higher unemployment, despite the potential beneficial effects of spending. If, on the other hand, spending by the unemployed was spread uniformly on goods and services provided in all counties, this aggregate component is not captured, as it is differenced out by our estimator. We find, however, that an increase in unemployment due to benefit extensions is similar in magnitude to the decline of employment. Thus, the total effect on spending is ambiguous as extending benefits increase spending by the unemployed but at the same time decrease spending as fewer people are employed. The potential offsetting effect of lower employment due to higher benefits was also recognized by policymakers but considered - based on the micro studies discussed above - to be quantitatively very small. Our results of a sizeable macro effect leads us to expect that the stimulative effect of higher spending by the unemployed is largely offset by the dramatic negative effect on employment from the general equilibrium effect of benefit expansion on vacancy creation. To evaluate this effect more explicitly, especially given the zero lower bound constraints imposed on monetary policy following the Great Recession, it is desirable to assess the effects of unemployment benefit extensions in a richer DSGE model with frictional labor market, such as the one in Christiano, Eichenbaum, and Trabandt (2013). It's interesting to note, however, that we find similar effects of increases in

benefits during the Great Recession and during the 2001 recession, despite the fact that the latter featured much higher nominal interest rates.

Chapter 4

Unemployment Benefit Extensions Cause Jobless Recoveries!?

A modified version of this chapter originally appeared as Mitman and Rabinovich (2013) and is co-authored with Stanislav Rabinovich.

A central question in macroeconomic analysis of the labor market is understanding the dynamics of unemployment. The emergence of jobless recoveries in the US economy presents a challenge for this research agenda. Jobless recoveries, phenomena in which aggregate labor productivity grows following a recession, but unemployment remains high, are a prominent and striking feature of the recessions of 1990-1991, 2001 and 2007-2009. These observations have been interpreted as a puzzle from the perspective of standard models of labor market dynamics, which attribute unemployment fluctuations to fluctuations in labor productivity. In this paper, we argue that jobless recoveries are a consequence of government policy, specifically of cyclical changes in unemployment insurance.

The unemployment system in the United States features automatic triggers that increase the duration of unemployment benefits during periods of high unemployment. Moreover, in each of the last major recessions, the government has enacted discretionary policies extending benefit duration further. The weeks of extended benefits available have increased over the last 50 years, reaching an unprecedented 99 weeks

of benefits available during the Great Recession. Crucially, because unemployment benefit duration is generally tied to the unemployment rate, high benefit durations persist long after labor productivity begins to recover following a recession.

To study the implications of this policy for the cyclical behavior of the labor market, we use a variant of the Diamond-Mortensen-Pissarides equilibrium search model with aggregate shocks to labor productivity. Workers and firms in the model match pairwise to produce and bargain over wages. Unemployment benefits increase the unemployment rate by raising the workers' outside option in wage negotiations, thereby discouraging firms from posting job vacancies. If unemployment benefits were constant, a recovery in productivity in the model would imply a drop in unemployment. However, the actual unemployment insurance system extends the duration of unemployment benefits when unemployment is high. Because unemployment is high in the aftermath of a productivity drop, a recovery in productivity is likely to coincide with an extension of unemployment benefits, which can slow down or even prevent the recovery of employment. We argue that this channel lowers the correlation between productivity and unemployment and has the capacity to explain the emergence of jobless recoveries that we observe.

We quantitatively evaluate the importance of this channel in our calibrated model by simulating the series of productivity shocks observed in the 1960-2012 and sequentially introducing the unemployment benefit extensions enacted during this period. We find that the model accounts well for observed time series of unemployment, in particular the observations that recoveries were not jobless prior to 1990 and became jobless thereafter. We then conduct counterfactual experiments to quantify the importance of the extensions: specifically, we examine how the cyclical behavior of unemployment would have been different had the extensions not occurred. We find that the model incorporating the observed countercyclical unemployment benefit extensions accounts for the data substantially better than a model with a

constant unemployment insurance policy. The model predicts a much faster recovery of employment if the unemployment benefit extensions are not enacted. Key to this quantitative result is the general equilibrium effect of unemployment benefits on firms' decisions to post vacancies, via their effect on the worker outside option in wage negotiations. Our analysis shows that appropriately incorporating unemployment benefit extensions is important in quantitatively accounting for unemployment dynamics.

In addition to matching the unemployment dynamics, we find that the model accounts for the apparent shift in the Beveridge curve observed following the 2007-2009 recession. The Beveridge curve - the observed negative correlation between unemployment and vacancies - is a robust feature of the post-war labor market. However, this correlation became substantially weaker in the aftermath of the recession, as the rise in job postings was not accompanied by a comparable fall in unemployment. We show that our simulated model reproduces an unemployment-vacancy correlation very similar to the one observed in the data - including the 2007-2012 period, during which the model reproduces the perceived shift in the simulated Beveridge curve. In other words, the large unemployment benefit extensions implemented during this period acted as shocks that induced a substantial departure from the theoretical Beveridge curve, making it appear as if the curve itself shifted, although all the parameters of our model, including the matching function, have remained the same.

The analysis in our paper is distinct from the large body of research that tries to explain the high volatility of unemployment, following the Shimer (2005) puzzle. Our aim here is not to offer an explanation for the high unemployment volatility.¹ Rather, the quantitative success of our model is evidenced by the fact that it accounts well for the entire time series of unemployment. In particular, it correctly predicts the

¹Our calibration, described in detail in section 5.2, is different from the calibration strategy of Hagedorn and Manovskii (2008b) but delivers similar parameter values; in particular, it implies a high value of non-market activity for unemployed workers. It is therefore not surprising that our model delivers a high volatility of unemployment in line with the data.

timing, not just the volatility, of unemployment dynamics, specifically the sluggish recovery of employment in the aftermath of a recession.

Our paper contributes to an already large and productive literature trying to account for the phenomenon of jobless recoveries. Previous research attempts to substantially modify existing models to account for the sluggish recovery of employment. Bernanke (2003) attributes jobless recoveries to sluggish aggregate demand. Groshen and Potter (2003) propose structural change as an explanation, and Bachmann (2011) studies the role of labor hoarding. Most recently, Berger (2011) has argued that countercyclical restructuring behavior of firms can generate jobless recoveries. This is by no means an exhaustive list.² Relative to this literature, our paper proposes a significantly smaller departure from a workhorse Mortensen-Pissarides model. Rather than modify the structural features of the model, we argue for incorporating a salient but previously overlooked feature of US government policy - time-varying unemployment insurance - into the standard framework. Our results imply not only that unemployment insurance is crucial for explaining the emergence of jobless recoveries, but also that a standard equilibrium search model explains unemployment dynamics very well once these time-varying policy changes are accounted for.

Our paper is also related to a recent literature attempting to quantify the importance of unemployment benefit extensions for unemployment in the 2007-2009 recession, including Nakajima (2011), Valletta and Kuang (2010), Fujita (2010), Rothstein (2011b), and Hagedorn, Karahan, Manovskii, and Mitman (2013). Our paper differs substantially from this literature by using a calibrated general equilibrium model in which the only exogenous inputs are productivity shocks and changes in unemployment benefit duration. Furthermore, while the above-mentioned literature focuses only on the 2007-2009 recession and its aftermath, we use time-varying unemployment benefits to explain the entire time series of unemployment over the last 50 years.

²Aaronson, Rissman, and Sullivan (2004) discuss existing explanations that have been proposed for jobless recoveries.

To the best of our knowledge, our paper is the first to link the growing generosity of extensions to the emergence of jobless recoveries, in particular to explain the unemployment experience of the 1990-1991 and 2001 recessions as well as the most recent one.

In section 5.1 we describe the model environment with time-varying unemployment benefits. In section 5.2 we lay out the calibration procedure. In section 4.3 we discuss the calibrated model's predictions and compare them with empirical estimates from the previous literature. In section 4.4, we describe the simulation and quantitative analysis that we conduct. Section 5.3.2 reports the results, and section 5.5 concludes. All tables and figures are collected in Appendix 4.7. Appendix D.1 provides an overview of the unemployment benefit extensions in the post-war period.

4.1 Model Description

4.1.1 Economic Environment

We consider a Diamond-Mortensen-Pissarides model with aggregate productivity shocks. Time is discrete and the time horizon is infinite. The economy is populated by a unit measure of workers and a larger continuum of firms.

Agents. In any given period, a worker can be either employed (matched with a firm) or unemployed. Workers are risk-neutral expected utility maximizers and have expected lifetime utility

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t x_t,$$

where \mathbb{E}_0 is the period-0 expectation operator, $\beta \in (0, 1)$ is the discount factor and x_t denotes consumption in period t . An unemployed worker produces h , which stands for the combined value of leisure and home production.

Firms are risk-neutral and maximize profits. Workers and firms have the same

discount factor β . A firm can be either matched to a worker or vacant. A firm posting a vacancy incurs a flow cost k .

Matching. Unemployed workers and vacancies match in pairs to produce output. The number of new matches in period t equals

$$M(u_t, v_t),$$

where u_t is the unemployment level in period t , and v_t is the measure of vacancies posted in period t .

The matching function M exhibits constant returns to scale, is strictly increasing and strictly concave in both arguments, and has the property that the number of new matches cannot exceed the number of potential matches: $M(u, v) \leq \min\{u, v\} \forall u, v$.

We define

$$\theta_t = \frac{v_t}{u_t}$$

to be the market tightness in period t . We define the functions

$$f(\theta) = \frac{M(u, v)}{u} = M(1, \theta) \quad \text{and}$$

$$q(\theta) = \frac{M(u, v)}{v} = M\left(\frac{1}{\theta}, 1\right)$$

where $f(\theta)$ is the job-finding probability for an unemployed worker and $q(\theta)$ is the probability of filling a vacancy. By the assumptions on M made above, the function $f(\theta)$ is increasing in θ and $q(\theta)$ is decreasing in θ .

Existing matches are exogenously destroyed with a constant job separation probability δ . Thus, any of the $l_t = 1 - u_t$ workers employed in period t has a probability δ of becoming unemployed in period $t + 1$.

Production. All worker-firm matches are identical: the only shocks to labor productivity are aggregate shocks. Specifically, a matched worker-firm pair produces output z_t in period t , where z_t is aggregate labor productivity. We assume that $\ln z_t$ follows an AR(1) process

$$\ln z_t = \rho \ln z_{t-1} + \sigma_\varepsilon \varepsilon_t, \quad (4.1)$$

where $0 \leq \rho < 1$, $\sigma_\varepsilon > 0$, and ε_t are independent and identically distributed standard normal random variables. We will write $z^t = \{z_0, z_1, \dots, z_t\}$ to denote the history of shocks up to period t .

4.1.2 Government Policy

The government levies a constant lump sum tax τ on firm profits and uses its tax revenues to finance unemployment benefits b . Every worker, at each point in time, can be either *eligible* or *ineligible* for unemployment insurance, and receives b only if unemployed and eligible. We assume stochastic benefit expiration, similarly to Fredriksson and Holmlund (2001) and Faig and Zhang (2012). Eligible workers may lose their eligibility if unemployed, and ineligible workers may regain eligibility when employed. Specifically, the eligibility status of a worker evolves as follows:

- A worker who is eligible for unemployment insurance retains his eligibility the following period with probability 1 if employed, and with probability $1 - e_t$ if unemployed; with probability e_t he instead becomes ineligible.
- A worker who is ineligible for unemployment insurance remains ineligible the following period if unemployed, and becomes re-entitled to unemployment insurance with probability r_t if employed.

This assumption is made to mimic the actual system of benefit expiration and re-entitlement in the US while ensuring the stationarity of the workers' and firms' decision problems. Finally, the government policy can potentially depend on the current

state of the economy, in particular on the unemployment rate.

4.1.3 Timing

1. The economy enters period t with some distribution of workers across employment and eligibility states:

- l_t^E = measure of eligible employed workers;
- l_t^I = measure of ineligible employed workers;
- u_t^E = measure of eligible unemployed workers;
- u_t^I = measure of ineligible unemployed workers.

Note that $l_t^E + l_t^I + u_t^E + u_t^I = 1$.

2. The aggregate shock z_t then realizes and is publicly observed. Production and consumption then take place: employed workers get wage w_t^E if eligible for unemployment insurance and w_t^I if ineligible (see below for how wages are determined). Unemployed workers receive $h + b$ if eligible for benefits and h if ineligible.
3. Firms decide how many vacancies to post, at cost k per vacancy. This determines the market tightness

$$\theta_t = \frac{v_t}{u_t^E + u_t^I} \quad (4.2)$$

4. $f(\theta)(u_t^E + u_t^I)$ workers find jobs. At the same time, a fraction δ of the existing $l_t = l_t^E + l_t^I$ matches are exogenously destroyed.
5. Eligible unemployed workers become ineligible with probability e_t and remain eligible with probability $1 - e_t$. At the same time, ineligible employed workers become eligible with probability r_t and remain ineligible with probability $1 - r_t$.

The laws of motion for the distribution of workers are then given by:

$$l_{t+1}^E = (1 - \delta) l_t^E + f(\theta_t) u_t^E + r_t [(1 - \delta) l_t^I + f(\theta_t) u_t^I] \quad (4.3)$$

$$l_{t+1}^I = (1 - r_t) [(1 - \delta) l_t^I + f(\theta_t) u_t^I] \quad (4.4)$$

$$u_{t+1}^E = (1 - e_t) [\delta l_t^E + (1 - f(\theta_t)) u_t^E] \quad (4.5)$$

$$u_{t+1}^I = \delta l_t^I + (1 - f(\theta_t)) u_t^I + e_t [\delta l_t^E + (1 - f(\theta_t)) u_t^E] \quad (4.6)$$

4.1.4 Worker Value Functions

We characterize the problem of the worker recursively. The aggregate state of the economy in period t is denoted by $\Omega_t \equiv (z_t, l_t^E, l_t^I, u_t^E, u_t^I)$. The evolution of the aggregate state is then determined by equations (4.1), (4.3)-(4.6).

A worker entering period t eligible employed receives a wage w_t^E . Then he retains his job with probability $1 - \delta$ and loses it with probability δ . If he loses his job, he also loses his eligibility with probability e_t and retains it with probability $1 - e_t$.³

A worker entering period t as ineligible employed receives a wage w_t^I . Then he retains his job with probability $1 - \delta$ and loses it with probability δ . If he retains his job, he becomes eligible the following period with probability r_t and remains ineligible with probability $1 - r_t$.

A worker entering period t as eligible unemployed receives $h+b$ and finds a job with probability $f(\theta_t)$. If he remains unemployed, he loses his eligibility with probability e_t and retains it with probability $1 - e_t$.

A worker entering period t as ineligible unemployed receives only h and finds a job with probability $f(\theta_t)$. If he remains unemployed, he also remains ineligible, and if he finds a job, he becomes eligible with probability r_t .

Denote the values of employed workers by W_t^E and W_t^I for eligible and ineligible

³We assume that a worker who has just become unemployed may lose his eligibility immediately. This timing assumption does not affect any of the results and is made purely for analytical convenience; we could have alternatively assumed that an eligible worker who just lost his job spends one period as eligible and only then may lose his eligibility.

workers, respectively. Similarly, denote the values of unemployed workers by U_t^E and U_t^I for eligible and ineligible workers, respectively. Then these values satisfy:

$$\begin{aligned} W_t^E(\Omega_t) &= w_t^E + \beta(1 - \delta)\mathbb{E}W_{t+1}^E(\Omega_{t+1}) \\ &\quad + \beta\delta(1 - e_t)\mathbb{E}U_{t+1}^E(\Omega_{t+1}) + \beta\delta e_t\mathbb{E}U_{t+1}^I(\Omega_{t+1}) \end{aligned} \quad (4.7)$$

$$\begin{aligned} W_t^I(\Omega_t) &= w_t^I + \beta(1 - \delta)r_t\mathbb{E}W_{t+1}^E(\Omega_{t+1}) \\ &\quad + \beta(1 - \delta)(1 - r_t)\mathbb{E}W_{t+1}^I(\Omega_{t+1}) + \beta\delta\mathbb{E}U_{t+1}^I(\Omega_{t+1}) \end{aligned} \quad (4.8)$$

$$\begin{aligned} U_t^E(\Omega_t) &= h + b + \beta f(\theta_t)\mathbb{E}W_{t+1}^E(\Omega_{t+1}) \\ &\quad + \beta(1 - f(\theta_t))(1 - e_t)\mathbb{E}U_{t+1}^E(\Omega_{t+1}) \\ &\quad + \beta(1 - f(\theta_t))e_t\mathbb{E}U_{t+1}^I(\Omega_{t+1}) \end{aligned} \quad (4.9)$$

$$\begin{aligned} U_t^I(\Omega_t) &= h + \beta f(\theta_t)r_t\mathbb{E}W_{t+1}^E(\Omega_{t+1}) \\ &\quad + \beta f(\theta_t)(1 - r_t)\mathbb{E}W_{t+1}^I(\Omega_{t+1}) \\ &\quad + \beta(1 - f(\theta_t))\mathbb{E}U_{t+1}^I(\Omega_{t+1}) \end{aligned} \quad (4.10)$$

4.1.5 Firm Value Functions

A firm matched to an eligible worker receives profits $z_t - \tau - w_t^E$ and retains the worker for the next period with probability $1 - \delta$. A firm matched to an ineligible worker receives profits $z_t - \tau - w_t^I$ and retains the worker for the next period with probability $1 - \delta$. If it retains the worker, the worker becomes eligible the next period with probability r_t . Denote the value of a vacancy by V_t and denote by J_t^E , J_t^I the values of a firm matched with an eligible and an ineligible worker, respectively. Then the values of a matched firm satisfy:

$$J_t^E(\Omega_t) = z_t - w_t^E - \tau + \beta(1 - \delta) \mathbb{E}J_{t+1}^E(\Omega_{t+1}) + \beta\delta \max\{0, V_t(\Omega_{t+1})\} \quad (4.11)$$

$$\begin{aligned} J_t^I(\Omega_t) &= z_t - w_t^I - \tau + \beta(1 - \delta)(1 - r_t) \mathbb{E}J_{t+1}^I(\Omega_{t+1}) \\ &\quad + \beta(1 - \delta)r_t \mathbb{E}J_{t+1}^E(\Omega_{t+1}) + \beta\delta \max\{0, V_t(\Omega_{t+1})\} \end{aligned} \quad (4.12)$$

A firm posting a vacancy in period t suffers a flow cost k and fills its vacancy with probability $q(\theta_t)$. Let ϖ_t be the probability that, conditional on filling a vacancy, the worker hired by the firm is eligible for benefits. Then the value of a vacancy satisfies:

$$V_t(\Omega_t) = -k + \beta q(\theta_t) \{ \varpi_t \mathbb{E}J_{t+1}^E(\Omega_{t+1}) + (1 - \varpi_t) \mathbb{E}J_{t+1}^I(\Omega_{t+1}) \} \quad (4.13)$$

The assumptions made above imply

$$\varpi_t = \frac{u_t^E + r_t u_t^I}{u_t^E + u_t^I} \quad (4.14)$$

Free entry of firms guarantees that the value of a vacancy is always zero in equilibrium, so we will have:

$$k = \beta q(\theta_t) \{ \varpi_t \mathbb{E}J_{t+1}^E(\Omega_{t+1}) + (1 - \varpi_t) \mathbb{E}J_{t+1}^I(\Omega_{t+1}) \} \quad (4.15)$$

4.1.6 Wage Bargaining

We make the assumption, standard in the literature, that wages are determined according to Nash bargaining: the wage is chosen to maximize a weighted product of the worker's surplus and the firm's surplus. An eligible worker's surplus from being employed is defined by $\Delta_t^E = W_t^E - U_t^E$, and an ineligible worker's surplus from being employed is $\Delta_t^I = W_t^I - U_t^I$. Similarly, we define the surplus of a firm employing

an eligible worker to be $\Gamma_t^E = J_t^E - V_t$, and for a firm employing an ineligible worker, $\Gamma_t^I = J_t^I - V_t$. The wage w_t^E is chosen to maximize the product

$$(\Delta_t^E)^\xi (\Gamma_t^E)^{1-\xi} \quad (4.16)$$

and similarly, the wage w_t^I is chosen to maximize the product

$$(\Delta_t^I)^\xi (\Gamma_t^I)^{1-\xi}, \quad (4.17)$$

where $\xi \in (0, 1)$ is the worker's bargaining weight. Since the value of a vacancy is always zero, we have $\Gamma_t^i = J_t^i$ for $i = E, I$ and so the first-order conditions for the bargaining problems (4.16), (4.17) imply $\Delta_t^E = \xi (\Delta_t^E + J_t^E)$ and $\Delta_t^I = \xi (\Delta_t^I + J_t^I)$.

4.1.7 Equilibrium

We now define the recursive equilibrium of the model.

Definition Given a policy $(\tau, b, e(\cdot), r(\cdot))$, an equilibrium is a set of functions for wages $w^E(\Omega_t)$, $w^I(\Omega_t)$, search effort $S^E(\Omega_t)$, $S^I(\Omega_t)$, market tightness $\theta(\Omega_t)$, and value functions

$$\{W^E(\Omega_t), W^I(\Omega_t), U^E(\Omega_t), U^I(\Omega_t), J^E(\Omega_t), J^I(\Omega_t), V(\Omega_t)\}$$

such that:

1. The value functions satisfy the worker and firm Bellman equations (4.7)-(4.13)
2. Free entry: The value $V(\Omega_t)$ of a vacant firm is zero for all Ω_t
3. Nash bargaining: The wage $w^E(\Omega_t)$ maximizes equation (4.16), and $w^I(\Omega_t)$ maximizes equation (4.17)

4. Laws of motion: The aggregate state Ω_t evolves according to equations (4.1), (4.3)-(4.6).

4.2 Calibration

We calibrate the model to match US data over the 1960-2005 period to match several salient features of the US labor market. The model period is taken to be 1 week. We normalize mean weekly productivity to one. Following Hall & Milgrom (2008) we set $b = 0.25$ to match the average replacement rate of unemployment insurance after accounting for the fact that take-up rates of unemployment are less than 100%. The tax rate is set so that the government balances its budget on average, resulting in $\tau = 0.023$. The function $e(\cdot)$ mimics the variation in benefit duration in the US economy.

Following den Haan, Ramey, and Watson (2000), we assume the functional form of the matching function to be

$$M(N, v) = \frac{Nv}{[N^\lambda + v^\lambda]^{1/\lambda}}$$

The choice of the matching technology is driven by the requirement that the job-finding rate and the job-filling rate always be strictly less than 1. We obtain:

$$f(\theta) = \frac{\theta}{(1 + \theta^\lambda)^{1/\lambda}}$$

$$q(\theta) = \frac{1}{(1 + \theta^\lambda)^{1/\lambda}}$$

Following Shimer (2005), labor productivity z_t is taken to mean real output per person in the non-farm business sector. This measure of productivity is taken from the quarterly data constructed by the BLS. We also use the seasonally adjusted unemployment series constructed by the BLS, and measure vacancies using the seasonally

adjusted help-wanted index constructed by the Conference Board.

We set the discount factor $\beta = 0.99^{1/12}$, implying a yearly discount rate of 4%. The parameters for the productivity shock process are estimated, at the weekly level, to be $\rho = 0.9895$ and $\sigma_\varepsilon = 0.0034$. The job separation parameter δ is set to 0.0081 to match the average weekly job separation rate. We set $k = 0.58$ following Hagedorn and Manovskii (2008b), who estimate the combined capital and labor costs of vacancy creation to be 58% of weekly labor productivity.

This leaves three parameters to be calibrated: (1) the value h of non-market activity; (2) the worker's bargaining weight ξ ; and (3) the matching function parameter λ . We calibrate these three parameters jointly to match three data targets, chosen to capture relevant statistics from the US labor market. The first two of these statistics are the average vacancy-unemployment ratio of 0.634 and the average job-finding rate of 0.4. The third target is the elasticity of unemployment duration with respect to potential unemployment benefit duration. Classic research based on large benefit extensions during the recessions of the 1980's, starting with e.g., Moffitt and Nicholson (1982), Moffitt (1985b), and Katz and Meyer (1990b), reached consensus estimates that a one week increase in benefit duration increases the average duration of unemployment spells by 0.1 to 0.2 weeks. We target 0.1, the lower end of this range. In the next section, we discuss the choice of this estimate. Table 5.1 reports the calibrated parameters.

4.3 Discussion: The Effect of Benefit Extensions

As described above, our calibration procedure has used findings from the previous literature estimating the effect of unemployment benefits on unemployment duration. In what follows, we discuss the various available estimates in the literature and compare them to our model's predictions.

Our chosen target for the elasticity of unemployment duration with respect to

unemployment benefits lies at the lower end of the range of estimates obtained by Moffitt and Nicholson (1982), Moffitt (1985b), and Katz and Meyer (1990b).⁴ Thus, we can interpret our findings as being very conservative estimates of the overall effects of unemployment benefit extensions. The estimate of 0.1 that we use implies that a ten-week increase in benefit duration results in a one week increase in unemployment duration. Although this elasticity might appear small, it is not innocuous in the context we study, for two reasons. First, an apparently small increase in unemployment duration can correspond to a large increase in the aggregate unemployment rate. Second, the unemployment benefit extensions we consider are large, especially the extensions in the most recent extensions, which increased potential benefit duration to as much as 99 weeks.

One potential concern could be that the findings from the literature that we use were based on the records of UI recipients and that non-recipients might react differently. But this was shown not to be the case by Rothstein (2011b). Indeed, he shows that the job finding rate of ineligible workers responds as much as that of the eligible ones to benefit extensions.

Another potential concern might be that these findings were obtained from the recessions of the 1980's, and that these recessions could, perhaps, be somehow fundamentally different from the subsequent ones. Card and Levine (2000) estimate the effects of a temporary unemployment benefit extension that took place in New Jersey in 1996. They found that a short-term extension of benefit duration by 13 weeks led to a 16.6% decline in the exit rate from unemployment. In our model a permanent 13 week benefit extension leads to a 17.5% decrease in the exit rate from unemployment. It is expected that our model should over-predict the numerical value from Card and

⁴Our model has deliberately abstracted from worker choice of search effort. The classic studies by Moffitt and Nicholson (1982), Moffitt (1985b), and Katz and Meyer (1990b), measuring the effect of unemployment insurance on unemployment duration, do not disentangle the effect on worker search intensity from the effect on firms' vacancy creation, and thus we interpret their estimates as measuring the combination of these two effects. On the other hand, recent innovative work by Rothstein (2011b) and Farber and Valletta (2013) estimates the effect reflecting an individual worker's search intensity response to unemployment benefits and finds that this effect is small.

Levine (2000), since they were measuring the effect of a temporary extension, whereas in the model we measured the effect of a permanent extension.

Finally, Hagedorn, Karahan, Manovskii, and Mitman (2013), estimate the effects of unemployment benefit extensions during the Great Recession, as well as during the 2002 recession. Hagedorn, Karahan, Manovskii, and Mitman (2013) conclude that extending benefit duration significantly increases unemployment, decreases employment and increases equilibrium wages. We find that our calibrated model is consistent with the effects of unemployment benefits on employment and vacancy creation measured by their study.

4.4 Simulation

In order to determine to what extent unemployment benefit extensions played a role in the jobless recoveries from 1992 onwards, we simulate our model from 1960 forward. Over that time period, as discussed in Appendix D.1, there were 19 changes to unemployment benefit duration (excluding extensions and reauthorizations). In order to deal with this large number of policy changes while still solving a stochastic weekly model, we make the following simplifying assumptions: (1) We assume that all policy changes are unanticipated, or equivalently zero probability events and (2) We assume that all agents in the model believe that the policy changes are permanent when enacted.

The only exogenous inputs to the model are labor productivity and the changes in unemployment benefits. We construct the labor productivity series using output per worker as reported by the BLS. We HP filter the quarter data with a smoothing parameter of 1600, then compute the log deviation from the filtered series. We then construct a smooth weekly series such that the quarterly average of the weekly series matches the quarterly detrended series. We take the unemployment rate in December 1960 as the initial condition and then simulate the model forward, feed-

ing in the constructed series for productivity and policy changes. The equilibrium is thus a rational expectations one, but not one with future foresight over productivity realizations. At dates which correspond to policy changes, we implement the policy change and simulate the model forward allowing the unemployment rate to evolve endogenously.

4.5 Results

The simulated model is able to account for key features of the post-war labor market. In figure 4.3, we plot the unemployment rate generated from the model and that observed in the data. The model with the implemented US unemployment benefit policy generates a time series of unemployment that closely matches what is seen in the data. Next, we confirm the model's ability to match key business cycle statistics. Tables 4.2 and 4.3 report the summary statistics from US data and from the model. Table 4.4 reports the same summary statistics from the simulated model with no benefit extensions. In addition, we report in Table 4.5 the autocorrelation of unemployment and, in Table 4.6, the correlation of unemployment with productivity lagged one quarter. These results show that the calibrated model performs well in matching the cyclical behavior of unemployment. Furthermore, shutting down time-varying unemployment benefit extensions would substantially worsen the model's ability to match the observed dynamics, in particular the persistence of unemployment, the weak correlation between unemployment and productivity, and the comparatively strong correlation between unemployment and lagged productivity.

We next investigate whether the model is consistent with the emergence of jobless recoveries. In figure 4.4, we plot the change in employment - actual and predicted by the model - relative to the NBER peak before the 1973-1975, 1980 and 1981-1982 recessions. The model replicates the response of employment over those periods quite well. Next, in figure 4.5, we similarly plot the change in employment for the 1990-1991,

2001 and 2007-2009 recessions. The model is able to replicate the observation that, unlike the previous three recessions, the recovery of productivity was not matched in this case by a rapid rise in employment.

The model is also able to successfully replicate the counterclockwise movement in the Beveridge curve in the Great Recession. The model and data Beveridge curves are plotted in Figure 4.8. This suggests that the large unemployment benefit extensions implemented during this period acted as shocks that induced a substantial departure from the theoretical Beveridge curve, making it appear as if the curve itself shifted, although all the parameters of our model, including the matching function, have remained the same. In order to elucidate the effect of benefit extensions on the Beveridge curve, in Figure 4.9 we plot the simulated Beveridge curve when productivity is held constant during the Great Recession and subsequent recovery, but benefit extensions are still enacted. The timing of the dynamics of unemployment significantly lags the data (because the drop in productivity preceded benefit extensions); however, it shows that the change in benefits alone can generate counter-clockwise movement in the Beveridge curve.

Finally, we examine the role of unemployment benefit extensions in generating jobless recoveries. To do so, we perform a counterfactual experiment in which we shut down all benefit extensions (i.e. fix the weeks of benefits at 26) and re-simulate the model. The result is shown in Figure 4.7 for the 1990-1991, 2001 and 2007-2009 recessions. The figure illustrates that the model without the additional extensions cannot generate jobless recoveries: employment recovers much faster in the model than it does in the data. Unemployment benefit extensions are thus quantitatively important for explaining the cyclical behavior of employment.

4.6 Conclusion

The last three recessions in the US were characterized by the presence of jobless recoveries. The last three recessions also featured extensions of unemployment benefits duration of unprecedented size. The thesis of this paper is that these two features of the recent recessions are linked: unemployment benefit extensions in recessions slow down the recovery of employment, by reducing firm incentives to post vacancies. Once these time-varying extensions are incorporated into an equilibrium search model, we argue that the model is able to reproduce observed unemployment dynamics.

4.7 Tables and Figures

Table 4.1: Internally Calibrated Parameters

| Parameter | Value |
|----------------------------------|-------|
| h Value of non-market activity | 0.81 |
| ξ Bargaining power | 0.13 |
| λ Matching parameter | 0.40 |

Table 4.2: Summary Statistics, Quarterly US Data, 1960:I to 2013:II

| | u | v | v/u | z |
|--------------------|--------|--------|---------|---------|
| Standard Deviation | 0.1201 | 0.1276 | 0.2758 | 0.0120 |
| Correlation Matrix | u | 1 | -0.8686 | -0.2144 |
| | v | | 1 | 0.2008 |
| | v/u | | | 1 |
| | z | | | |

Table 4.3: Results from the Calibrated Model

| | u | v | v/u | z |
|--------------------|--------|--------|---------|---------|
| Standard Deviation | 0.0866 | 0.1077 | 0.2138 | 0.0120 |
| Correlation Matrix | u | 1 | -0.7729 | -0.2829 |
| | v | | 1 | 0.4000 |
| | v/u | | | 1 |
| | z | | | |

Table 4.4: Results from the Model with No Benefit Extensions

| | u | v | v/u | z |
|--------------------|--------|--------|---------|---------|
| Standard Deviation | 0.0794 | 0.0684 | 0.1431 | 0.0120 |
| Correlation Matrix | u | 1 | -0.7905 | -0.7548 |
| | v | | 1 | 0.8407 |
| | v/u | | | 1 |
| | z | | | 1 |

Table 4.5: Autocorrelation of Unemployment

| Quarter Lag | Data | Model | Model w/o Extensions |
|-------------|---------|---------|-------------------------|
| 0 | 1 | 1 | 1 |
| 1 | 0.9154 | 0.8833 | 0.8576 |
| 2 | 0.7478 | 0.6602 | 0.5598 |
| 3 | 0.5375 | 0.4517 | 0.2408 |
| 4 | 0.3193 | 0.2753 | -0.0336 |
| 5 | 0.1254 | 0.1173 | -0.2302 |
| 6 | -0.0428 | -0.02 | -0.3484 |
| 7 | -0.188 | -0.1248 | -0.3919 |

Table 4.6: Correlation with lagged productivity, z_{t-1}

| Variable | Data | Model | Model |
|-----------|---------|----------------|---------|
| | | w/o Extensions | |
| u_t | -0.4321 | -0.4420 | -0.8929 |
| v_t | 0.4680 | 0.5047 | 0.6927 |
| v_t/u_t | 0.4102 | 0.4589 | 0.8016 |

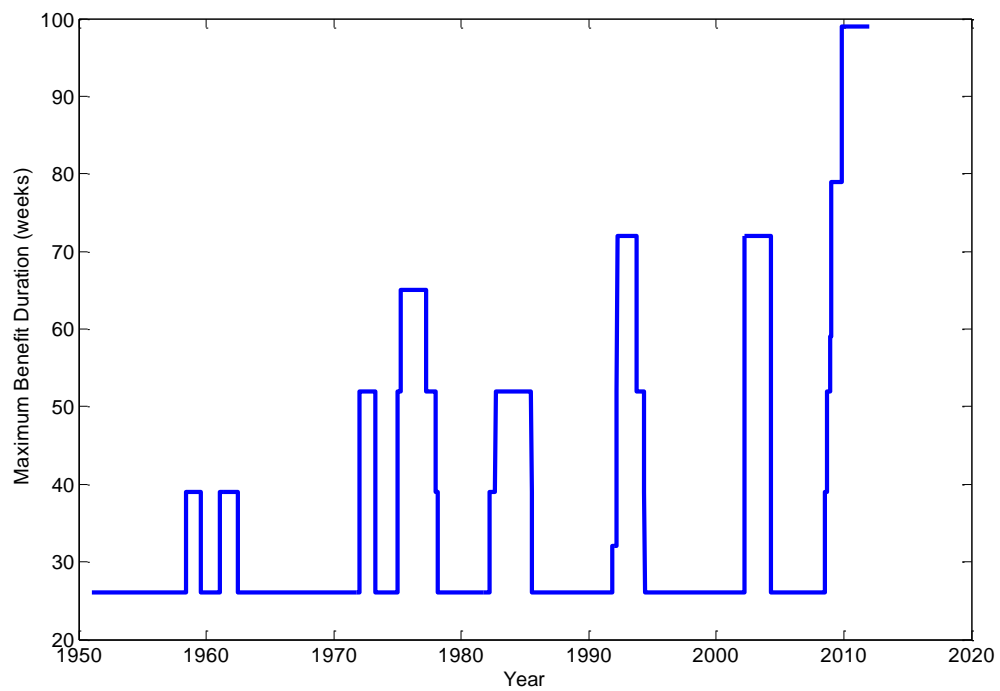


Figure 4.1: Maximum possible benefit duration available during the Post-War period. The extensions include a combination of discretionary federal extensions and the state-federal extended benefits program.

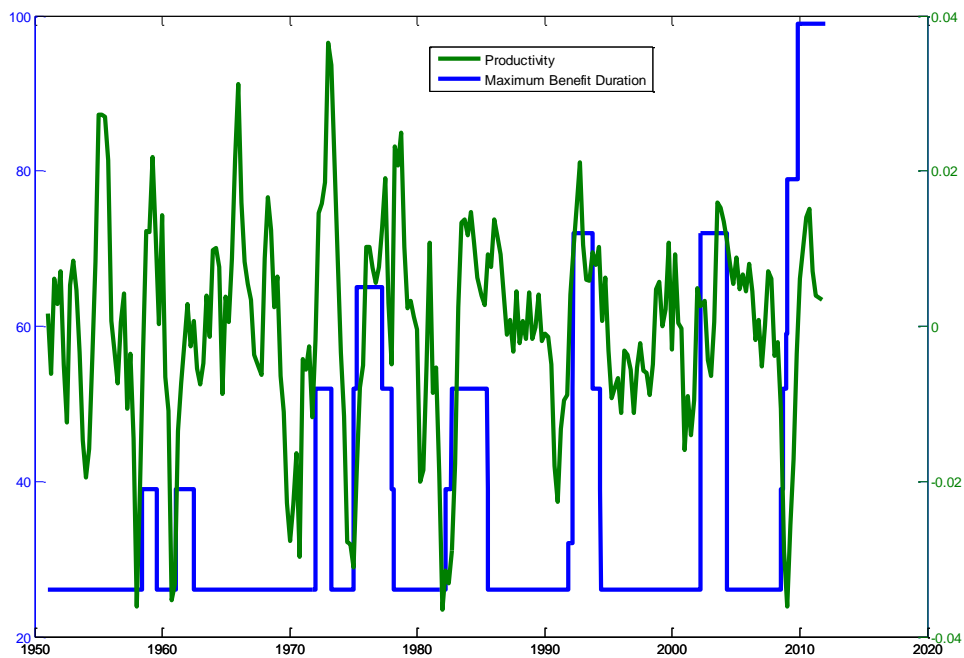


Figure 4.2: Maximum possible benefit duration available during the Post-War period and productivity. Productivity is calculate as log deviation from HP filtered trend of output per worker in the non-farm business sector reported by the Bureau of Labor Statistics. In the recessions follow the 1981-1982 recession, benefit extensions were more likely to occur after productivity had already begun to recover.

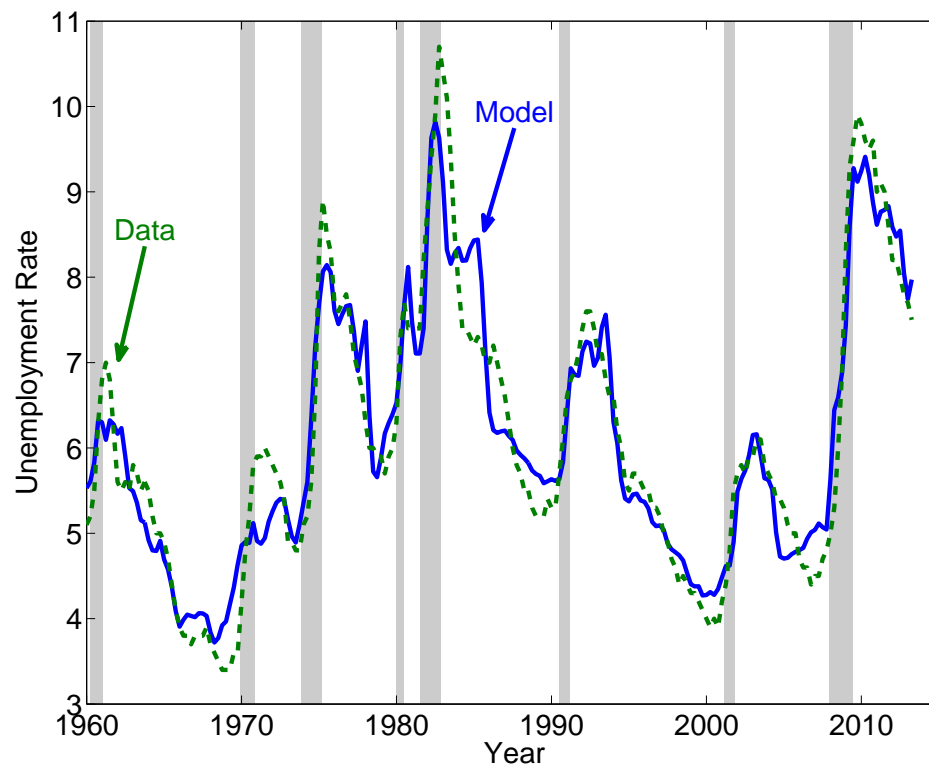


Figure 4.3: Simulated and actual unemployment from January 1960 through June 2013. NBER dated recessions are shaded.

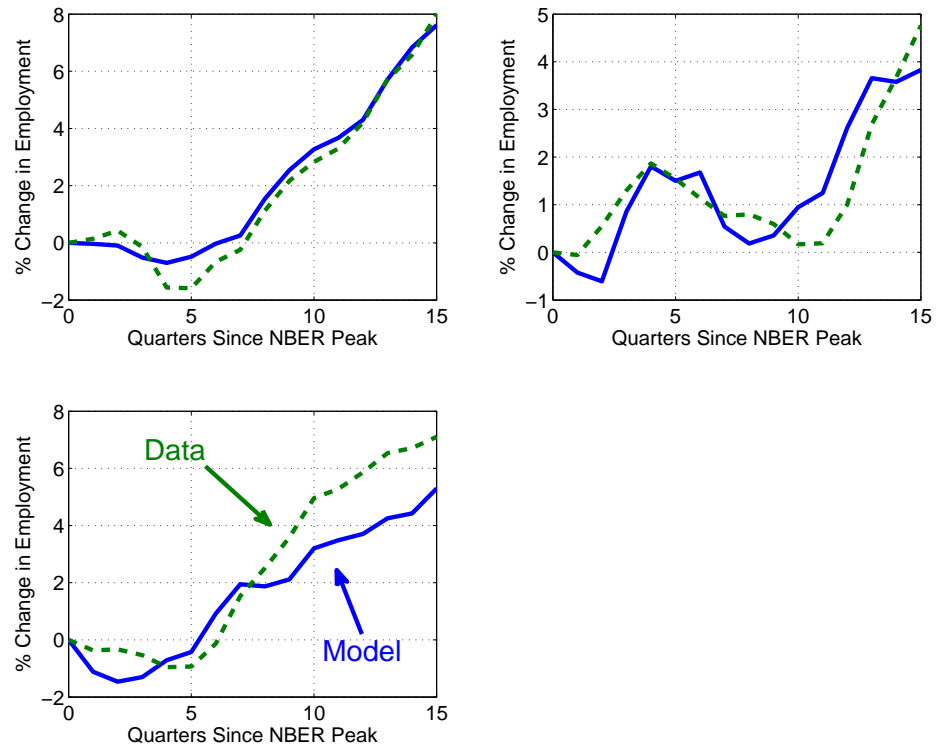


Figure 4.4: Simulated and actual percentage change in employment from NBER peak before the 1973-75, 1980 and 1981-82 recessions. The blue line is the model and dashed green line is the data. Data and model are not filtered.

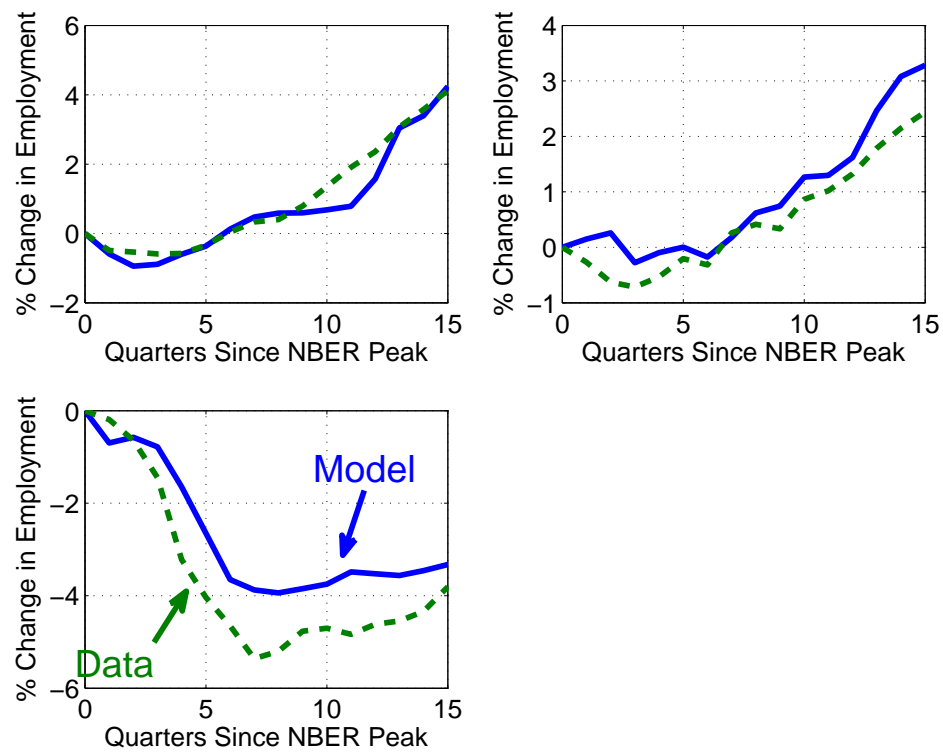


Figure 4.5: Simulated and actual percentage change in employment from NBER peak before the 1990-91, 2001 and 2007-09 recessions. The blue line is the model and dashed green line is the data. Data and model are not filtered.

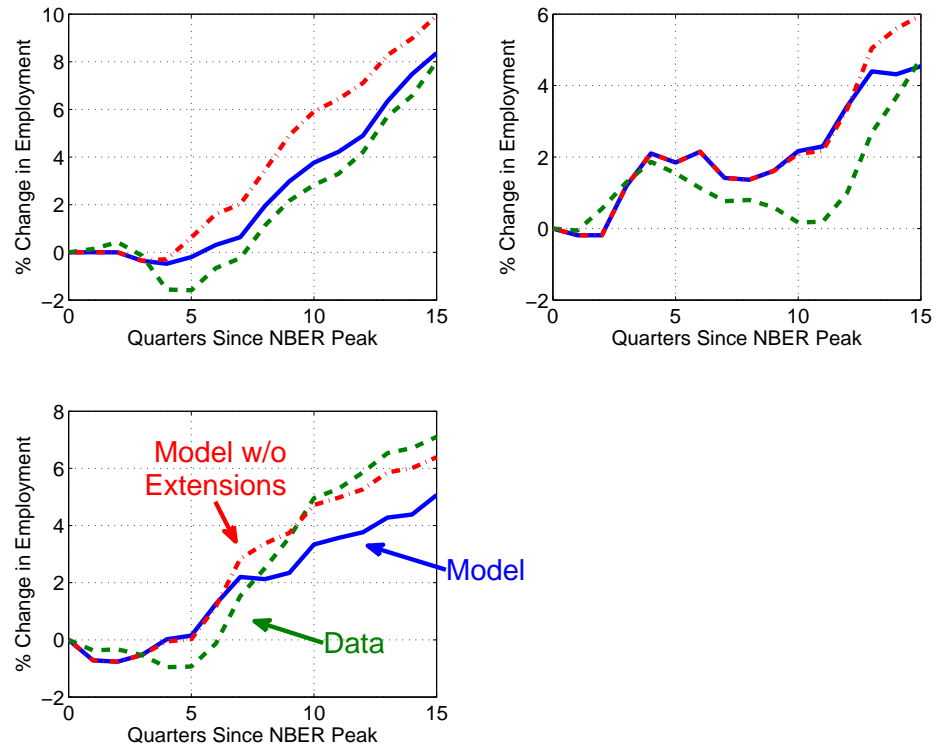


Figure 4.6: Simulated and actual percentage change in employment from NBER peak before the 1973-75, 1980 and 1981-82 recessions. The blue line is the model, the red dot-dashed line is the model without extensions, and dashed green line is the data. Data and model are not filtered.

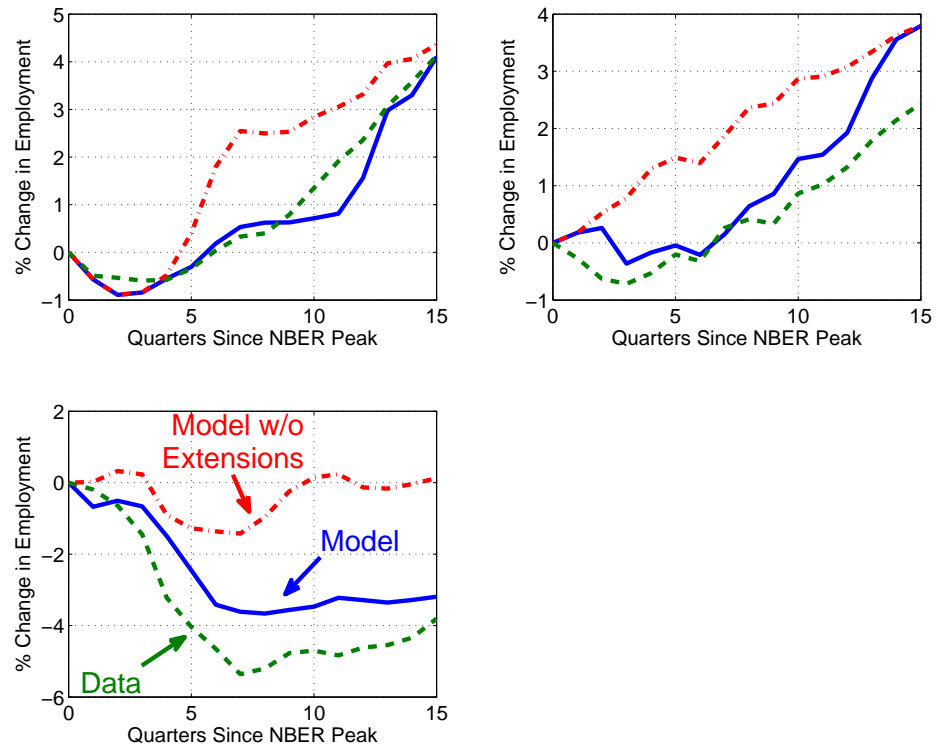


Figure 4.7: Simulated and actual percentage change in employment from NBER peak before the 1990-91, 2001 and 2007-09 recessions. The blue line is the model, the red dot-dashed line is the model without extensions, and green dashed line is the data. Data and model are not filtered.

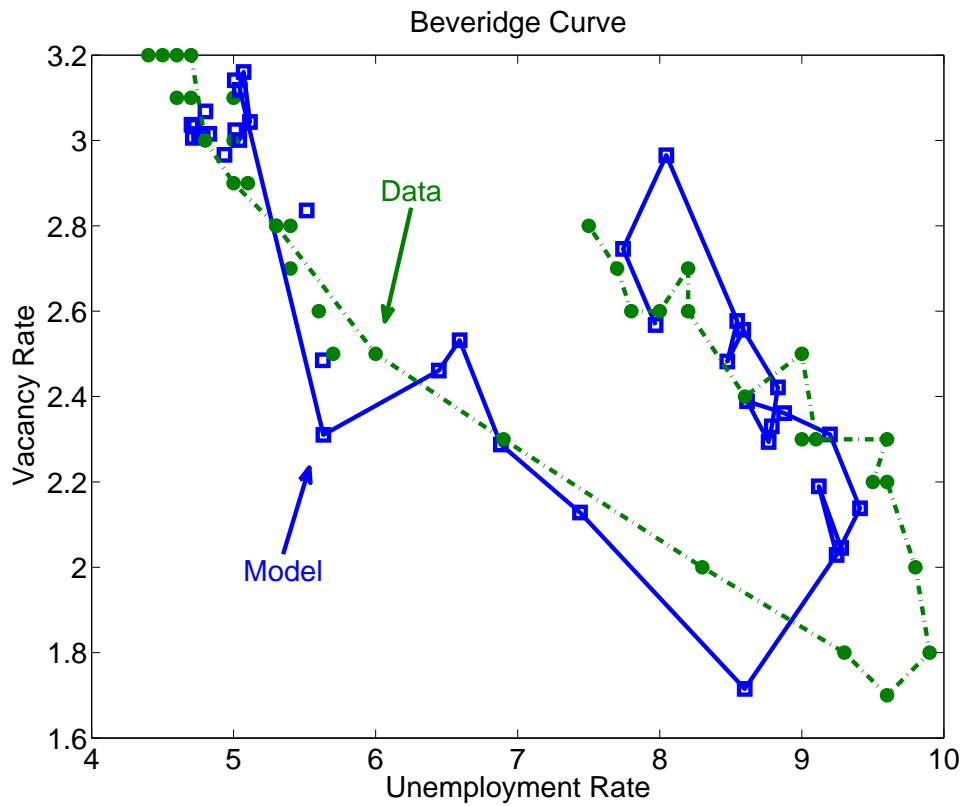


Figure 4.8: Simulated and actual Beveridge curve from January 2005 through December 2011. The unemployment and vacancy rates come from the BLS JOLTS database. Both series are plotted as quarterly averages of monthly (JOLTS) and weekly (model) data. Data and model are not filtered.

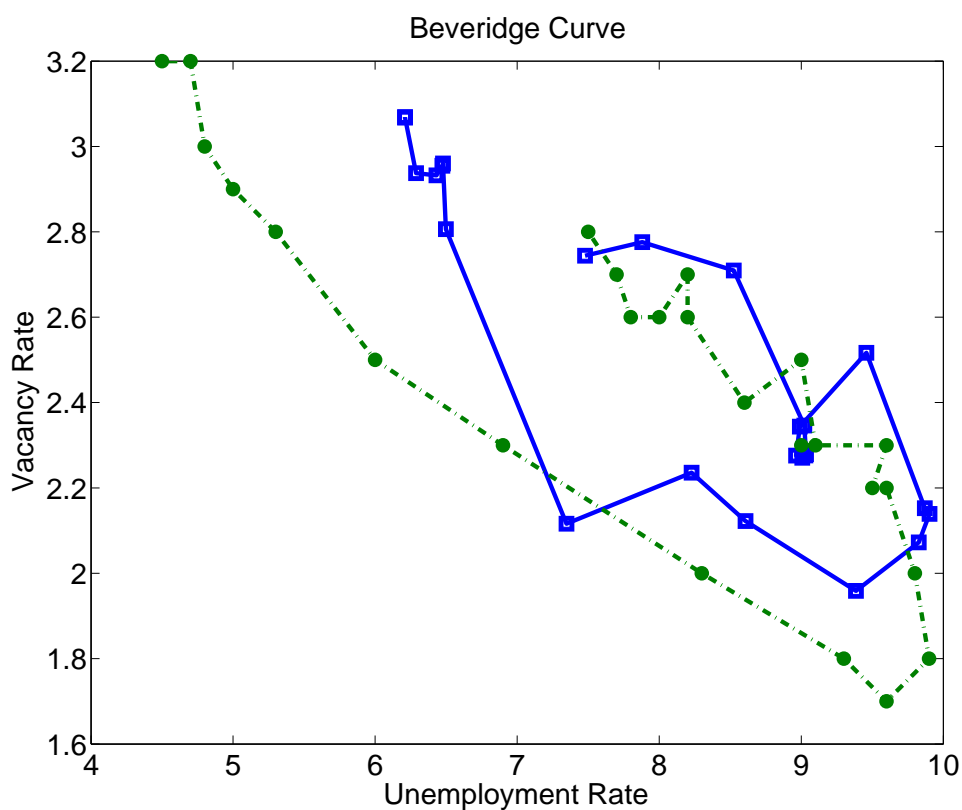


Figure 4.9: Actual and counterfactual Beveridge curve from 2007 Q:IV-2013 Q:II. The unemployment and vacancy rates come from the BLS JOLTS database. Both series are plotted as quarterly averages of monthly (JOLTS) and weekly (model) data. Labor productivity is held constant during the model simulation and only benefit extensions are enacted. Data and model are not filtered.

Chapter 5

Pro-cyclical Unemployment Benefits? Optimal Policy in an Equilibrium Business Cycle Model

A modified version of this chapter originally appeared as Mitman and Rabinovich (2012) and is co-authored with Stanislav Rabinovich.

How should unemployment insurance (UI) respond to fluctuations in labor productivity and unemployment? This question has gained importance in light of the high and persistent unemployment rates following the 2007-2009 recession. In the United States, existing legislation automatically extends unemployment benefit duration in times of high unemployment. Nationwide benefit extensions have been enacted in every major recession since 1958, including the most recent one, in which the maximum duration of unemployment benefits reached an unprecedented 99 weeks. The desirability of such extensions is the subject of an active policy debate, which has only recently begun to receive attention in economic research. In this paper, we use an equilibrium search model to characterize the optimal cyclical behavior of unemployment insurance.

Our approach integrates risk-averse workers and endogenous worker search effort into the workhorse Diamond-Mortensen-Pissarides model, with business cycles driven by shocks to aggregate labor productivity. The key motivation for using the Diamond-Mortensen-Pissarides model is to explore the consequences of general equilibrium ef-

fects for the optimal design of UI policy over the business cycle. The equilibrium search approach is ideal for studying these effects: it accounts for the possibility that more generous unemployment benefits not only discourage unemployed workers from searching, but also raise the worker outside option in wage bargaining, thereby discouraging firms from posting vacancies. Although the framework we choose is a classic one, commonly used to study labor market dynamics and policies, the normative implications of this framework - such as optimal UI - are still very much an open question and need to be more fully understood. Our paper is a step within this research agenda.

We characterize the optimal state-contingent UI policy by solving the Ramsey problem of the government, taking the equilibrium conditions of the model as constraints. Specifically, we allow the government to choose the generosity of unemployment benefits (level and expiration) optimally over the business cycle, and to condition its policy choices on the past history of aggregate productivity shocks. Our main result is that, contrary to the current US policy, the optimal benefit schedule is *pro-cyclical* over long time horizons: when the model is simulated under the optimal policy, optimal UI benefits are positively correlated with labor productivity and negatively correlated with the unemployment rate. This overall pro-cyclicality of benefits, however, masks richer dynamics of the optimal policy. In particular, the optimal policy response to a one-time productivity drop is different in the short run and in the long run: optimal benefit levels and duration initially rise in response to a negative shock, but both subsequently fall below their pre-recession level. Thus, the behavior of optimal benefits in response to productivity is non-monotonic, and the fall in benefit generosity lags the fall in productivity. The intuition for these dynamics of the optimal policy is that the initial fall in productivity lowers the gains from creating additional jobs, hence the opportunity cost of raising the generosity of UI benefits is low. On the other hand, the subsequent rise in unemployment raises the social

gains from posting vacancies but does not raise the private incentives for doing so. As a consequence, UI generosity optimally rises initially in response to a productivity drop, but then quickly falls in response to the subsequent rise in unemployment.

Our paper contributes to the literature on optimal policy design within search and matching models, which emphasize that policy affects firm vacancy creation decisions. It is thus in the tradition of the general equilibrium approach to optimal unemployment insurance, exemplified by Cahuc and Lehmann (2000), Fredriksson and Holmlund (2001), Coles and Masters (2006), and Lehmann and van der Linden (2007). The novelty of our analysis is to determine how unemployment insurance should optimally respond to business cycle conditions, rather than analyzing optimal policy in steady state.

Our paper also contributes to the emerging literature on optimal unemployment insurance over the business cycle. Two recent papers in this literature are Kroft and Notowidigdo (2010) and Landais, Michaillat, and Saez (2013). Kroft and Notowidigdo (2010) examine optimal state-contingent UI in a principal-agent framework, extending the approach of Baily (1978), Shavell and Weiss (1979), Hopenhayn and Nicolini (1997), and Shimer and Werning (2008). This approach focuses on the tradeoff between insurance and incentive provision for an individual unemployed worker, but abstracts from the effects of policy on firm hiring decisions. Landais, Michaillat, and Saez (2013) incorporate firm hiring decisions into their model, but these decisions do not respond to UI policy because wages do not depend on the workers' outside option.¹ Our paper complements this literature by instead examining optimal UI in the Diamond-Mortensen-Pissarides model, where UI does affect vacancy creation. Interestingly, our result that the optimal path of benefits is pro-cyclical is new to the above literature. Our findings thus serve to illustrate that the choice of modeling framework, in particular the presence or absence of general equilibrium effects, can

¹In section 5.4.3 we compare our paper to Landais, Michaillat, and Saez (2013) in terms of testable predictions and discuss a way to distinguish between the two empirically.

have drastic implications for optimal policy.

The paper is organized as follows. We present the model in section 5.1. In section 5.2, we describe our calibration strategy. Section 5.3 defines the optimal policy and contains our main optimal policy results. In section 5.4, we discuss our results and conduct sensitivity analysis. Finally, we conclude in section 5.5. All tables and figures are in section 5.6.

5.1 Model Description

5.1.1 Economic Environment

We consider a Diamond-Mortensen-Pissarides model with aggregate productivity shocks. Time is discrete and the time horizon is infinite. The economy is populated by a unit measure of workers and a larger continuum of firms.

Agents. In any given period, a worker can be either employed (matched with a firm) or unemployed. Workers are risk-averse expected utility maximizers and have expected lifetime utility

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [u(x_t) - c(s_t)],$$

where \mathbb{E}_0 is the period-0 expectation operator, $\beta \in (0, 1)$ is the discount factor, x_t denotes consumption in period t , and s_t denotes search effort exerted in period t if unemployed. Only unemployed workers can supply search effort: there is no on-the-job search. The within-period utility of consumption $u : \mathbb{R}_+ \rightarrow \mathbb{R}$ is twice differentiable, strictly increasing, strictly concave, and satisfies $u'(0) = \infty$. The cost of search effort for unemployed workers $c : [0, 1] \rightarrow \mathbb{R}$ is twice differentiable, strictly increasing, strictly convex, and satisfies $c'(0) = 0$, $c'(1) = \infty$. An unemployed worker produces h , which stands for the combined value of leisure and home production.

There do not exist private insurance markets and workers cannot save or borrow.²

Firms are risk-neutral and maximize profits. Workers and firms have the same discount factor β . A firm can be either matched to a worker or vacant. A firm posting a vacancy incurs a flow cost k .

Matching. Unemployed workers and vacancies match in pairs to produce output. The number of new matches in period t equals

$$M(S_t(1 - L_{t-1}), v_t),$$

where $1 - L_{t-1}$ is the unemployment level in period $t - 1$, S_t is the average search effort exerted by unemployed workers in period t , and v_t is the measure of vacancies posted in period t . The quantity $N_t = S_t(1 - L_{t-1})$ represents the measure of efficiency units of worker search.

The matching function M exhibits constant returns to scale, is strictly increasing and strictly concave in both arguments, and has the property that the number of new matches cannot exceed the number of potential matches: $M(N, v) \leq \min\{N, v\} \forall N, v$. We define

$$\theta_t = \frac{v_t}{N_t}$$

to be the market tightness in period t . We define the functions

$$f(\theta) = \frac{M(N, v)}{N} = M(1, \theta) \quad \text{and}$$

$$q(\theta) = \frac{M(N, v)}{v} = M\left(\frac{1}{\theta}, 1\right)$$

where $f(\theta)$ is the job-finding probability per efficiency unit of search and $q(\theta)$ is the probability of filling a vacancy. By the assumptions on M made above, the function $f(\theta)$ is increasing in θ and $q(\theta)$ is decreasing in θ . For an individual worker exerting

²In section 5.4.1 we discuss the possible consequences of relaxing this assumption.

search effort s , the probability of finding a job is $sf(\theta)$. When workers choose the amount of search effort s , they take as given the aggregate job-finding probability $f(\theta)$.

Existing matches are exogenously destroyed with a constant job separation probability δ . Thus, any of the L_{t-1} workers employed in period $t-1$ has a probability δ of becoming unemployed in period t .

Production. All worker-firm matches are identical: the only shocks to labor productivity are aggregate shocks. Specifically, a matched worker-firm pair produces output z_t in period t , where z_t is aggregate labor productivity. We assume that $\ln z_t$ follows an AR(1) process

$$\ln z_t = \rho \ln z_{t-1} + \sigma_\varepsilon \varepsilon_t,$$

where $0 \leq \rho < 1$, $\sigma_\varepsilon > 0$, and ε_t are independent and identically distributed standard normal random variables. We will write $z^t = \{z_0, z_1, \dots, z_t\}$ to denote the history of shocks up to period t .

5.1.2 Government Policy

The US UI system is financed by payroll taxes on firms and is administered at the state level. However, under the provisions of the Social Security Act, each state can borrow from a federal unemployment insurance trust fund, provided it meets certain federal requirements. Motivated by these features of the UI system, we assume that the government in the model economy can insure against aggregate shocks by buying and selling claims contingent on the aggregate state and is required to balance its budget only in expectation. Further, we assume that the price of a claim to one unit of consumption in state z_{t+1} after a history z^t is equal to the probability of z_{t+1} conditional on z^t ; this would be the case, e.g., in the presence of a large number of out-of state risk-neutral investors with the same discount factor.

Government policies are restricted to take the following form. The government levies a constant lump sum tax τ on firm profits and uses its tax revenues to finance unemployment benefits. The government is allowed to choose both the level of benefits and the rate at which they expire. We assume stochastic benefit expiration. This assumption is likewise made in Fredriksson and Holmlund (2001), Albrecht and Vroman (2005) and Faig and Zhang (2012) and will ensure the stationarity of the worker's optimization problem.³

A benefit policy at time t thus consists of a pair (b_t, e_t) , where $b_t \geq 0$ is the level of benefits provided to those workers who are eligible for benefits at time t , and $e_t \in [0, 1]$ is the probability that an unemployed worker eligible for benefits becomes ineligible the following period. The eligibility status of a worker evolves as follows. A worker employed in period t is automatically eligible for benefits in case of job separation. An unemployed worker eligible for benefits in period t becomes ineligible the following period with probability e_t , and an ineligible worker does not regain eligibility until he finds a job. All eligible workers receive the same benefits b_t ; ineligible workers receive no unemployment benefits.

We allow the benefit policy to depend on the entire history of past aggregate shocks; thus the policy $b_t = b_t(z^t), e_t = e_t(z^t)$ must be measurable with respect to z^t .⁴ Benefits are constrained to be non-negative: the government cannot tax h .

5.1.3 Timing

The government commits to a policy $(\tau, b_t(\cdot), e_t(\cdot))$ once and for all before the period-0 shock realizes. Within each period t , the timing is as follows.

1. The economy enters period t with a level of employment L_{t-1} . Of the $1 - L_{t-1}$ unemployed workers, a measure $D_{t-1} \leq 1 - L_{t-1}$ are eligible for benefits, i.e.

³We find that our main results are robust to the possibility of benefit expiration. See section 5.4.4 for a further discussion of benefit expiration.

⁴Note, however, that b_t is not allowed to depend on an individual worker's history.

will receive benefits in period t if they do not find a job.

2. The aggregate shock z_t then realizes. Firms observe the aggregate shock and decide how many vacancies to post, at cost k per vacancy. At the same time, workers choose their search effort s_t at the cost of $c(s_t)$. Letting S_t^E and S_t^I be the search effort exerted by an eligible unemployed worker and an ineligible unemployed worker, respectively, the aggregate search effort is then equal to $S_t^E D_{t-1} + S_t^I (1 - L_{t-1} - D_{t-1})$, and the market tightness is therefore equal to

$$\theta_t = \frac{v_t}{S_t^E D_{t-1} + S_t^I (1 - L_{t-1} - D_{t-1})} \quad (5.1)$$

3. $f(\theta) (S_t^E D_{t-1} + S_t^I (1 - L_{t-1} - D_{t-1}))$ unemployed workers find jobs. At the same time, a fraction δ of the existing L_{t-1} matches are exogenously destroyed.
4. All the workers who are now employed produce z_t and receive a bargained wage w_t (below we describe wage determination in detail). Workers who (i) were employed and lost a job, or (ii) were eligible unemployed workers and did not find a job, consume h plus unemployment benefits, $h + b_t$ and lose their eligibility for the next period with probability e_t . Ineligible unemployed workers who have not found a job consume h , and remain ineligible for the following period.

This determines the law of motion for employment

$$\begin{aligned} L_t(z^t) &= (1 - \delta) L_{t-1}(z^{t-1}) \\ &\quad + f(\theta_t(z^t)) [S_t^E(z^t) D_{t-1}(z^{t-1}) + S_t^I(z^t) (1 - L_{t-1}(z^{t-1}) - D_{t-1}(z^{t-1}))] \end{aligned} \quad (5.2)$$

and the law of motion for the measure of eligible unemployed workers:

$$D_t(z^t) = (1 - e_t(z^t)) [\delta L_{t-1}(z^{t-1}) + (1 - S_t^E(z^t) f(\theta_t(z^t))) D_{t-1}(z^{t-1})] \quad (5.3)$$

Thus, the measure of workers receiving benefits in period t is

$$\delta L_{t-1} + (1 - S_t^E f(\theta_t)) D_{t-1} = \frac{D_t}{1 - e_t}$$

Since we assume that the government has access to financial markets in which a full set of state-contingent claims is traded, its budget constraint is a present-value budget constraint

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ L_t(z^t) \tau - \left(\frac{D_t(z^t)}{1 - e_t(z^t)} \right) b_t(z^t) \right\} \geq 0 \quad (5.4)$$

5.1.4 Worker Value Functions

A worker entering period t employed retains his job with probability $1 - \delta$ and loses it with probability δ . If he retains his job, he consumes his wage $w_t(z^t)$ and proceeds as employed to period $t + 1$. If he loses his job, he consumes $h + b_t(z^t)$ and proceeds as unemployed to period $t + 1$. With probability $1 - e_t(z^t)$ he then retains his eligibility for benefits in period $t + 1$, and with probability $e_t(z^t)$ he loses his eligibility. Denote by $W_t(z^t)$ the value after a history z^t for a worker who enters period t employed.

A worker entering period t unemployed and eligible for benefits chooses search effort s_t^E and suffers the disutility $c(s_t^E)$. He finds a job with probability $s_t^E f(\theta_t(z^t))$ and remains unemployed with the complementary probability. If he finds a job, he earns the wage $w_t(z^t)$ and proceeds as employed to period $t + 1$. If he remains unemployed, he consumes $h + b_t(z^t)$, and proceeds as unemployed to the next period. With probability $1 - e_t(z^t)$ he retains his eligibility for benefits in period $t + 1$, and with probability $e_t(z^t)$ he loses his eligibility. Denote by $U_t^E(z^t)$ the value after a history z^t for a worker who enters period t as eligible unemployed.

Finally, a worker entering period t unemployed and ineligible for benefits chooses search effort s_t^I and suffers the disutility $c(s_t^I)$. He finds a job with probability $s_t^I f(\theta_t(z^t))$ and remains unemployed with the complementary probability. If he finds

a job, he earns the wage $w_t(z^t)$ and proceeds as employed to period $t + 1$. If he remains unemployed, he consumes h and proceeds as ineligible unemployed to the next period. Denote by $U_t^I(z^t)$ the value after a history z^t for a worker who enters period t as ineligible unemployed.

The Bellman equations for the three types of workers are then:

$$W_t(z^t) = (1 - \delta) [u(w_t(z^t)) + \beta \mathbb{E}W_{t+1}(z^{t+1})] \\ + \delta [u(h + b_t(z^t)) + \beta(1 - e_t) \mathbb{E}U_{t+1}^E(z^{t+1}) + \beta e_t \mathbb{E}U_{t+1}^I(z^{t+1})] \quad (5.5)$$

$$U_t^E(z^t) = \max_{s_t^E} -c(s_t^E) + s_t^E f(\theta_t(z^t)) [u(w_t(z^t)) + \beta \mathbb{E}W_{t+1}(z^{t+1})] \\ + (1 - s_t^E f(\theta_t(z^t))) [u(h + b_t(z^t)) + \beta(1 - e_t(z^t)) \mathbb{E}U_{t+1}^E(z^{t+1}) + \\ \beta e_t \mathbb{E}U_{t+1}^I(z^{t+1})] \quad (5.6)$$

$$U_t^I(z^t) = \max_{s_t^I} -c(s_t^I) + s_t^I f(\theta_t(z^t)) [u(w_t(z^t)) + \beta \mathbb{E}W_{t+1}(z^{t+1})] \\ + (1 - s_t^I f(\theta_t(z^t))) [u(h) + \beta \mathbb{E}U_{t+1}^I(z^{t+1})] \quad (5.7)$$

It will be useful to define the worker's surplus from being employed. The surplus utility from being employed, as compared to eligible unemployed, in period t is

$$\Delta_t(z^t) = [u(w_t(z^t)) + \beta \mathbb{E}_t W_{t+1}(z^{t+1})] - \\ [u(h + b_t(z^t)) + \beta(1 - e_t) \mathbb{E}U_{t+1}^E(z^{t+1}) + \beta e_t \mathbb{E}U_{t+1}^I(z^{t+1})] \quad (5.8)$$

Similarly, we define the surplus utility from being employed as compared to being unemployed and ineligible for benefits:

$$\Xi_t(z^t) = [u(w_t(z^t)) + \beta \mathbb{E}_t W_{t+1}(z^{t+1})] - [u(h) + \beta \mathbb{E}U_{t+1}^I(z^{t+1})] \quad (5.9)$$

5.1.5 Firm Value Functions

A matched firm retains its worker with probability $1 - \delta$. In this case, the firm receives the output net of wages and taxes, $z_t - w_t(z^t) - \tau$, and then proceeds into the next period as a matched firm. If the firm loses its worker, it gains nothing in the current period and proceeds into the next period unmatched. A firm that posts a vacancy incurs a flow cost k and finds a worker with probability $q(\theta_t(z^t))$. If the firm finds a worker, it gets flow profits $z_t - w_t(z^t) - \tau$ and proceeds into the next period as a matched firm. Otherwise, it proceeds unmatched into the next period.

Denote by $J_t(z^t)$ the value of a firm that enters period t matched to a worker, and denote by $V_t(z^t)$ the value of an unmatched firm posting a vacancy. These value functions satisfy the following Bellman equations:

$$J_t(z^t) = (1 - \delta) [z_t - w_t(z^t) - \tau + \beta \mathbb{E}_t J_{t+1}(z^{t+1})] + \delta \beta \mathbb{E}_t V_{t+1}(z^{t+1}) \quad (5.10)$$

$$V_t(z^t) = -k + q(\theta_t(z^t)) [z_t - w_t(z^t) - \tau + \beta \mathbb{E}_t J_{t+1}(z^{t+1})] + (1 - q(\theta_t(z^t))) \beta \mathbb{E}_t V_{t+1}(z^{t+1}) \quad (5.11)$$

The firm's surplus from employing a worker in period t is denoted

$$\Gamma_t(z^t) = z_t - w_t(z^t) - \tau + \beta \mathbb{E}_t J_{t+1}(z^{t+1}) - \beta \mathbb{E}_t V_{t+1}(z^{t+1}) \quad (5.12)$$

5.1.6 Wage Bargaining

We make the assumption, standard in the literature, that wages are determined according to Nash bargaining: the wage is chosen to maximize a weighted product of the worker's surplus and the firm's surplus. Further, the worker's outside option is being unemployed and eligible for benefits, since he becomes eligible upon locating an employer and retains eligibility if negotiations with the employer break down. The

worker-firm pair therefore chooses the wage $w_t(z^t)$ to maximize

$$\Delta_t(z^t)^\xi \Gamma_t(z^t)^{1-\xi}, \quad (5.13)$$

where $\xi \in (0, 1)$ is the worker's bargaining weight.

5.1.7 Equilibrium Given Policy

In this section, we define the equilibrium of the model, taking as given a government policy $(\tau, b_t(\cdot), e_t(\cdot))$ and characterize it.

Equilibrium Definition

Taking as given an initial condition (z_{-1}, L_{-1}) , we define an equilibrium given policy:

Definition Given a policy $(\tau, b_t(\cdot), e_t(\cdot))$ and an initial condition (z_{-1}, L_{-1}) an equilibrium is a sequence of z^t -measurable functions for wages $w_t(z^t)$, search effort $S_t^E(z^t)$, $S_t^I(z^t)$, market tightness $\theta_t(z^t)$, employment $L_t(z^t)$, measures of eligible workers $D_t(z^t)$, and value functions

$$\{W_t(z^t), U_t^E(z^t), U_t^I(z^t), J_t(z^t), V_t(z^t), \Delta_t(z^t), \Xi_t(z^t), \Gamma_t(z^t)\}$$

such that:

1. The value functions satisfy the worker and firm Bellman equations (5.5), (5.6), (5.7), (5.8), (5.9), (5.10), (5.11), (5.12)
2. Optimal search: The search effort S_t^E solves the maximization problem in (5.6) for s_t^E , and the search effort S_t^I solves the maximization problem in (5.7) for s_t^I
3. Free entry: The value $V_t(z^t)$ of a vacant firm is zero for all z^t
4. Nash bargaining: The wage maximizes equation (5.13)

5. Law of motion for employment and eligibility status: Employment and the measure of eligible unemployed workers satisfy (5.2) , (5.3)
6. Budget balance: Tax revenue and benefits satisfy (5.4)

Characterization of Equilibrium

We characterize the equilibrium given policy via a system of equations that involves allocations only, and does not involve the value functions. This will be helpful in computing the optimal policy.

Lemma 1. *Fix an initial condition and a policy $(\tau, b_t(\cdot), e_t(\cdot))$. Suppose that the sequence*

$$\Upsilon_t(z^t) = \{w_t(z^t), S_t^E(z^t), S_t^I(z^t), \theta_t(z^t), L_t(z^t), D_t(z^t), \\ W_t(z^t), U_t^E(z^t), U_t^I(z^t), J_t(z^t), V_t(z^t), \Delta_t(z^t), \Xi_t(z^t), \Gamma_t(z^t)\}$$

is an equilibrium. Then the sequences $\{w_t(z^t), S_t^E(z^t), S_t^I(z^t), \theta_t(z^t), L_t(z^t), D_t(z^t)\}$ satisfy:

1. *The laws of motion (5.2) , (5.3)*
2. *The budget equation (5.4)*
3. *Modified worker Bellman equations (dependence on z^t is understood throughout)*

$$\begin{aligned} \frac{c'(S_t^E)}{f(\theta_t)} &= u(w_t) - u(h + b_t) + \\ & (1 - e_t) \beta \mathbb{E}_t \left(c(S_{t+1}^E) + (1 - \delta - S_{t+1}^E f(\theta_{t+1})) \frac{c'(S_{t+1}^E)}{f(\theta_{t+1})} \right) \\ & + e_t \beta \mathbb{E}_t \left(c(S_{t+1}^I) + (1 - S_{t+1}^I f(\theta_{t+1})) \frac{c'(S_{t+1}^I)}{f(\theta_{t+1})} - \delta \frac{c'(S_{t+1}^E)}{f(\theta_{t+1})} \right) \end{aligned} \tag{5.14}$$

$$\frac{c'(S_t^I)}{f(\theta_t)} = u(w_t) - u(h) + \beta \mathbb{E}_t \left(c(S_{t+1}^I) + (1 - S_{t+1}^I f(\theta_{t+1})) \frac{c'(S_{t+1}^I)}{f(\theta_{t+1})} - \delta \frac{c'(S_{t+1}^E)}{f(\theta_{t+1})} \right) \quad (5.15)$$

4. *Modified firm Bellman equation*

$$\frac{k}{q(\theta_t)} = z_t - w_t - \tau + \beta(1 - \delta) \mathbb{E}_t \frac{k}{q(\theta_{t+1})} \quad (5.16)$$

5. *Nash bargaining condition*

$$\xi u'(w_t) k \theta_t = (1 - \xi) c'(S_t^E) \quad (5.17)$$

Conversely, if $\{w_t(z^t), S_t^E(z^t), S_t^I(z^t), \theta_t(z^t), L_t(z^t), D_t(z^t)\}$ satisfy (5.2)-(5.4) and (5.14)-(5.17), then there exist value functions such that $\Upsilon_t(z^t)$ is an equilibrium.

Proof. See Appendix E.1.1. □

The conditions (5.14)-(5.17) are straightforward to interpret. Equations (5.14) and (5.15) state that the marginal cost of increasing the job finding probability for the eligible and ineligible workers, respectively, equals the marginal benefit. The marginal cost (left-hand side of each equation) of increasing the job finding probability is the marginal disutility of search for that worker weighted by the aggregate job finding rate. The marginal benefit (right-hand side of each equation) equals the current consumption gain from becoming employed plus the benefit of economizing on search costs in the future. Equation (5.16) gives a similar optimality condition for firms: it equates the marginal cost of creating a vacancy, weighted by the probability of filling that vacancy, to the benefit of employing a worker. Finally, (5.17) is a restatement of the first-order condition of the bargaining problem. It will be clear in section 5.3 that the conditions (5.14)-(5.17) will play the role of incentive constraints in the

optimal policy problem, analogous to incentive constraints in principal-agent models of unemployment insurance, e.g. Hopenhayn and Nicolini (1997).

5.2 Calibration

We calibrate the model to match salient features of the US labor market. The model period is taken to be 1 week. We normalize mean weekly productivity to one. We assume a benefit scheme that mimics the benefit extension provisions currently in place within the US policy. We set the benefit level $b = 0.4$ to match the average replacement rate of unemployment insurance. The standard benefit duration is 26 weeks; local and federal employment conditions trigger automatic 20-week and 33-week extensions. In the model we assume that $e_t = 1/59$ when productivity is more than 3% below the mean, $e_t = 1/46$ when productivity is between 1.5% and 3% below the mean, and $e_t = 1/26$ otherwise. We pick the tax rate $\tau = 0.023$ so that the government balances its budget if the unemployment rate is 5.5%.

We assume log utility: $u(x) = \ln x$. For the cost of search, we assume the functional form

$$c(s) = \frac{A}{1+\psi} \left[(1-s)^{-(1+\psi)} - 1 \right] - As \quad (5.18)$$

This functional form is chosen to ensure that the optimal search effort will always be strictly between 0 and 1. In particular, the functional form above guarantees that, for any $A > 0$, we have $c' > 0$, $c'' > 0$, as well as $c(0) = c'(0) = 0$, $c(1) = c'(1) = \infty$.

For the matching function, we follow den Haan, Ramey, and Watson (2000) and pick

$$M(N, v) = \frac{Nv}{[N^\chi + v^\chi]^{1/\chi}}$$

The choice of the matching technology is likewise driven by the requirement that the job-finding rate and the job-filling rate always be strictly less than 1.⁵ We obtain:

⁵The frequently used alternative is the Cobb-Douglas specification. However, commonly used local solu-

$$f(\theta) = \frac{\theta}{(1 + \theta x)^{1/x}}$$

$$q(\theta) = \frac{1}{(1 + \theta x)^{1/x}}$$

Following Shimer (2005), labor productivity z_t is taken to mean real output per person in the non-farm business sector. This measure of productivity is taken from the quarterly data constructed by the BLS for the time period 1951-2004. We also use the 1951-2004 seasonally adjusted unemployment series constructed by the BLS, and measure vacancies using the seasonally adjusted help-wanted index constructed by the Conference Board.

We set the discount factor $\beta = 0.99^{1/12}$, implying a yearly discount rate of 4%. The parameters for the productivity shock process are estimated, at the weekly level, to be $\rho = 0.9895$ and $\sigma_\varepsilon = 0.0034$. The job separation parameter δ is set to 0.0081 to match the average weekly job separation rate.⁶ We set $k = 0.58$ following Hagedorn and Manovskii (2008b), who estimate the combined capital and labor costs of vacancy creation to be 58% of weekly labor productivity.

This leaves five parameters to be calibrated: (1) the value h of non-market activity; (2) the worker bargaining weight ξ ; (3) the matching function parameter χ ; (4) the level coefficient of the search cost function A ; and (5) the curvature parameter of the search cost function ψ . We jointly calibrate these five parameters to simultaneously match five data targets: (1) the average vacancy-unemployment ratio; (2) the standard deviation of vacancy-unemployment ratio; (3) the average weekly job-finding rate; (4) the average duration of unemployment; and (5) the elasticity of unemployment duration with respect to benefits. The first four of these targets are directly measured in the data. For the elasticity of unemployment duration with

tion methods for the model do not guarantee that the job-finding rate is less than one under this specification.

⁶We use the same procedure of adjusting for time aggregation as Hagedorn and Manovskii (2008b) to obtain the weekly estimates for the job finding rate and the job separation rate from monthly data.

respect to benefits, $\mathcal{E}_{d,b}$, we use micro estimates reported by Meyer (1990b) and target an elasticity of 0.9⁷. Note that the model counterpart of the measured elasticity is taken to be the *micro* (partial-equilibrium) elasticity: the percentage change of unemployment duration due to decreased search effort alone, in response to a 1% increase in the benefit level, but keeping fixed the value of $f(\theta)$.⁸ Intuitively, given the first three parameters, the average unemployment duration and its elasticity with respect to benefits identify the parameters A and ψ , since these parameters govern the distortions in search behavior induced by benefits.

Table 5.1 reports the calibrated parameters and the matching of the calibration targets. Note that our calibration procedure implies a large value of h . In fact, the combined value of h and unemployment benefits is $h + b = 0.981$, while the mean equilibrium wage is $w = 0.955$. This might seem surprising, considering that empirical studies (e.g. Gruber (1997), Browning and Crossley (2001), Aguiar and Hurst (2005)) report a consumption drop for workers upon becoming unemployed. However, this is, in fact, consistent with the best available evidence on consumption of the unemployed. First, Gruber (1997) and Browning and Crossley (2001) do not distinguish between consumption of the unemployed and consumption expenditures of the unemployed; in other words, their measures of consumption exclude items such as home production and searching for cheaper products. On the other hand, Aguiar and Hurst (2005), who properly distinguish between consumption and expenditure, show that the consumption drop for the unemployed is only 5%, illustrating that most earlier estimates of the consumption drop are biased upward. Second, studies such as Browning and Crossley (2001) include, in their sample of unemployed workers, a significant fraction who are ineligible for benefits. The model counterpart of the consumption of the unemployed would thus be some weighted average of $h + b$ and

⁷There exist a range of estimates (e.g. Krueger and Meyer (2002b)) in the literature for the elasticity of unemployment duration with respect to benefit level. However, we find that qualitatively our results are robust to calibrating to higher or lower values of the elasticity.

⁸This is distinct from the macro elasticity, which would comprise the total effect of a 1% increase in UI benefits, and thus include the general equilibrium effect on θ . See section 5.4.3 for a discussion.

h . Third, h includes the consumption value of leisure, which would not appear as consumption in the data. Fourth, and most importantly, we show in section 5.4.6 that our optimal policy results are robust to the calibrated value of h : they hold even if we assume a substantially lower value for h .

5.3 Optimal Policy

5.3.1 Optimal Policy Definition

We assume that the government is utilitarian: it chooses a policy to maximize the period-0 expected value of worker utility, taking the equilibrium conditions as constraints.

Definition A policy $\tau, b_t(z^t), e_t(z^t)$ is feasible if there exists a sequence of z^t -measurable functions $\{w_t(z^t), S_t^E(z^t), S_t^I(z^t), \theta_t(z^t), L_t(z^t), D_t(z^t)\}$ such that (5.2), (5.3), (5.14)-(5.17) hold for all z^t , and the government budget constraint (5.4) is satisfied.

Definition The optimal policy is a policy $\tau, b_t(z^t), e_t(z^t)$ that maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{l} L_t(z^t) u(w_t(z^t)) + \left(\frac{D_t(z^t)}{1-e_t(z^t)} \right) u(h + b_t(z^t)) + \\ \left(1 - L_t(z^t) - \frac{D_t(z^t)}{1-e_t(z^t)} \right) u(h) - D_{t-1}(z^{t-1}) c(S_t^E(z^t)) - \\ (1 - L_{t-1}(z^{t-1}) - D_{t-1}(z^{t-1})) c(S_t^I(z^t)) \end{array} \right\} \quad (5.19)$$

over the set of all feasible policies.

The government's problem can be written as one of choosing a policy $\tau, b_t(z^t), e_t(z^t)$ together with functions $\{w_t(z^t), S_t^E(z^t), S_t^I(z^t), \theta_t(z^t), L_t(z^t), D_t(z^t)\}$ to maximize (5.19) subject to (5.2), (5.3), (5.14)-(5.17) holding for all z^t , and subject to the government budget constraint (5.4). We find the optimal policy by solving the system of necessary first-order conditions for this problem. The period- t solution will naturally be state-dependent: in particular, it will depend on the current productiv-

ity z_t , as well as the current unemployment level $1 - L_{t-1}$, and current measure of benefit-eligible workers D_{t-1} with which the economy has entered period t . However, in general the triple $(z_t, 1 - L_{t-1}, D_{t-1})$ is not a sufficient state variable for pinning down the optimal policy, which may depend on the entire past history of aggregate shocks. In the appendix, we show that the optimal period t solution is a function of $(z_t, 1 - L_{t-1}, D_{t-1})$ as well as $(e_{t-1}, \mu_{t-1}, \nu_{t-1}, \gamma_{t-1})$, where e_{t-1} is the previous period's benefit expiration rate and $\mu_{t-1}, \nu_{t-1}, \gamma_{t-1}$ are Lagrange multipliers on the constraints (5.14), (5.15), (5.16), respectively, in the maximization problem (5.19). The tuple $(z_t, 1 - L_{t-1}, D_{t-1}, e_{t-1}, \mu_{t-1}, \nu_{t-1}, \gamma_{t-1})$ captures the dependence of the optimal b_t, e_t on the history z^t . The fact that the $z_t, 1 - L_{t-1}$ and D_{t-1} are not sufficient reflects the fact that the optimal policy is time-inconsistent: for example, the optimal benefits after two different histories of shocks may differ even though the two histories result in the same current productivity and the same current unemployment level. Intuitively, the government might want to induce firms to post vacancies - and workers to search - by promising low unemployment benefits, but has an ex post incentive to provide higher benefits, so as to smooth worker consumption, after employment outcomes have realized. Including the variables $e_{t-1}, \mu_{t-1}, \nu_{t-1}, \gamma_{t-1}$ as state variables in the optimal policy captures exactly this trade-off. Note that we assume throughout the paper that the government can fully commit to its policy. In Appendix E.1.2 we explain the method used to solve for the optimal policy.

5.3.2 Optimal Policy Results

We now investigate how the economy behaves over time under the optimal policy. To this end, we simulated the model both under the current benefit policy and under the optimal policy. Table 5.4 reports the summary statistics, under the optimal policy, for the behavior of unemployment benefit levels b and potential benefit duration $1/e$. Benefits are higher and expire faster under the optimal policy than under the current

policy. The optimal tax rate under the optimal policy is $\tau = 0.018$, lower than under the current policy.

The key observation is that, over a long period of time, the correlation of optimal benefits with productivity is positive: both benefit levels and potential benefit duration are pro-cyclical in the long run and, in particular, negatively correlated with the unemployment rate. Moreover, this result is not driven by any balanced budget requirement, since we allow the government to run deficits in recessions.

In order to understand the mechanism behind this behavior of the optimal policy, in Figure 5.1 we plot the optimal benefit policy function $b_t(z_t, 1 - L_{t-1}, D_{t-1}, e_{t-1}, \mu_{t-1}, \nu_{t-1}, \gamma_{t-1})$ as a function of current z and last period's $1 - L$ only, keeping D_{t-1} , e_{t-1} , μ_{t-1} , ν_{t-1} and γ_{t-1} fixed at their average values. The optimal benefit level is decreasing in current productivity z and decreasing in unemployment $1 - L$. The intuition for this result is that the optimal benefit is lower in states of the world when the marginal social benefit of job creation is higher, because lower benefits are used to encourage search effort by workers and vacancy creation by firms. The marginal social benefit of job creation is higher when z is higher, since the output of an additional worker-firm pair is then higher. The marginal social benefit is also higher when current employment is lower, because the expected output gain of increasing θ is proportional to the number of unemployed workers. Note, however, that although the social gains from creating jobs are high when unemployment is high, the private gains to firms of posting vacancies do not directly depend on unemployment. As a consequence, optimal benefits are lower, all else equal, when current unemployment is high. Figure 5.2 illustrates the same result for the optimal duration of benefits: optimal benefit duration is lowest at times of high productivity and high unemployment. This shape of the policy function also implies that during a recession, there are two opposing forces at work - low productivity and high unemployment - which give opposite prescriptions for the response of optimal benefits. This gives an ambiguous prediction

for the overall cyclicality of benefit levels and benefit duration.

In Figures 5.3 and 5.4 we analyze the dynamic response of the economy to a negative productivity shock under the optimal policy and compare it to the response under the current policy. In Figure 5.3 we plot the impulse response of the optimal policy to a productivity drop of 1.5% below its mean. Note that under the current policy, benefit duration does not change in response to the shock, since automatic extensions are only activated when productivity is more than 1.5% below the mean. The optimal benefit level initially jumps up, but then falls for about two quarters following the shock, and slowly reverts to its pre-shock level. The same is true of optimal benefit duration. Unemployment rises in response to the drop in productivity and continues rising for about one quarter before it starts to return to its pre-shock level. Note that the rise in unemployment is significantly lower than under the current benefit policy. The intuition for this optimal policy response is that the government would like to provide immediate insurance against the negative shock and, expecting future productivity to rise, would like to induce a recovery in vacancy creation and search effort. Thus, benefit generosity responds positively to the initial drop in productivity but negatively to the subsequent rise in unemployment, precisely as implied by Figures 5.1 and 5.2.

In Figure 5.4 we plot the response of other key labor market variables. As compared to the current benefit policy, the optimal policy results in a faster recovery of the vacancy-unemployment ratio, the search intensity of unemployed workers eligible for benefits, and the job finding rate. Wages also fall less, in percent deviation terms, under the optimal policy than they do under the current policy. This is due to the fact that the initial rise in benefits smooths the fall in wages through an increase in the worker outside option. The fact that wages fall less in percentage terms indicates that firm profits fall more. Despite the fall in contemporaneous profits, there is not a large fall in market tightness. The reason for this is that firms expect future benefits

to fall. The figure thus illustrates that the labor market response depends not only on the contemporaneous benefit policy but also on agents' expectations about future policy dynamics.

Tables 5.5 and 5.6 report the moments of key labor market variables when the model is simulated under the current policy and the optimal policy, respectively. As compared to the optimal policy, the optimal policy results in lower average unemployment and lower unemployment volatility. These results show that the optimal benefit policy stabilizes cyclical fluctuations in unemployment.

Finally, we compute the expected welfare gain from switching from the current policy to the optimal policy. We find that implementing the optimal policy results in a significant welfare gain: 0.67% as measured in consumption equivalent variation terms.

5.4 Discussion of the Results

5.4.1 The assumption of no savings

An important assumption made for transparency in this paper is that workers cannot save or borrow. We now briefly discuss how relaxing this assumption could affect our results. On one hand, if workers are allowed to hold wealth, cyclical variations in this wealth will affect how government-provided insurance should vary over the business cycle. Periods in which unemployed workers' wealth is lower would warrant higher unemployment benefits. Intuitively, this effect is similar to the effect that would arise if h varied over the business cycle. In particular, if workers are more liquidity-constrained in recessions than in booms, this would provide a motive for raising unemployment benefits in recessions (or raising their duration), with the potential to reverse our optimal policy results.

On the other hand, the presence of savings reduces the responsiveness of the worker

outside option to unemployment benefits. As a result, both worker search effort and firm vacancy posting will respond less to policy than they would in the absence of savings. Therefore, in the presence of savings, inducing any given behavioral response requires a larger change in benefits than it would have required otherwise. This effect would amplify the cyclical behavior of optimal benefits in our model, potentially making optimal benefits even more strongly pro-cyclical.

The overall effect of introducing savings in the model on the pro-cyclicality of optimal benefits is thus ambiguous. We believe that it is an important extension to investigate whether our results are robust to relaxing the no-savings assumption. Assessing this robustness is research in progress.

5.4.2 The Hosios condition and its relationship to our model

A concern in the Diamond-Mortensen-Pissarides model with Nash bargaining is that the laissez-faire equilibrium is not constrained efficient. Even with risk-neutral workers, the Hosios (1990) condition requires that the worker bargaining weight be equal to the elasticity of the matching function in order to attain efficiency. If the Hosios condition is violated, there is a role for government intervention - such as unemployment benefits - even in the absence of insurance considerations. The reason for this is that when an individual firm posts a vacancy, it reduces the matching probability of other firms and increases the matching probability for workers, thereby imposing an externality.

The Hosios condition is not applicable to our model: since workers are risk-averse in our model, output maximization is not equivalent to welfare maximization. Nevertheless, the question can still be posed to what extent our optimal policy results are driven by corrections for the externality that an individual firm imposes when entering. To answer this question, we first find the value of the worker bargaining power ξ such that the optimal government intervention (UI benefit and tax) is zero

in the steady state, keeping all the other parameters fixed at their calibrated values. This serves as the intuitive analogue of the Hosios condition in our model. We obtain a value of $\xi = 0.72$. Next, we solve for the optimal policy for this value of ξ , keeping all other parameters fixed at the benchmark calibration values. A comparison of the impulse responses shown in figures 5.3 and 5.9 shows that the shape of the optimal policy is robust to raising ξ to 0.72. The same holds for the overall pro-cyclicality of optimal benefits. These qualitative results are also unchanged if we use a value of ξ higher than 0.72. This indicates that our results are not driven by a search externality.

5.4.3 Comparison to Landais, Michailat and Saez (2010)

In closely related work, Landais, Michailat, and Saez (2013) also examine optimal UI policy over the business cycle but use a model very different from ours. Unlike our paper, they find that optimal UI benefits should be countercyclical. In this section, we discuss the difference in the testable implications of the two models.

In Landais, Michailat, and Saez (2013), wages are assumed to be an exogenous function of labor productivity. Since wages are exogenously fixed, the labor market does not adjust to equate labor supply and labor demand, and jobs are therefore rationed. A fall in unemployment benefits triggers an increase in search intensity by unemployed workers, but, because the number of jobs does not respond to this policy change, this increase in search intensity has a crowding-out effect that partially offsets the effect on unemployment. A key implication of that model is that general equilibrium effects *dampen* the responsiveness of unemployment to UI policy. Thus, Landais, Michailat, and Saez (2013) predict that the sensitivity of unemployment to economy-wide changes in benefit policy should be smaller, in percentage terms, than its sensitivity to policy changes for a small group of workers: the macro elasticity of unemployment with respect to UI benefits is smaller than the micro elasticity.

In contrast, in our model, wages are determined by bargaining and are therefore an increasing function of the workers' outside option. Unemployment benefits raise this outside option, thereby discouraging firms from posting vacancies. General equilibrium effects thus *amplify* the responsiveness of unemployment to UI policy. As a result, our model implies that the sensitivity of unemployment to large-scale policy changes should be greater than what would be measured in small-scale experiments: the macro elasticity of unemployment with respect to UI benefits is *larger* than the micro elasticity. As stated above in section 5.2, we calibrated our model parameters to match the empirical finding that the micro elasticity is about 0.9. Consistent with the above intuition, our model predicts a macro elasticity of 2.4, substantially larger than the micro elasticity.

Both our model and that of Landais, Michaillat, and Saez (2013) thus generate clear testable predictions regarding the micro and macro elasticity of unemployment with respect to UI benefits. The relative size of these elasticities in the data is still an open empirical question. A large literature has estimated the micro effect of UI: for example, the classic studies by Moffitt (1985b) and Meyer (1990b) estimate that the micro elasticities of unemployment duration with respect to benefit duration and benefit level, respectively, are about 0.16 and 0.9. Measuring the macro elasticity, however, requires obtaining reliable estimates of general equilibrium effects of UI. These general equilibrium effects are difficult to measure, because large scale policy changes are typically endogenous to changing macroeconomic conditions. Several recent studies have attempted this, with mixed results. Using French data on young long-term unemployed people, Crepon, Duflo, Gurgand, Rathelot, and Zamora (2012) evaluate the effect of a job placement counseling program, both on the workers who participated in the program and on those who did not. When they consider the entire sample of workers, they find no evidence that an increase in search by some workers crowds out the job finding probability of other job seekers. However, when

they restrict their estimates to a select group of males, they do find evidence of crowding out, suggesting - indirectly - that the macro elasticity of unemployment with respect to benefits may be smaller than the micro elasticity for certain segments of the labor market. Note, however, that the policy evaluated in Crepon, Duflo, Gurgand, Rathelot, and Zamora (2012) is neither an unemployment benefit extension nor a change in the benefit level, and may therefore not have the same effect as UI on the workers' outside option; as such, it might not have delivered an amplifying general equilibrium effect through vacancy posting even if such an effect existed. On the other hand, for the US, Hagedorn, Karahan, Mitman, and Manovskii (2013) use exogenous variation in benefit extensions across states and estimate an aggregate elasticity of unemployment with respect to benefit duration of about 0.9, significantly larger than the micro estimate of 0.16 in Moffitt (1985b).⁹ Their result implies that the macro elasticity is larger than the micro elasticity. In a study of Sweden, Fredriksson and Soderstrom (2008) exploit cross-regional variation in unemployment benefit generosity and likewise find a very large macro elasticity. Our conclusion from these very recent studies is that empirical work on measuring the macro elasticity is a promising but nascent research agenda, and that the current evidence on this subject seems to suggest that the macro elasticity is larger than the micro. Our model's prediction provides a way of testing between the two models if further reliable estimates of the macro elasticity do become available in the future.

5.4.4 Benefit level and duration

To jointly characterize the optimal behavior of benefit levels and duration, we have assumed stochastic benefit expiration. This assumption is made for tractability, since it renders the dynamic problem of the worker stationary. We find that the optimal cyclical behavior of benefit levels and expected benefit duration is qualitatively

⁹Note that the measure of 0.9 from Meyer (1990b) is the micro elasticity with respect to level and not duration.

similar: both are pro-cyclical and both exhibit the same dynamic response to a productivity shock. However, the presence of stochastic benefit expiration in the model is not important for our results. To illustrate this, we examine the optimal policy when the government is restricted to change only one of these two policy dimensions. We conduct three alternative policy experiments. In the first, we fix the benefit level at its current level: $b = 0.4$, and allow only the duration to change over the business cycle. The results, reported in Figure 5.5, show that the optimal policy response is similar qualitatively to our benchmark: in response to a negative productivity shock, potential duration of benefits should initially rise, and then fall considerably below its initial level. However, both the initial rise in the potential duration and its subsequent decline are greater than in the benchmark optimal policy result. In the second experiment, we fix the benefit expiration rate at its current level of $e = 1/26$ and compute the optimal benefit policy. Finally, in the third experiment, we ask how the benefit level should vary if benefits are not allowed to expire at all, i.e. if we fix $e = 0$. The results are shown in Figures 5.6 and 5.7. We find that the shape of the policy response is once again similar to the benchmark: benefits initially rise and then fall. Thus, our main result is quite robust and, in particular, holds when expiration is shut down altogether and the only policy variable is the benefit level.

5.4.5 The replacement ratio of unemployment benefits

The actual UI system in the US indexes an individual's unemployment benefits to his wage in the previous job. Because of this, the policy variable of interest in policy discussions is often not the benefit level, but the replacement ratio - the ratio of an unemployed worker's benefits to his previous wage. In our model, however, we deliberately use the benefit level, rather than the replacement ratio, as the government's choice variable. In order to realistically mimic the administration of the replacement ratio in the US, the model would need to assume that the replacement ratio is a

function of wages received during the worker's previous employment spell - not the current aggregate wage. At any point in time, unemployed workers differ in the past wages they received while employed, and would thus differ in their benefit levels if the replacement ratio were used. This would also imply that workers would differ in their outside option during wage negotiations, leading to a distribution of wages at any point in time. Computing welfare would require the government to keep track of the distribution of past employment histories, making the model intractable.

On the other hand, assuming that the government's choice variable is b/w , where b is the current unemployment benefit and w is the current aggregate wage, could lead to misleading results. For example, consider a worker who had been employed in a boom and gets fired at the beginning of a recession. The US unemployment insurance system would assign this worker an unemployment benefit based on his previous wages, which are likely to have been high. A system that conditions b on the current aggregate w would assign this worker a considerably lower unemployment benefit level. Furthermore, unlike the US system, a policy that varies b based on the aggregate w , rather than the worker's own history, would result in an unemployment benefit level that fluctuates throughout the worker's unemployment spell, whereas it is constant in the data. These two features make this alternative problematic. Thus, our assumption that the government chooses b rather than b/w , while imperfect, appears to be a good compromise.

5.4.6 Sensitivity analysis

We examine the robustness of our results to the parameterization of the model. We have calibrated the model parameters - in particular, the value of non-market activity and the worker bargaining power - to make the model's behavior consistent with US labor market volatility data. However, since several alternative calibrations exist in the literature (see e.g. Shimer (2005)), we conduct sensitivity analysis to determine

whether our optimal policy results remain valid under alternative parameterizations. Below, we report the results of sensitivity experiments in which we change the values of selected parameters (e.g. h) while keeping the remaining parameters unchanged at their benchmark calibrated values. Similar robustness results hold if we recalibrate the other parameters.

Figure 5.8 displays the optimal policy results when h is set to 0. Because the value of unemployment is now considerably lower, the optimal policy prescribes for benefits not to expire at all ($e_t = 0$), but the optimal response of the benefit level is similar to our benchmark. Figure 5.9 displays the results when worker bargaining power is increased to 0.72. As already discussed in section 5.4.2, the business cycle response of the benefit level is the same qualitatively as in the benchmark. Next, we adopt a calibration similar to Shimer (2005), in which we set h to 0 and the bargaining power of the workers to 0.72. The result is displayed in Figure 5.10; once again, optimal benefits do not expire, but the optimal response of the benefit level is the same as in our benchmark. The main qualitative features of our results, including the result that the optimal benefit scheme is pro-cyclical, do not depend on which calibration is used.

In addition, we have computed the optimal policy for different values of worker risk aversion: specifically, we have computed it for constant relative risk aversion utility, for values of relative risk aversion equal to 1/2 and 2. The results are displayed in Figures 5.13 and 5.14. Once again, the qualitative features of our results remain intact.

5.5 Conclusion

We analyzed the design of an optimal UI system in the presence of aggregate shocks in an equilibrium search and matching model. Optimal benefits respond non-monotonically to productivity shocks: while raising benefit generosity may be optimal at the on-

set of a recession, it becomes suboptimal as the recession progresses and inducing a recovery is desirable. We find that optimal benefits are pro-cyclical overall, counter to previous results in the literature and to the way UI policy is currently conducted. Our findings thus demonstrate that conventional wisdom guiding policymakers may be overturned in a quite standard equilibrium search model of the labor market.

Our paper has focused on the optimal cyclical behavior of UI benefits and thus serves to inform the ongoing policy debate on the desirability of benefit extensions in recessions. UI benefits are a worker-side intervention, as they affect the economy by changing the workers' value of being unemployed. An interesting extension would be to consider the optimal behavior of UI benefits in conjunction with firm-side interventions, such as hiring subsidies. Increasing hiring subsidies in recessions may be desirable as another instrument for stimulating an employment recovery. A potential concern with hiring subsidies, frequently articulated in policy debates, is the firm-side moral hazard they generate: firms could, for example, fire existing employees only to hire them again in order to receive hiring subsidies. A thorough investigation of the tradeoffs involved with such policies seems a fruitful extension for future work.

Finally, an important direction for future research is investigating the role of government commitment. The ability of the government to commit matters because the behavior of agents in our model depends not only on the current policy, but also on their expectations about future policy. Throughout the paper, we have assumed that the government can fully commit to its policy. A government without commitment power might be tempted not to lower benefits when there are a lot of unemployed workers. It will therefore be interesting to characterize the time-consistent policy and compare it to the optimal policy in the presence of aggregate shocks.

5.6 Tables and Figures

Table 5.1: Internally Calibrated Parameters

| Parameter | Value | Target | Data | Model |
|----------------------------------|--------|---------------------------|-------|-------|
| h Value of non-market activity | 0.581 | Mean $v/(1-L)$ | 0.634 | 0.634 |
| ξ Bargaining power | 0.141 | St. dev of $\ln(v/(1-L))$ | 0.259 | 0.259 |
| χ Matching parameter | 0.492 | Mean job finding rate | 0.139 | 0.139 |
| A Disutility of search | 0.0063 | Unemployment duration | 13.2 | 13.2 |
| ψ Search cost curvature | 2.224 | $\mathcal{E}_{d,b}$ | 0.9 | 0.9 |

Note: $\mathcal{E}_{d,b}$ is the elasticity of unemployment duration with respect to benefits.

Table 5.2: Summary statistics - quarterly US data, 1951:1-2004:4

| | z | $1-L$ | v | $v/(1-L)$ |
|--------------------|-----------|-------|--------|-----------|
| Standard Deviation | 0.013 | 0.125 | 0.139 | 0.259 |
| | z | 1 | -0.302 | 0.460 |
| Correlation | $1-L$ | - | 1 | -0.919 |
| Matrix | v | - | - | 1 |
| | $v/(1-L)$ | - | - | - |

Note: Standard deviations and correlations are reported in logs as quarterly deviations from an HP-filtered trend with a smoothing parameter of 1600.

Table 5.3: Summary statistics - calibrated model

| | z | $1-L$ | v | $v/(1-L)$ |
|--------------------|-----------|-------|--------|-----------|
| Standard Deviation | 0.013 | 0.128 | 0.151 | 0.259 |
| | z | 1 | -0.855 | 0.867 |
| Correlation | $1-L$ | - | 1 | -0.758 |
| Matrix | v | - | - | 1 |
| | $v/(1-L)$ | - | - | - |

Note: Standard deviations and correlations are reported in logs as quarterly deviations from an HP-filtered trend with a smoothing parameter of 1600.

Table 5.4: Optimal benefit behavior

| | Benefit level | Potential duration |
|--------------------------|---------------|--------------------|
| | b | $1/e$ |
| Mean | 0.478 | 11.7 |
| Standard deviation | 0.010 | 0.059 |
| Correlation with z | 0.694 | 0.476 |
| Correlation with $1 - L$ | -0.331 | -0.08 |
| Correlation with b | 1 | 0.962 |

Table 5.5: Model statistics simulated under the current US policy

| | z | $1 - L$ | $v/(1 - L)$ | \hat{f} | w | S^E | S^I |
|--------------------|-------------|---------|-------------|-----------|--------|--------|--------|
| Mean | 1 | 0.058 | 0.634 | 0.139 | 0.954 | 0.503 | 0.667 |
| Standard Deviation | 0.013 | 0.128 | 0.259 | 0.152 | 0.010 | 0.045 | 0.002 |
| | z | 1 | -0.855 | 0.914 | 0.895 | 0.926 | 0.888 |
| | $1 - L$ | - | 1 | -0.913 | -0.918 | -0.679 | -0.923 |
| | $v/(1 - L)$ | - | - | 1 | 0.997 | 0.729 | 0.992 |
| Correlation | \hat{f} | - | - | - | 1 | 0.697 | 0.998 |
| Matrix | w | - | - | - | - | 1 | 0.686 |
| | S^E | - | - | - | - | - | 1 |
| | S^I | - | - | - | - | - | - |
| | | | | | | | 1 |

Note: Means are reported in levels, standard deviations and correlations are reported in logs as quarterly deviations from an HP-filtered trend with a smoothing parameter of 1600. \hat{f} denotes the weekly job finding rate.

Table 5.6: Model statistics simulated under the optimal US policy

| | z | $1 - L$ | $v/(1 - L)$ | \hat{f} | w | S^E | S^I |
|--------------------|-------------|---------|-------------|-----------|--------|--------|--------|
| Mean | 1 | 0.048 | 0.772 | 0.161 | 0.956 | 0.523 | 0.668 |
| Standard Deviation | 0.013 | 0.027 | 0.061 | 0.032 | 0.011 | 0.009 | 0.003 |
| | z | 1 | -0.875 | 0.815 | 0.774 | 0.918 | 0.744 |
| | $1 - L$ | - | 1 | -0.937 | -0.923 | -0.653 | -0.907 |
| | $v/(1 - L)$ | - | - | 1 | 0.998 | 0.519 | 0.993 |
| Correlation | \hat{f} | - | - | - | 1 | 0.459 | 0.999 |
| Matrix | w | - | - | - | - | 1 | 0.419 |
| | S^E | - | - | - | - | - | 1 |
| | S^I | - | - | - | - | - | - |
| | | | | | | | 1 |

Note: Means are reported in levels, standard deviations and correlations are reported in logs as quarterly deviations from an HP-filtered trend with a smoothing parameter of 1600. \hat{f} denotes the weekly job finding rate.

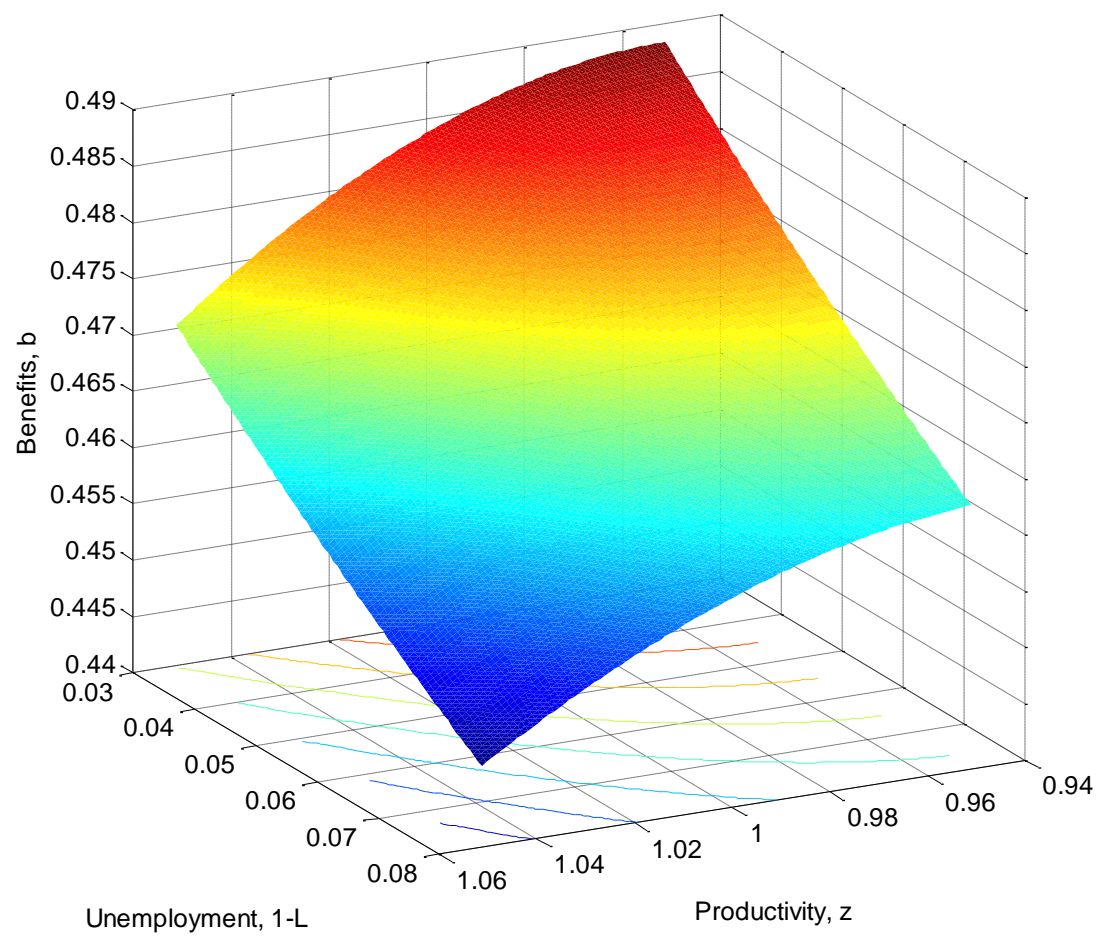
Figure 5.1: Optimal policy: benefit level

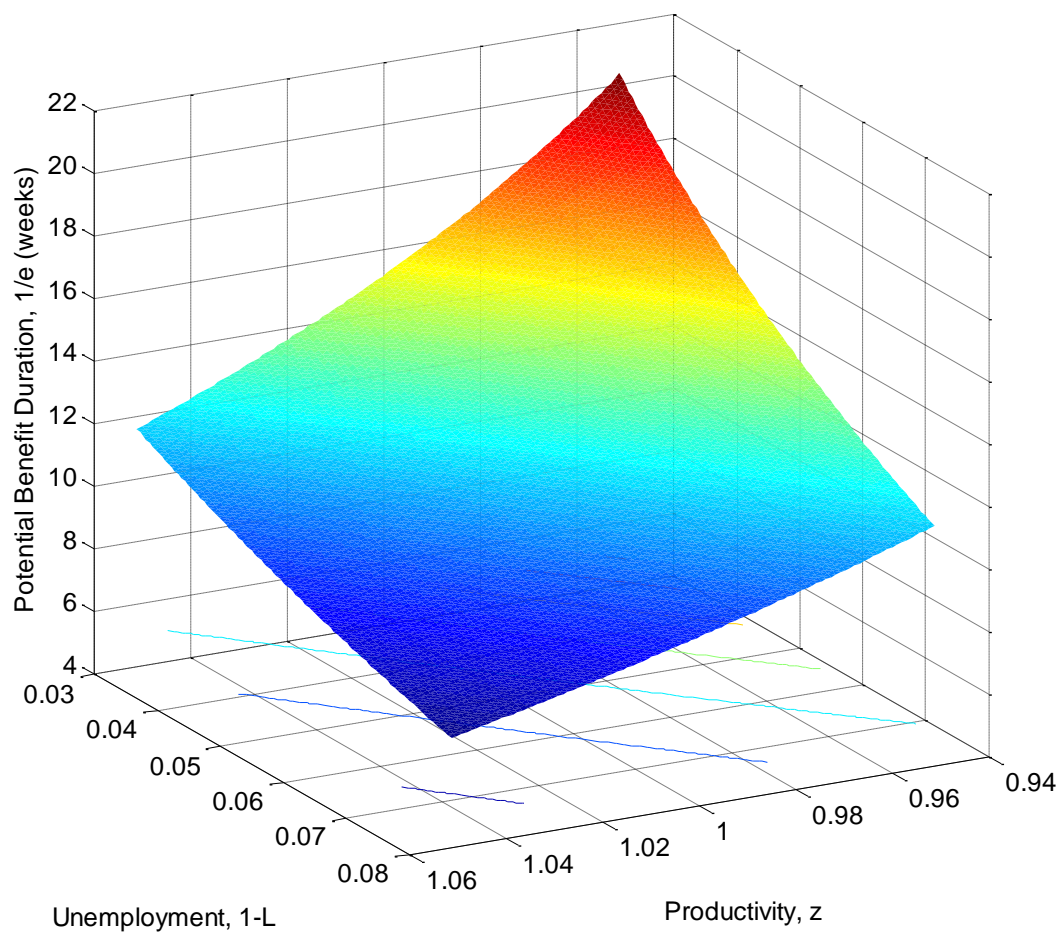
Figure 5.2: Optimal policy: benefit duration

Figure 5.3: Responses to 1.5% drop in productivity

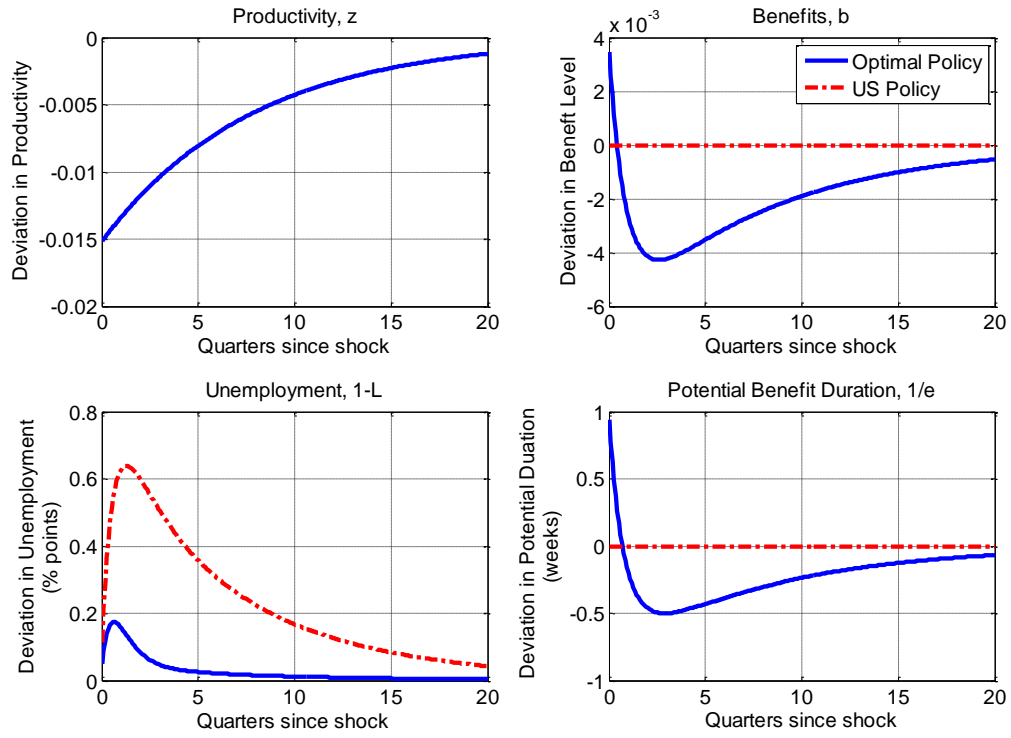


Figure 5.4: Responses to 1.5% drop in productivity

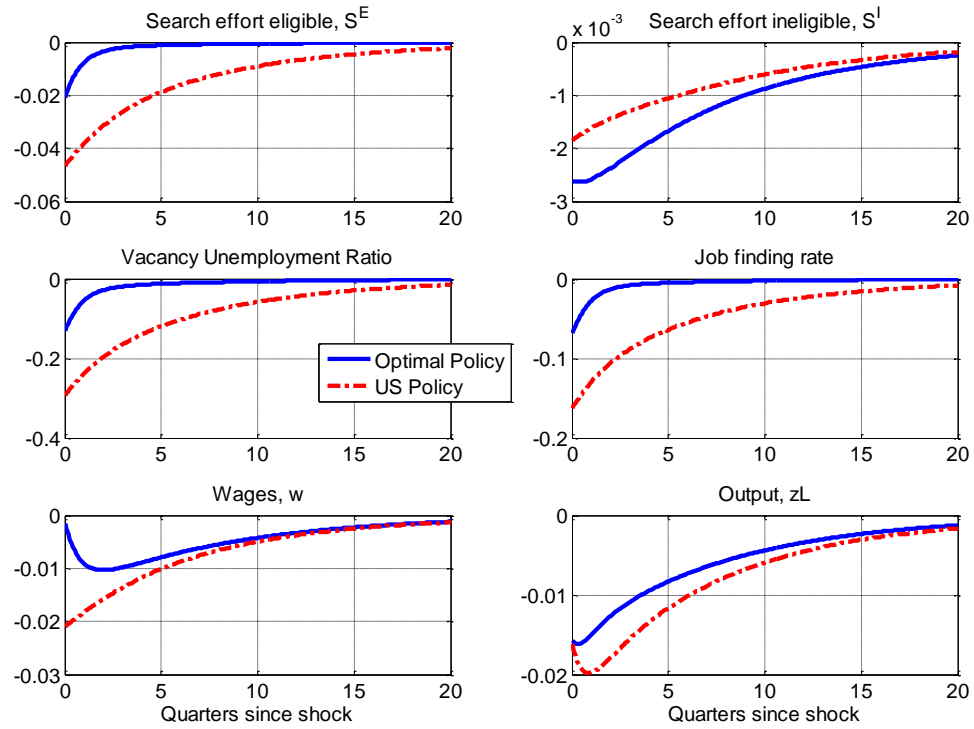


Figure 5.5: Response of duration to a 1.5% shock, fixing benefit level at $b = 0.4$

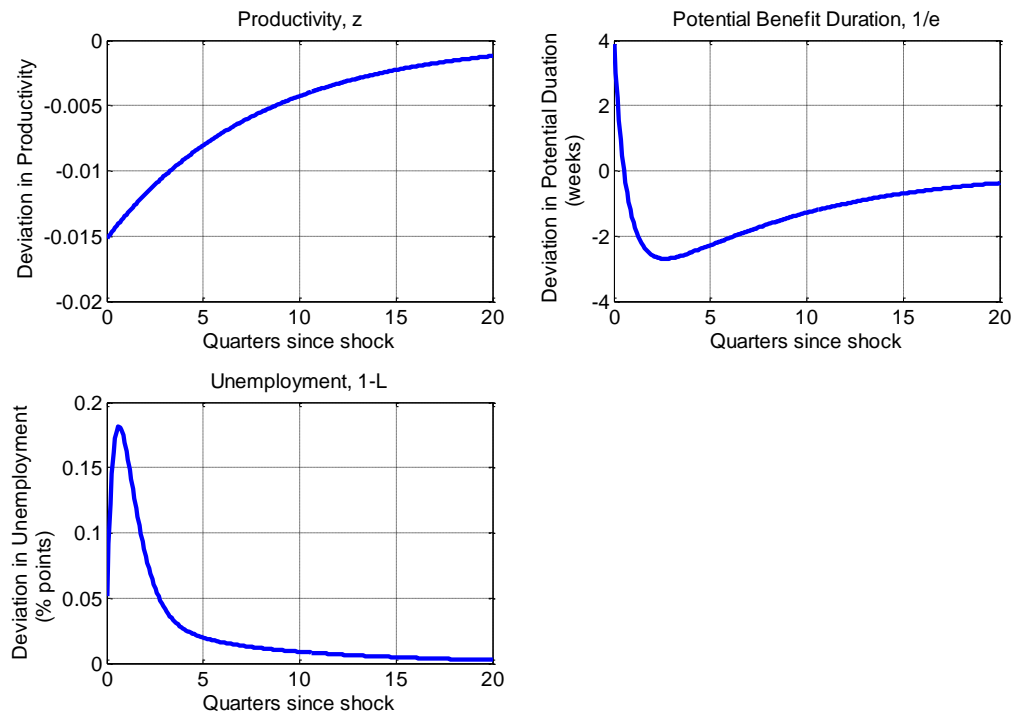


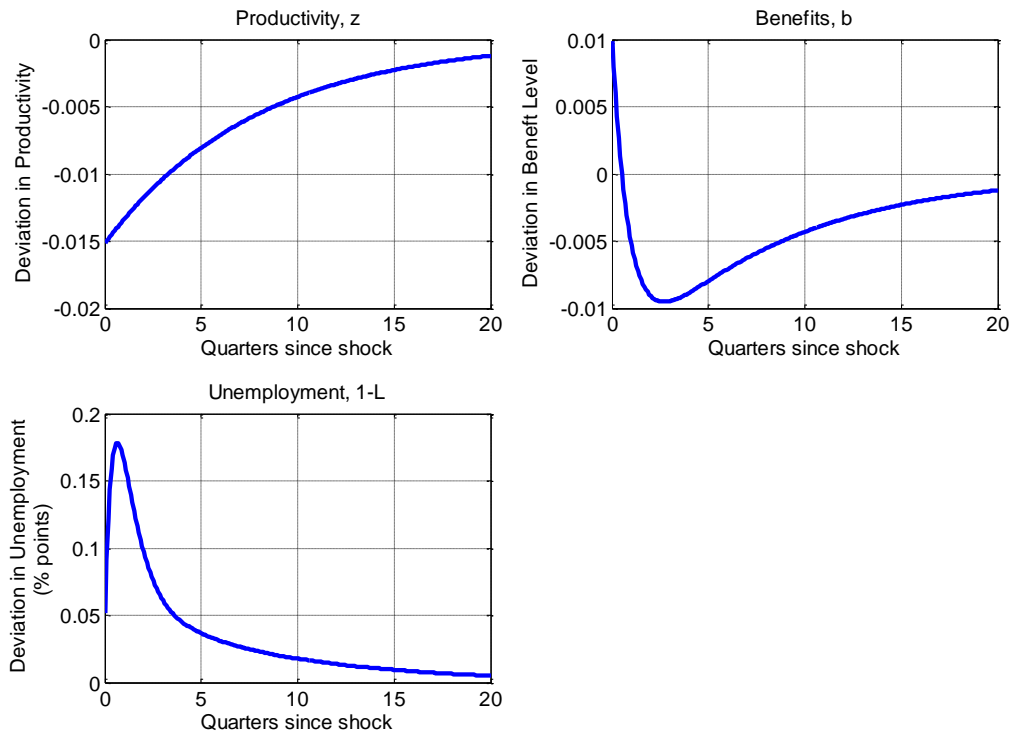
Figure 5.6: Response of benefit level to a 1.5% shock, fixing expected duration at 26 weeks

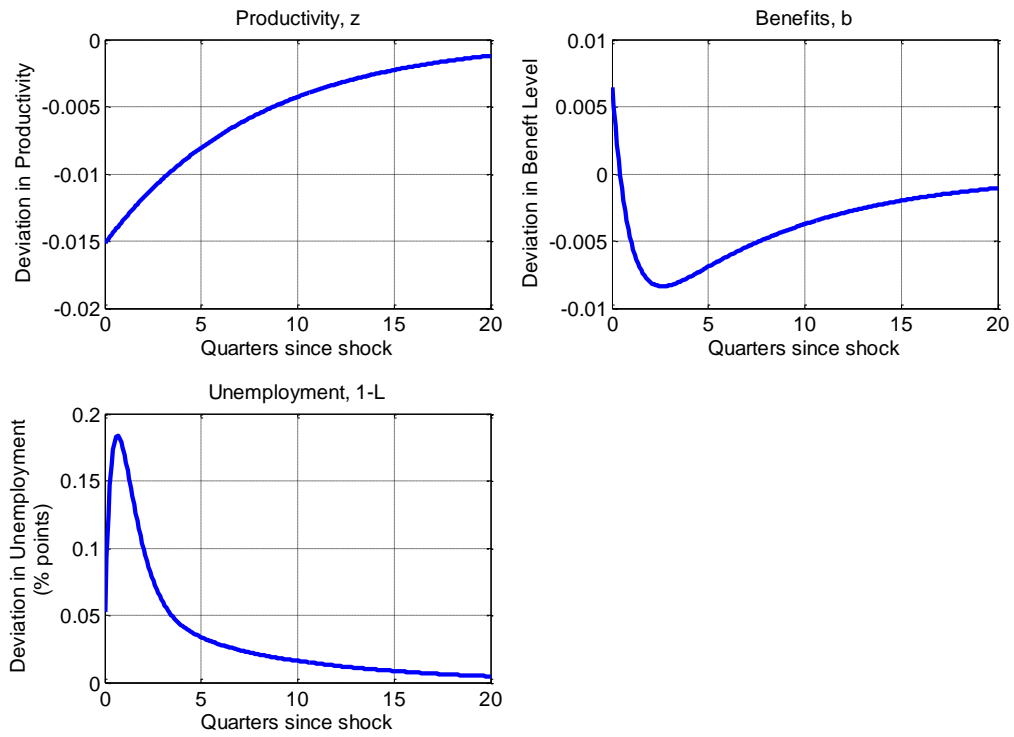
Figure 5.7: Response of benefit level to a 1.5% shock with no benefit expiration

Figure 5.8: Response to a 1.5% shock with $h = 0$. Note: The optimal policy under this parameterization prescribes that benefits do not expire, which is why the behavior of $1/e$ is omitted.

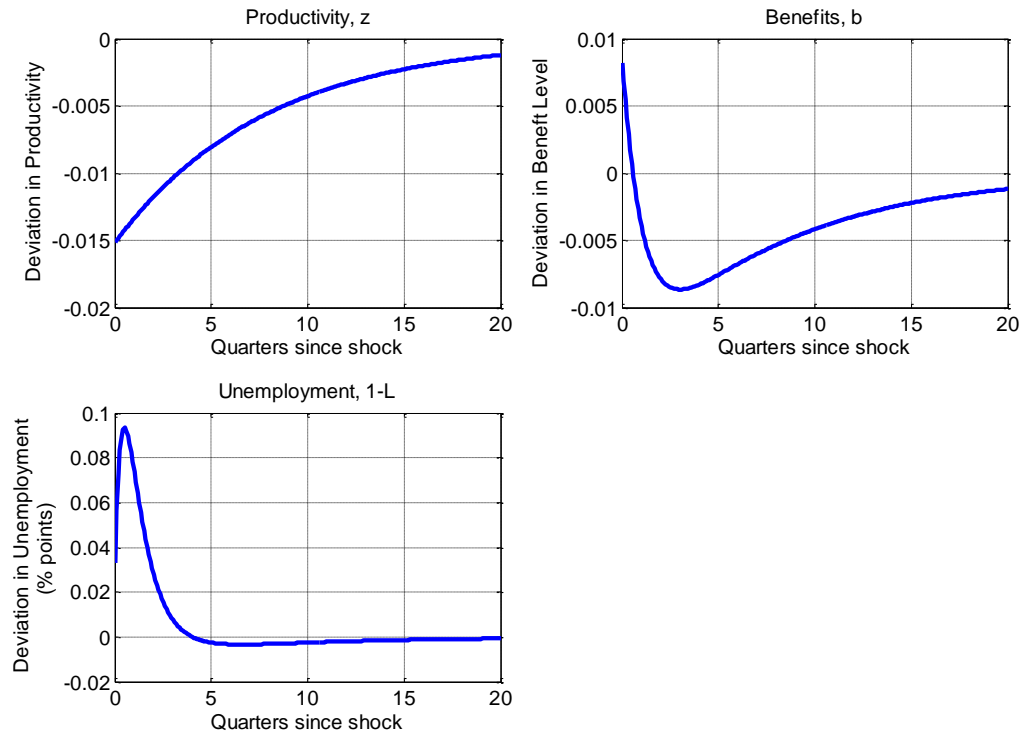


Figure 5.9: Response to a 1.5% shock with $\xi = 0.72$. Note: The optimal policy under this parameterization prescribes that benefits do not expire, which is why the behavior of $1/e$ is omitted.

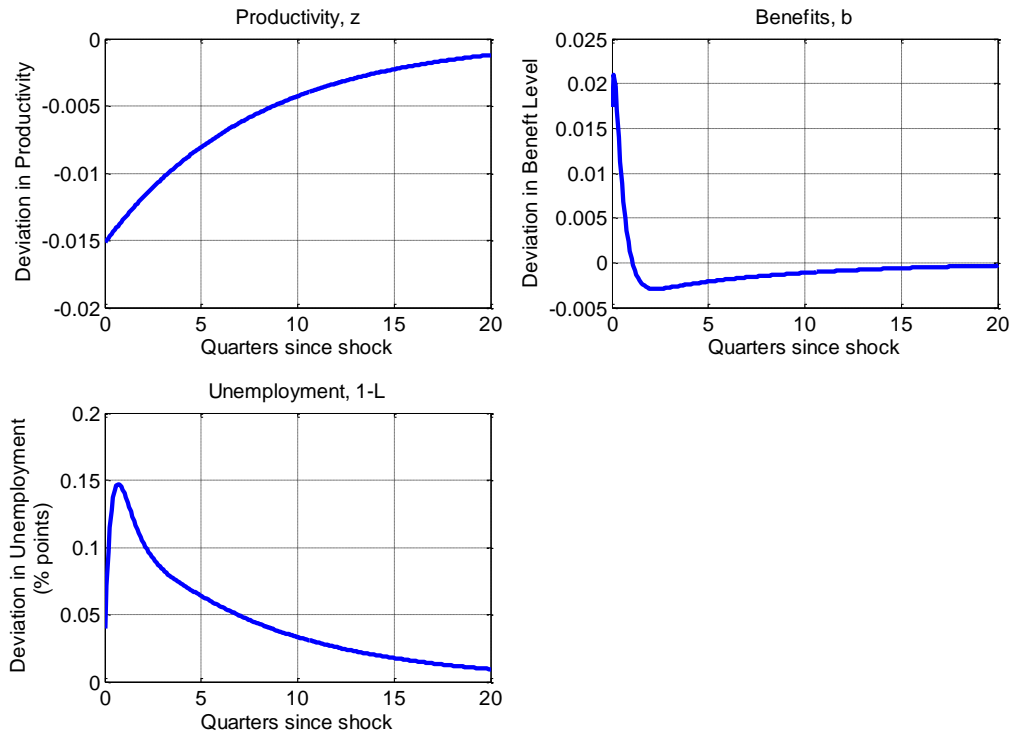


Figure 5.10: Response to a 1.5% shock with $\xi = 0.72$, $h = 0$. Note: The optimal policy under this parameterization prescribes that benefits do not expire, which is why the behavior of $1/e$ is omitted.

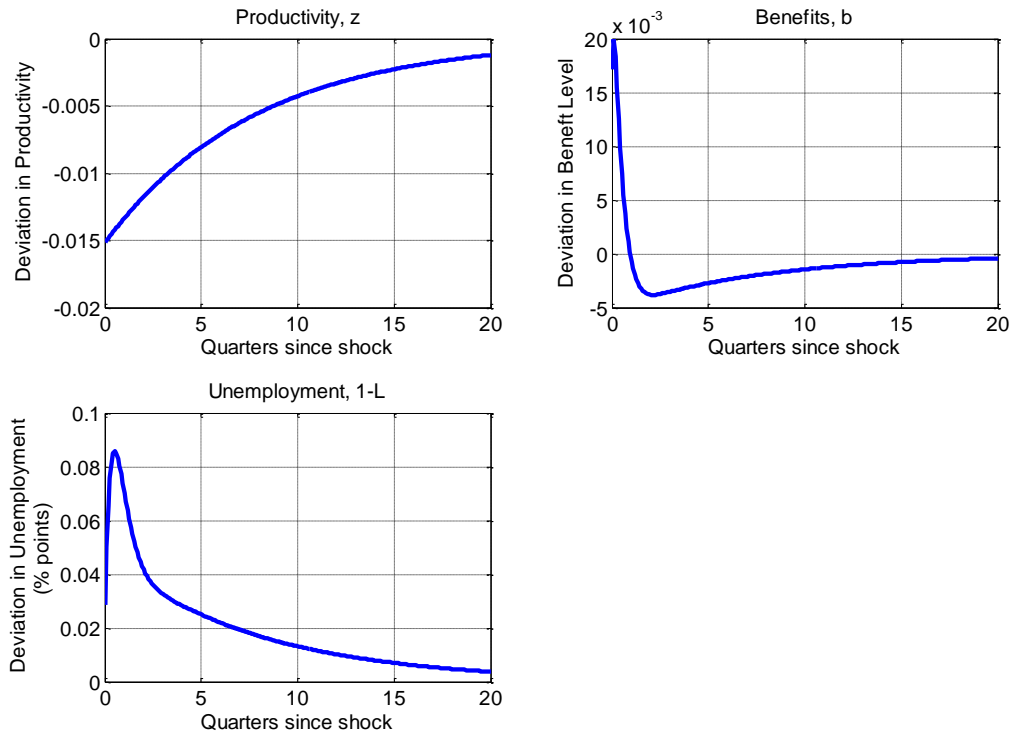


Figure 5.11: Response of benefit replacement ratio to a 1.5% shock

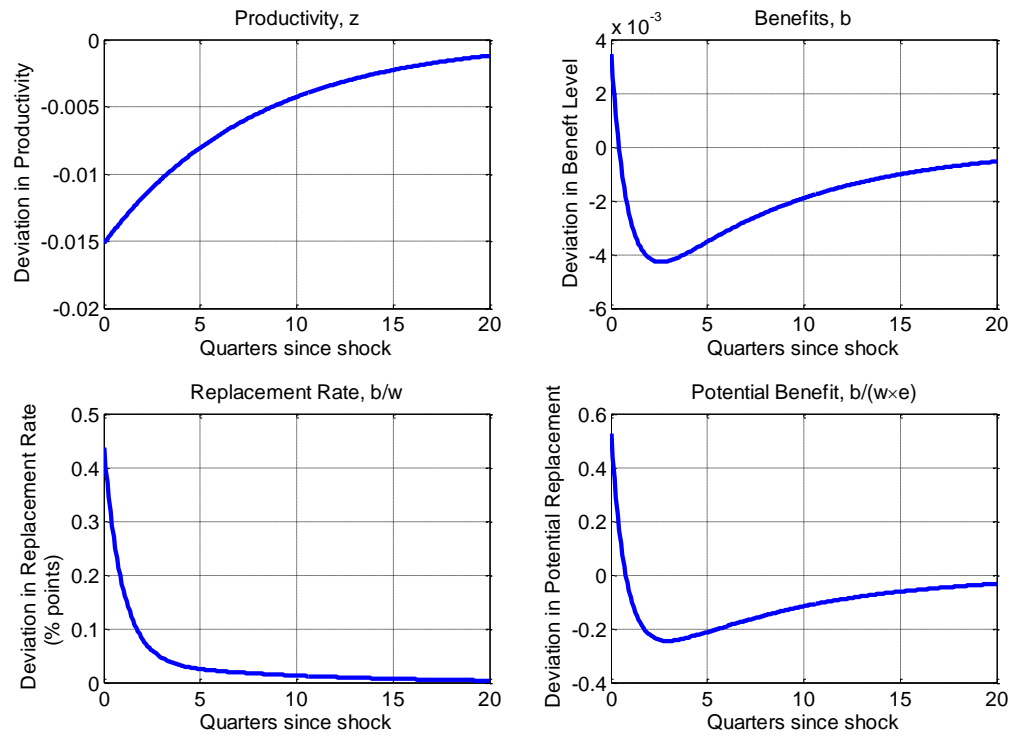


Figure 5.12: Response of benefit replacement ratio to a 1.5% shock with no benefit expiration

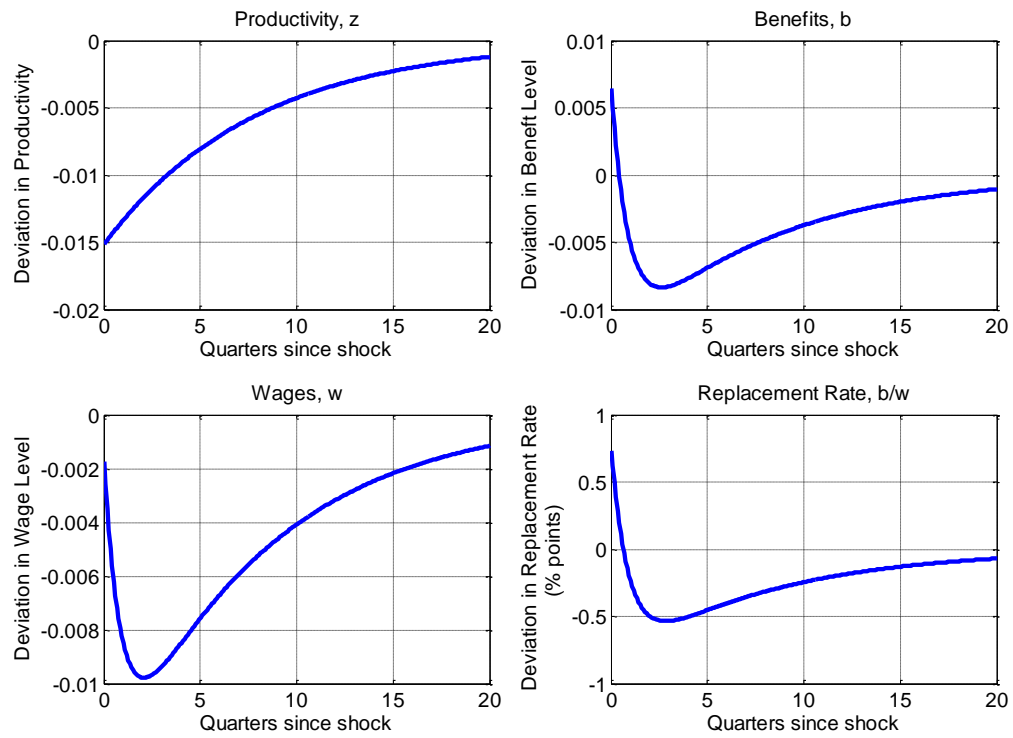


Figure 5.13: Response to a 1.5% shock under risk aversion of $\sigma = 1/2$

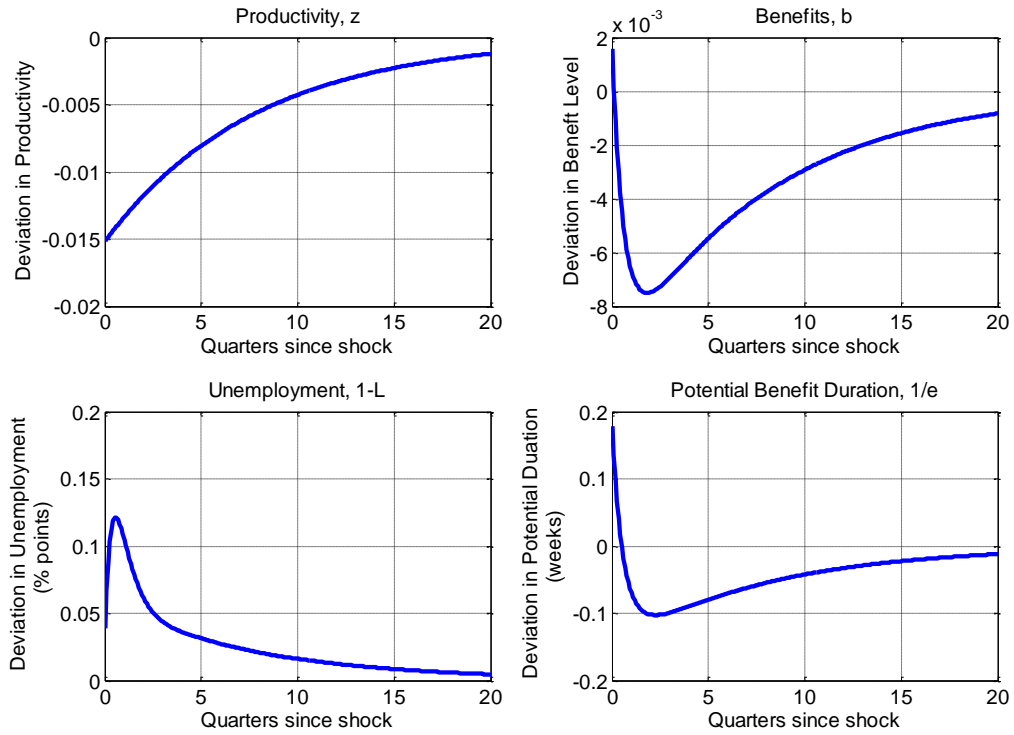
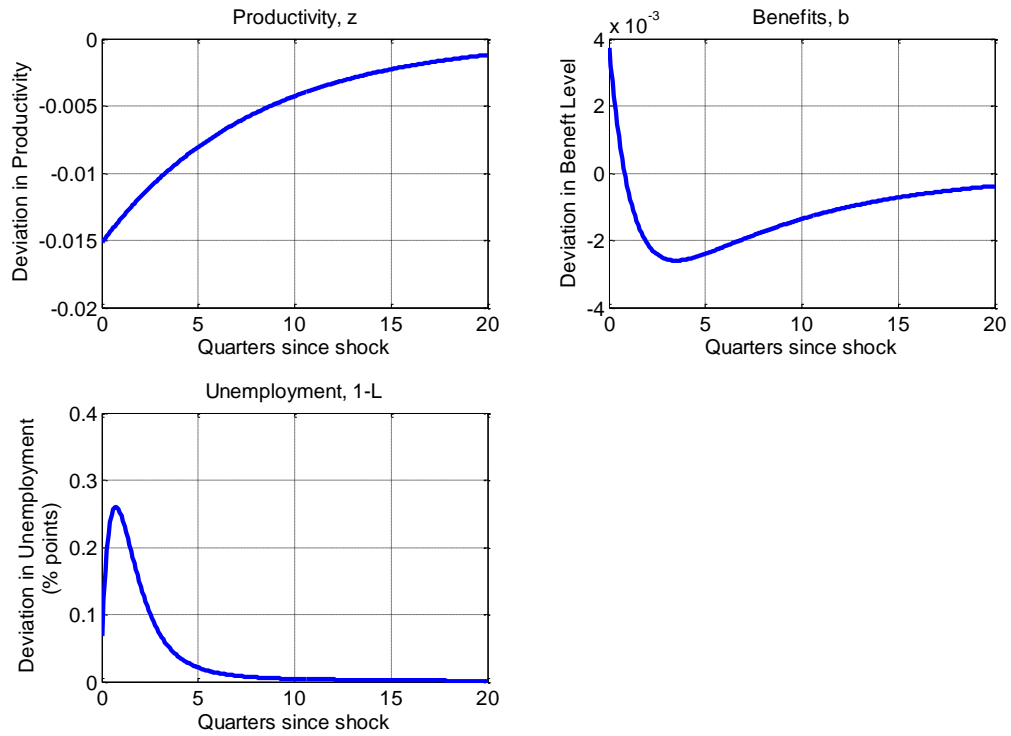


Figure 5.14: Response to a 1.5% shock under risk aversion of $\sigma = 2$. Note: The optimal policy under this parameterization prescribes that benefits do not expire, which is why the behavior of $1/e$ is omitted.



APPENDICES

Appendix A

Appendices to Chapter 1

In this appendix I present the proofs for Propositions 3-5. All remaining proofs can be found in the Appendix.

Proof of Proposition 3.

- (a) Suppose $y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi_1, z)$. Take $\xi_2 < \xi_1$. Since $W_{\mathcal{F}}^B$ is increasing in the first argument $W_{\mathcal{F}}^B(\eta - \xi_1, y, z) \leq W_{\mathcal{F}}^B(\eta - \xi_2, y, z)$. However, since $y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi_1, z)$ this implies that $W_{\mathcal{F}}^{NB}(b_F + \eta + y, z) \leq W_{\mathcal{F}}^B(\eta - \xi_1, y, z)$, which implies that $y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi_2, z)$. \square
- (b) Suppose $y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$. Take $x > 0$. Since $W_{\mathcal{F}}^B$ is increasing in its first argument, $W_{\mathcal{F}}^B(\eta + x - \xi, y, z) \geq W_{\mathcal{F}}^B(\eta - \xi, y, z)$. However, since $y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$ this implies that $W_{\mathcal{F}}^{NB}(\eta + y + b_F, z) \leq W_{\mathcal{F}}^B(\eta - \xi, y, z)$, and $W_{\mathcal{F}}^{NB}(\eta + y + b_F, z) = W_{\mathcal{F}}^{NB}((\eta + x) + y + (b_F - x), z)$, therefore $y \in \overline{\mathcal{B}}^*(b_F - x, \eta + x, \xi, z)$. \square
- (c) Suppose $y \notin \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$, where $\xi > 0$. Take $x > 0$. Since $W_{\mathcal{F}}^{NB}$ is increasing in the first argument, $W_{\mathcal{F}}^{NB}(b_F + \eta + x + y, z) \geq W_{\mathcal{F}}^{NB}(b_F + \eta + y, z)$. Note that since $\xi > 0$, the additional home equity is forfeited in bankruptcy, $W_{\mathcal{F}}^B((\eta + x) - (\xi + x), y, z) = W_{\mathcal{F}}^B(\eta - \xi, y, z)$. Thus, since $y \notin \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$ this implies that $W_{\mathcal{F}}^{NB}(b_F + \eta + x + y, z) \geq W_{\mathcal{F}}^{NB}(b_F + \eta + y, z) \geq W_{\mathcal{F}}^B(\eta - \xi, y, z)$, which

implies that $y \notin \overline{\mathcal{B}}^*(b_F, \eta + x, \xi + x, z)$. \square

(d) When there is no homestead exemption the value of defaulting only depends on the endowment y and state z . Today's budget set only depends on the net asset position, therefore the bankruptcy set only depends on $\eta + b_F$ and z . \square

(e) This comes directly from Proposition 1 and that $W_{\mathcal{F}}^{NB}(a, i) \geq W_{\mathcal{F}}^{BC}(a, i)$. Let $\varepsilon = b_F + \eta - \chi^s > 0$. Suppose not, i.e. $\exists y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$. This implies that $u(y; p_s) + \beta \mathbb{E}V^{BC} \geq u(c^*(\eta + b_F + y); p_s) + \beta \mathbb{E}V^G$. However, consuming $y + \varepsilon$ and saving χ was a feasible choice, which implies that: $u(c^*(\eta + b_F + y); p_s) + \beta \mathbb{E}V^G \geq u(y + \varepsilon; p_s) + \beta \mathbb{E}V^{BC} > u(y; p_s) + \beta \mathbb{E}V^{BC}$ from the strict monotonicity of u , which arrives at the desired contraction. \square

\square

Proof of Proposition 4. When $\gamma < 1$ and $h(1 - \delta) > m$ implies $h(1 - \delta) - m > \gamma h(1 - \delta) - m$ (the deficiency judgment value) and $h(1 - \delta) - m > \max\{\gamma h(1 - \delta) - m, 0\}$ (the no deficiency judgment value). Thus, the household can guarantee itself strictly more resources tomorrow if it does not declare bankruptcy (if it has a good credit history), then from since the value functions are increasing in their first argument, we are done. In case of bankruptcy and $\chi > 0$ the same argument holds. If $\chi = 0$ the assumption that when a household has positive home equity and is indifferent between foreclosing and not it chooses to repay completes the proof. \square \square

Proof of Proposition 5. The proof is immediate from Proposition 4 and the definition of foreclosure when $\psi = 0$. When $\delta \geq 1 - \kappa \Rightarrow h(1 - \delta) \leq m$, thus the household will always have more resources if it chooses foreclosure. \square \square

A.1 Supplementary Tables

Table A.1: Legal Environments Considered

| States | Homestead Exemption | Recourse | Median HH Income | Weight |
|---|---------------------|----------|------------------|--------|
| Washington , N. Carolina | 0.64 | No | 42334 | 0.053 |
| California , Alaska, N. Dakota | 1.58 | No | 47211 | 0.112 |
| Minnesota , Arizona, Montana | 3.33 | No | 42154 | 0.050 |
| Maryland , Ohio, Georgia, Illinois, Tennessee, Indiana, Virginia | 0.23 | Yes | 42146 | 0.248 |
| Kentucky, S. Carolina, Alabama | | | | |
| Michigan , Missouri, Louisiana, New York, Wyoming, New Jersey, Nebraska, Michigan, Pennsylvania, Hawaii, Oregon, West Virginia, Utah, Wisconsin, Arkansas, Delaware, Colorado, Idaho | 0.677 | Yes | 42650 | 0.305 |
| Massachusetts , New Mexico, Maine, New Hampshire, Mississippi, Nevada, Connecticut, Vermont, Rhode Island | 3.65 | Yes | 44872 | 0.075 |
| Florida , Texas, Kansas, Oklahoma, S. Dakota, D.C. | ∞ | Yes | 38944 | 0.158 |

Table A.2: State Results - Recourse

| | Maryland $\chi^s = 0.23$ | Michigan $\chi^s = 0.68$ | Massachusetts $\chi^s = 3.7$ | Florida $\chi^s = \infty$ |
|--|-----------------------------|-----------------------------|---------------------------------|------------------------------|
| Unsecured debt, B_- | -0.59 | -0.48 | -0.04 | -0.01 |
| Mortgages M | 3.34 | 3.39 | 3.81 | 3.83 |
| Bankruptcy rate | 1.24% | 1.22% | 0.91% | 0.88% |
| Foreclosure rate | 0.49% | 0.54% | 0.61% | 0.62% |
| Joint | 42% | 36% | 21% | 21% |
| In debt | 5.5% | 5.4% | 4.9% | 4.9% |
| Fraction of households with Unsecured Debt | 60% | 45% | 24% | 22% |

Table A.3: State Results - No Recourse

| | Washington $\chi^s = 0.64$ | California $\chi^s = 1.57$ | Minnesota $\chi^s = 3.32$ |
|---|-------------------------------|-------------------------------|------------------------------|
| Unsecured debt, B_- | -0.38 | -0.20 | -0.04 |
| Mortgages M | 3.54 | 3.64 | 3.78 |
| Bankruptcy rate | 1.15% | 1.00% | 0.62% |
| Foreclosure rate | 0.53% | 0.58% | 0.63% |
| Joint | 23% | 10% | 2% |
| In debt | 5.3% | 5.2% | 5.0% |
| Fraction of households with Unsecured Debt | 35% | 16% | 3% |

Table A.4: State Level Implications of BAPCPA

| State | Foreclosure Rates | | Bankruptcy Rates | |
|---------------|-------------------|--------|------------------|--------|
| | Baseline | BAPCPA | Baseline | BAPCPA |
| Maryland | 0.49% | 1.28% | 1.24% | 2.27% |
| Michigan | 0.54% | 1.29% | 1.22% | 2.32% |
| Massachusetts | 0.61% | 1.30% | 0.91% | 2.57% |
| Florida | 0.62% | 1.31% | 0.88% | 2.58% |
| Washington | 0.53% | 0.61% | 1.14% | 2.44% |
| California | 0.58% | 0.69% | 1.00% | 2.77% |
| Minnesota | 0.63% | 0.71% | 0.62% | 2.86% |

A.2 Supplementary Figures

Notes: as a function of leverage, $\kappa = \frac{m}{h}$, for a household in Michigan, a recourse state, and in all no recourse states. The Michigan line represents the price schedule given its optimal choice of housing and unsecured debt: \$210K house and \$6K of unsecured debt. The No-Recourse line is independent of house size and unsecured debt position.

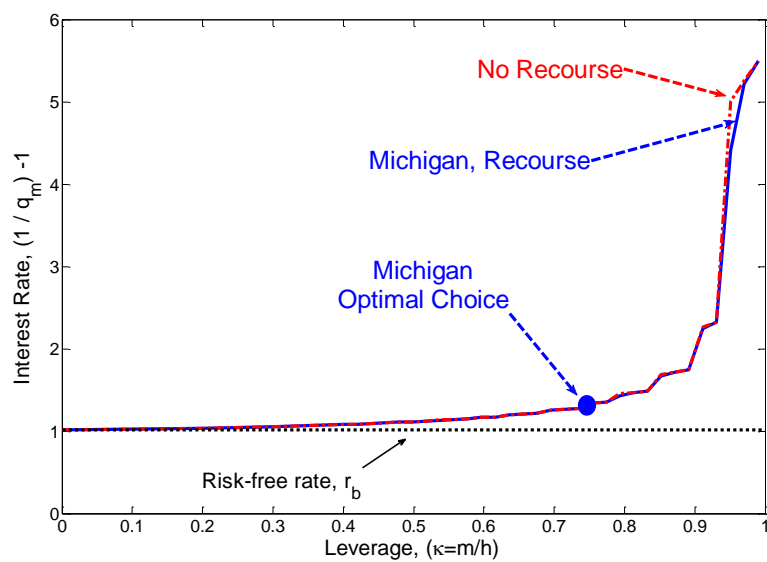
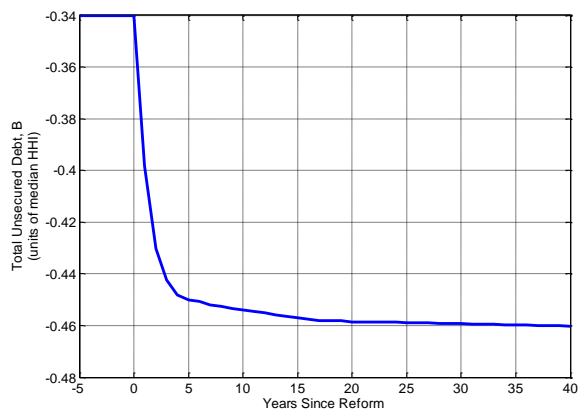
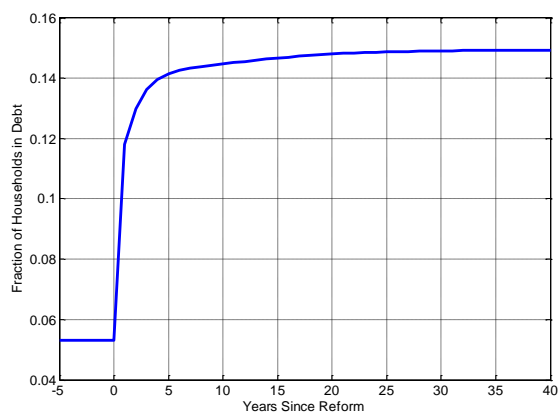


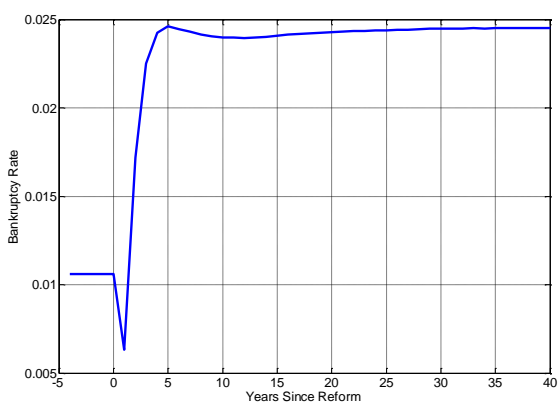
Figure A.1: Model mortgage interest rates



(a) Total unsecured debt along the transition path.



(b) Fraction of households that have non-positive network along the transition path.



(c) Bankruptcy rate along the transition path.

Figure A.2: Transitional dynamics after the implementation of BAPCPA at time 0.

A.3 Proofs Related to the Household Problem

I can simplify the household problem because of the static intra-temporal substitution between consumption and housing services. Thus, in the household problem define:

$$\begin{aligned} u(c; p_s) &= \max_{\tilde{c}, s \geq 0} U(\tilde{c}, s) \\ &\text{s.t.} \\ \tilde{c} + p_s s &= c \end{aligned}$$

Assumption 1. $U(c, s) : \mathbb{R}_+^2 \rightarrow \mathbb{R}$ is strictly increasing, concave and differentiable. Further, it is bounded above by \bar{U} , and given $p_s > 0$,

$$u(\underline{y}^i/\lambda; p_s) - u(0; p_s) > \frac{\beta}{1-\beta}(\bar{U} - u(\underline{y}^i/\lambda; p_s)) \quad \forall i$$

In addition, to rule out Ponzi schemes, I assume that there exist maximum levels of borrowing, both secured and unsecured:

Assumption 2. There exists a maximum level of unsecured borrowing, b_{\min} , and a maximum mortgage size, m_{\max} .

Lemma 2. $u(c; p_s)$ is continuous, strictly concave, strictly increasing.

Proof. Take $c_1, c_2 > 0$ and $c_\theta = \theta c_1 + (1 - \theta)c_2$ for $\theta \in (0, 1)$. $u(c_i; p_s) \equiv U(\tilde{c}_i, s_i)$ where \tilde{c}_i and s_i are from the maximizers. From the strict concavity of U , we know that

$$\begin{aligned} \theta U(\tilde{c}_1, s_1) + (1 - \theta)U(\tilde{c}_2, s_2) &< U(\theta\tilde{c}_1 + (1 - \theta)\tilde{c}_2, \theta s_1 + (1 - \theta)s_2) \\ &\leq U(\tilde{c}_\theta, s_\theta) \end{aligned}$$

where the first inequality comes from the strict concavity of U and the second from

the fact that $\theta\tilde{c}_1 + (1 - \theta)\tilde{c}_2 + p_s(\theta s_1 + (1 - \theta)s_2) = \theta c_1 + (1 - \theta)c_2 = c_\theta$, thus it is a feasible choice for the maximization for $u(c_\theta; p_s)$, and by definition of a max. Continuity and strict monotonicity follow from the properties of U . \square \square

Let $M \subset \mathbb{R}_+$ be the mortgage choice set, $B \subset \mathbb{R}$ be the bond/unsecured choice set, $H \subset \mathbb{R}_+$ be the housing choice set, $C \subset \mathbb{R}_+$ be the consumption expenditure choice set. The continuous state variable, cash-at-hand, $a \in A \subset \mathbb{R}_+$. Let Z and Y be the set of possible realizations for the persistent shock and income. The possible credit histories are $\mathcal{H} = \{G, B, BC\}$. For the household problem, I take the pricing functions $q_b : B \times H \times M \times Z \rightarrow \mathbb{R}_+$ and $q_m : B \times H \times M \times I \times \mathcal{H} \rightarrow \mathbb{R}_+$ as given. To economize on notation, I will typically not make explicit the dependence of the prices on the choice parameters.

I define the budget correspondence for households with a good credit history and foreclosure choice \mathcal{F} who didn't go bankrupt, $\Gamma_{\mathcal{F}}^{NB} : A \times Z \rightarrow C \times B \times H \times M$ as:

$$\Gamma_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z) = \{(c, b, h, m) \in C \times B \times H \times M : c + bq_b + h[1 - p_s] - mq_m \leq a_{\mathcal{F}}\} \quad (\text{A.1})$$

and households who did go bankrupt, I define the budget correspondence $\Gamma^B : A \times Z \rightarrow \times H \times M$ as:

$$\Gamma_{\mathcal{F}}^B(a_{\mathcal{F}}, z) = \{(h, m) \in G \times M : h[1 - p_s] - mq_m \leq a_{\mathcal{F}}\} \quad (\text{A.2})$$

Households with bad credit histories face the budget correspondence $\Gamma_{\mathcal{F}}^{BC} : A \times Z \rightarrow C \times B \times H \times M$ as:

$$\Gamma_{\mathcal{F}}^{BC}(a_{\mathcal{F}}, z) = \{(c, b, h, m) \in C \times B \times H \times M : \lambda c + bq_b + h[1 - p_s] - mq_m \leq a_{\mathcal{F}}, b \geq 0\} \quad (\text{A.3})$$

Now, I can define the value functions of households that begin the period with

good and bad credit histories:

$$\begin{aligned}
V^G(b, g, m, \delta, y, z) &= \max_{\mathcal{F} \in \{0,1\}} \mathbb{E}_{\mathcal{J}} \max \{W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z), W_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z)\} \\
\eta_{\mathcal{F}} &= (1 - \mathcal{F})[(1 - \delta)h - m] \\
a_{\mathcal{F}} &= y + (1 - \mathcal{F})[(1 - \delta)h - m + b] + \mathcal{F}b_F \\
V^{BC}(b, g, m, \delta, y, z) &= \max_{\mathcal{F} \in \{0,1\}} \mathbb{E}_{\mathcal{J}} \{W_{\mathcal{F}}^{BC}(a_{\mathcal{F}}, z)\} \\
a_{\mathcal{F}} &= y + (1 - \mathcal{F})[(1 - \delta)h - m + b] + \mathcal{F}b_F
\end{aligned}$$

where

$$W_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z) = \max_{x \in \Gamma_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z)} \left\{ u(c; p_s) + \beta \mathbb{E}_{(\delta', y', z')|z} V^G(b', h', m', \delta', y', z') \right\} \quad (\text{A.4})$$

$$W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z) = u(y; p_s) + \max_{x \in \Gamma_{\mathcal{F}}^B} \left\{ \beta \mathbb{E}_{(\delta', y', z')|z} V^{BC}(b', h', m', \delta', y', z') \right\} \quad (\text{A.5})$$

$$W_{\mathcal{F}}^{BC}(a_{\mathcal{F}}, z) = \max_{x \in \Gamma_{\mathcal{F}}^{BC}(a_{\mathcal{F}}, z)} \left\{ u(c; p_s) + \beta \mathbb{E}_{(\delta', y', z')|z} \left[\begin{array}{c} \alpha V^G(X') + \\ (1 - \alpha) V^{BC}(X') \end{array} \right] \right\} \quad (\text{A.6})$$

Denote the cardinality of the number of credit states by $N_{\mathcal{H}}$. Let \mathcal{V} be the set of all continuous (in b, h, m, δ, y, z), vector-valued functions $V : B \times H \times M \times \Delta \times Y \times Z \rightarrow \mathbb{R}^{N_{\mathcal{H}}}$ that are increasing in b, h, y and decreasing in m, δ that satisfy the following:

$$V^H(b, h, m, \delta, y, z) \in \left[\frac{u(0; p_s)}{1 - \beta}, \frac{\bar{u}}{1 - \beta} \right] \quad (\text{A.7})$$

$$V^G(b, h, m, \delta, y, z) \geq V^{BC}(b, h, m, \delta, y, z) \quad (\text{A.8})$$

Lemma 3. \mathcal{V} is nonempty. With $\|V\| = \max_H \{\sup |V^H|\}$ as the norm, $(\mathcal{V}, \|\cdot\|)$ is a complete metric space.

Proof. Any constant vector-valued function that satisfies (A.7) is clearly continuous

and satisfies the monotonicity requirements. The set of all continuous vector-valued functions coupled with the same norm $(\mathcal{C}, \|\cdot\|)$ is a complete metric space, thus to prove that $(\mathcal{V}, \|\cdot\|)$ is a complete metric space I need to show that $\mathcal{V} \subset \mathcal{C}$ is closed under the defined norm. Take an arbitrary sequence of functions from \mathcal{V} , $\{V_n\}$ that is converging to a function V^* . If V^* violates any of the conditions (A.7)-(A.8) or the monotonicity properties, then there must exist some N , such that V_N also violates those conditions or properties, but that contradicts the assertion that $V_n \in \mathcal{V} \forall n$. Therefore, V^* must satisfy conditions (A.7)-(A.8) and the monotonicity properties. To prove the continuity of V^* , one can apply Theorem 3.1 in Stokey, Lucas and Prescott 1989, adapted to a vector-valued function. \square \square

Lemma 4. $\Gamma_{\mathcal{F}}^B$ is nonempty, monotone, compact-valued and continuous.

Lemma 5. Given $V \in \mathcal{V}$, $W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z; V)$ defined by (A.5) exists, is continuous in $a_{\mathcal{F}}$ and y , increasing in $a_{\mathcal{F}}$ and strictly increasing in y .

Proof. The existence and continuity of $W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z; V)$ are a direct consequence of the Theorem of the Maximum, since V is continuous and $\Gamma_{\mathcal{F}}^B$ is compact valued and continuous. The strict monotonicity in y comes from the strict monotonicity of $u(\cdot; p_s)$. The monotonicity in $\eta_{\mathcal{F}}$ comes from the fact that $\Gamma_{\mathcal{F}}^B$ is monotone in $\eta_{\mathcal{F}}$ and the monotonicity of V . \square \square

In order to show the existence of $W_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z)$ and $W_{\mathcal{F}}^{BC}(a_{\mathcal{F}}, z)$ I first need to extend their definitions, because for some values of a the budget correspondence may be empty. First, I will denote by $c_H(a, z, x')$ the consumption of a household with a, z, H who makes the portfolio choice x' . Thus, $c_G(a, z, x') \equiv a - b'q_b - h'[1 - p_s] + m'q_m$ and $c_B(a, z, x') \equiv (a - b'q_b - h'[1 - P_s] + m'q_m) / \lambda$. Note that these consumptions can be negative. Using this notation, I can define lifetime utility from choosing portfolio x'

as follows:

$$\omega_{\mathcal{F}}^{BC}(a, z, x'; W) \equiv u(\max\{c_{BC}(a, z, x'), 0\}) + \beta \mathbb{E}_{(\delta', y', z')|z} \left[\begin{array}{l} \alpha V^G(X') + \\ (1 - \alpha)V^{BC}(X') \end{array} \right] \quad (\text{A.9})$$

$$\omega_{\mathcal{F}}^{NB}(a, z, x'; V) \equiv u(\max\{c_G(a, z, x'), 0\}) + \beta \mathbb{E}_{(\delta', y', z')|z} V^G(x', \delta', y', z') \quad (\text{A.10})$$

where $X' = (x', \delta', y', z')$

Lemma 6. $\omega_{\mathcal{F}}^H(a, z, x'; V)$ is continuous in a and x' . Further, for any i, x' , ω^s is increasing in a , and strictly increasing if $c_H(a, z, x') > 0$.

Proof. Note that $c_s(a, z, x')$ are continuous functions of a and x' and $u(\cdot; p_s)$ is continuous in its first argument. Further, since $V \in \mathcal{V}$ it is continuous in x' and integration preserves continuity. The monotonicity comes because of the strict monotonicity in $u(\cdot; p_s)$ and the fact that $c_H(a, z, x')$ is increasing in a and strictly increasing in a when $c_H(a, z, x') > 0$ □ □

Thus, I redefine the extended value functions as:

$$W_{\mathcal{F}}^H(a_{\mathcal{F}}, z; V) = \max_{x' \in \bar{X}_s(a_{\mathcal{F}}, z)} \omega_{\mathcal{F}}^H(a_{\mathcal{F}}, z, x'; V) \quad (\text{A.11})$$

where $\bar{X}_{\mathcal{F}}^H(a_{\mathcal{F}}, i) = \{(b, g, m) \in B \times H \times M : bq_b + h[1 - p_s] - mq_m \leq a\} \cup \mathbf{0}$ is taken to be the budget correspondence (without c).

Lemma 7. $W_{\mathcal{F}}^H(a_{\mathcal{F}}, z; V)$ exists, is continuous in its first argument and is increasing in its first argument.

Proof. Immediate from the Theorem of the Maximum and the monotonicity of $\omega_{\mathcal{F}}^H$. □ □

Lemma 8. A bad credit history lowers lifetime utility $W_{\mathcal{F}}^{BC} \leq W_{\mathcal{F}}^{NB}$

Proof. Since $V \in \mathcal{V}$, $\alpha V^{BC} + (1 - \alpha)V^G \leq V^G$. From the definition of $c_H(a, z, x')$, $\max \{c_B(a, z, x'), 0\} \leq \max \{c_G(a, z, x'), 0\}$. Thus, from the strict monotonicity of $u(\cdot; p_s)$, $\omega_{\mathcal{F}}^B(a, z, x'; V) \leq \omega_{\mathcal{F}}^{BC}(a, z, x'; V)$. Hence, since $\bar{X}_{\mathcal{F}}^{BC} \subset \bar{X}_{\mathcal{F}}^{NB}$, $W_{\mathcal{F}}^{BC} \leq W_{\mathcal{F}}^{NB}$.

□

□

I define the operator vector valued operator $TV(b, h, m, y, \delta) = \{TV^H(b, h, m, \delta, y, z) : H \in \mathcal{H}\}$ by:

$$\begin{aligned} TV^G(b, h, m, \delta, y, z) &= \max_{\mathcal{F} \in \{0,1\}} \mathbb{E}_{\mathcal{J}} \max \{W_{\mathcal{F}}^B(\eta_{\mathcal{F}}, y, z; V), W_{\mathcal{F}}^{NB}(a_{\mathcal{F}}, z; V)\} \\ \eta_{\mathcal{F}} &= (1 - \mathcal{F})[(1 - \delta)h - m] \\ a_{\mathcal{F}} &= y + (1 - \mathcal{F})[(1 - \delta)h - m + b] + \mathcal{F}b_{\mathcal{F}} \\ TV^{BC}(b, h, m, \delta, y, z) &= \max_{\mathcal{F} \in \{0,1\}} \mathbb{E}_{\mathcal{J}} \{W_{\mathcal{F}}^{BC}(a_{\mathcal{F}}, z; V)\} \\ a_{\mathcal{F}} &= y + (1 - \mathcal{F})[(1 - \delta)h - m + b] + \mathcal{F}b_{\mathcal{F}} \end{aligned}$$

Lemma 9. T is a contraction mapping with modulus β .

Proof. In order to prove that T is a contract mapping I appeal to Blackwell's sufficient conditions:

1. Self-map: $TV \subset \mathcal{V}$. In order to show this first note that $W_{\mathcal{F}}^H$ are all continuous in their first argument, the convex combination of two continuous functions is continuous and the maximum of two continuous functions is continuous. The boundedness property (A.7) is satisfied by the boundedness of $W_{\mathcal{F}}^H$. That TV is increasing in b', h' and y' comes from the fact that all the $W_{\mathcal{F}}^H$ are increasing in their first argument and that $W_{\mathcal{F}}^B$ is strictly increasing in y . By the same argument, TV is decreasing in both δ' and m' . The monotonicity property (A.8) is satisfied by virtue of $W_{\mathcal{F}}^{NB} \geq W_{\mathcal{F}}^{BC}$ since the payoff in V^B can always be achieved in V^G .

2. Monotonicity: $\hat{V} \geq V \rightarrow T\hat{V} \geq TV$. For each $H \in \mathcal{H}$, $W_{\mathcal{F}}^H(\cdot; V)$ is increasing in V . Therefore, because the convex combination of two increasing functions is increasing and the maximum of two increasing functions is increasing $T\hat{V} \geq TV$.
3. Discounting: $T(V + k) = TV + \beta k$. Notice that for each $H \in \mathcal{H}$ $W_{\mathcal{F}}^H(\cdot; V)$, $W_{\mathcal{F}}^H(\cdot; V+k) = W_{\mathcal{F}}^H(\cdot; V) + \beta k$, thus for each $H \in \mathcal{H}$, $T(V^H + k) = TV^H + \beta k$. \square

\square

Since I have extended the domain of $W_{\mathcal{F}}^{BC}$ and $W_{\mathcal{F}}^{NB}$, I must now verify that an agent will never make a choice such that he will have no feasible choices (i.e. for $W_{\mathcal{F}}^{NB}$ he would choose to go bankrupt rather than repay, and for $W_{\mathcal{F}}^{BC}$ that he would never pick a portfolio choice that could result in a negative asset position at the beginning of the next period). First I prove that an agent will choose to go bankrupt rather than not go bankrupt and have zero consumption.

Lemma 10. *Under Assumption 1, an agent with a good credit history will always choose to go bankrupt rather than not go bankrupt and have zero consumption. Furthermore, an agent that chooses not to go bankrupt always consumes a strictly positive amount.*

Proof. The utility from choosing not to go bankrupt when the budget set is empty is bounded by $u(0; p_s) + \beta\bar{u}/(1 - \beta)$. By choosing bankruptcy the agent can guarantee lifetime utility of at least $u(y_{\min}/\lambda)/(1 - \beta)$, which by Assumption 1 is strictly greater. To ensure that conditional on not going bankrupt agents consume a strictly positive amount, note that from the continuity of $u(\cdot; p_s)$, there exists some $\tilde{c} > 0$ such that $u(\tilde{c}; p_s) + \beta\bar{u}/(1 - \beta) < u(y_{\min}/\lambda)/(1 - \beta)$, which implies that conditional on not going bankrupt an agent will consume at least \tilde{c} . \square \square

When an agent is in the bankruptcy or bad credit state, he does not have the option to declare bankruptcy, only foreclosure. Therefore, I must show that an agent

will never make a portfolio or foreclosure choice that would result in zero consumption in the subsequent period.

First consider the case where there is no recourse after foreclosure, i.e. $\psi = 0$. From Lemma 5, when $\psi = 0$ an agent will choose foreclosure whenever $(1 - \delta')h' < m'$. Hence, an agent will always begin the subsequent period with a positive a since y_{\min} is bounded away from zero.

When there is a positive probability of recourse, i.e. $\psi > 0$, even if an agent chooses foreclosure, he may still be responsible for the entire balance of the mortgage. Further, since the support of $F(\delta')$ includes 1, there is a positive probability that the depreciated value of the house $(1 - \delta')h'$ is arbitrarily close to zero. Thus, I need to rule out any *portfolio choices* (b', h', m') , that could result in cash-at-hand positions for which the budget set is empty in the subsequent period. However, since my choice of $u(0; p_s)$ is unrestricted, I can set it arbitrarily low, such that a household would always find it optimal to never choose a portfolio that resulted in 0 consumption with positive probability.

Proof of Proposition 1. The existence and uniqueness of the value functions is an immediate consequence of Lemma 9 and the Contraction Mapping Theorem. The monotonicity properties of the value functions and the effect of a bad credit score follow immediately from Lemmas 7 & 8. □ □

The proof of Proposition 2 is an extension of Chatterjee et al. 2007. I first prove two lemmas.

Lemma 11. *Let $\hat{y} \in Y \setminus \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$, $y > \hat{y}$. If $y \in \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$, then the optimal consumption with \hat{y} , $c^*(\eta + b_F + \hat{y}) > \hat{y}$.*

Proof. Since $\hat{y} \in Y \setminus \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$, the agent strictly prefers not declaring bankruptcy, i.e.:

$$u(c^*(\eta + b_F + \hat{y}); p_s) + \beta \text{EV}^G(X'^*) > u(\hat{y}; p_s) + \beta \text{EV}^{BC}(X') \quad (\text{A.12})$$

Let $\epsilon = y - \hat{y}$. The choices: $\check{c} = c^*(\eta + b_F + \hat{y}) + \epsilon, \check{b}' = b^*, \check{h}' = h^*, \check{m}' = m^*$ were feasible choices with resources $y + \eta + b_F$, but were not chosen since $y \in \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ (where the starred variables are the optimal choices under endowment \hat{y}), therefore:

$$u(\check{c}; p_s) + \beta \mathbb{E}V^G(X'^*) \leq u(y; p_s) + \beta \mathbb{E}V^{BC}(X') \quad (\text{A.13})$$

Subtracting equations (A.12) and (A.13) I obtain:

$$u(\hat{y} + \epsilon; p_s) - u(\hat{y}; p_s) > u(c^*(\eta + b_F + \hat{y}) + \epsilon; p_s) - u(c^*(\eta + b_F + \hat{y}); p_s) \quad (\text{A.14})$$

which from the strict concavity of $u(\cdot; p_s)$ implies that $c^*(\eta + b_F + \hat{y}) > \hat{y}$. The portfolio choice is unchanged for the household conditional on bankruptcy, thus X' is the same across (A.13) and (A.14). □ □

Lemma 12. *Let $\hat{y} \in Y \setminus \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$, $y < \hat{y}$. If $y \in \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$, then the optimal consumption with \hat{y} , $c^*(\eta + b_F + \hat{y}) < \hat{y}$.*

Proof. Omitted. The proof is essentially identical to the previous. □ □

Proof of Proposition 2.

(a) If $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ is non-empty let $\underline{y}^B = \inf \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ and $\bar{y}^B = \sup \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$.

These both exist from the Completeness Property of \mathbb{R} since $\bar{\mathcal{B}}^*(b_F, \eta, \xi, z) \subseteq Y \subset \mathbb{R}$. If they're equal, I'm done, therefore suppose $\underline{y}^B < \bar{y}^B$. Take $\hat{y} \in (\underline{y}^B, \bar{y}^B)$. Suppose by way of contradiction that $\hat{y} \notin \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$. Now, there exists a $y \in \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ such that $y > \hat{y}$ (if not $\bar{y}^B = \hat{y}$, contradicting that $\hat{y} \in (\underline{y}^B, \bar{y}^B)$). Thus, from Lemma 1, $c^*(\eta + b_F + \hat{y}) > \hat{y}$. By the same argument there exists a $y \in \bar{\mathcal{B}}^*(b_F, \eta, \xi, z)$ such that $y < \hat{y}$, but from Lemma 2 this implies $c^*(\eta + b_F + \hat{y}) < \hat{y}$, a contradiction. The closedness comes from the continuity of $W_{\mathcal{F}}^{NB}$ and $u(\cdot; p_s)$. □

(b) Suppose $y \in \overline{\mathcal{B}}^*(\hat{b}_F, \eta, \xi, z)$. Take $b_F < \hat{b}_F$. Since $W_{\mathcal{F}}^{NB}$ is increasing in the first argument, $W_{\mathcal{F}}^{NB}(b_F + \eta + y, z) \leq W_{\mathcal{F}}^{NB}(\hat{b}_F + \eta + y, z)$. However, since $y \in \overline{\mathcal{B}}^*(\hat{b}_F, \eta, \xi, z)$ this implies that $W_{\mathcal{F}}^{NB}(\hat{b}_F + \eta + y, z) \leq W_{\mathcal{F}}^B(\eta - \xi, y, z) \Rightarrow W_{\mathcal{F}}^{NB}(b_F + \eta + y, z) \leq W_{\mathcal{F}}^B(\eta - \xi, y, z) \Rightarrow y \in \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$, which implies $\overline{\mathcal{B}}^*(\hat{b}_F, \eta, \xi, z) \subseteq \overline{\mathcal{B}}^*(b_F, \eta, \xi, z)$. \square

\square

Lemma 13. *Conditional on the foreclosure choice and deficiency judgment realization, the bankruptcy decision B^* depends only on unsecured debt b_F , positive home equity η , non-exempt equity ξ , endowment y , and persistent state z .*

Proof. Immediate from the definition of the foreclosure value functions and b_F . \square

\square

A.4 Proofs Related to the Intermediaries Problem

Proof of Proposition 7. The proof is a direct consequence of Proposition 5. The characterization is obtained by dividing 1.2 by m' . \square \square

Proof of Proposition 8. The proof is a direct consequence of Propositions 2-3 and 5.

\square

\square

A.5 Computational Details

In order to calibrate the model I employ a nested fixed point algorithm to match relevant moments from the model with the data. I discretize the state space and the choice parameters.

The outline of the algorithm is as follows:

1. **Loop 1** - Guess a vector of the structural parameters Θ^0
 - (a) **Loop 2** - Make an initial guess for the price of housing services p_s^0
 - i. **Loop 3** - Make an initial guess for the price schedules q_b^0 and q_m^0
 - ii. Compute the policy choice $(\check{b}', \check{h}', \check{m}')$ that yields the maximal resources in the current period, and denote it by \check{a} .
 - A. **Loop 4** - Make an initial guess for W^0 on the domain $[\check{a} - \underline{c}, \bar{a}]$, and define v^0 for $a < \check{a} - \underline{c}$ as $u(\underline{c}) + \beta\bar{u}/(1 - \beta)$, where \underline{c} is a minimal consumption level.
 - B. Compute $\mathbb{E}_{\delta', y', z'} V^H(b', h', m', y', \delta', z')$ for each choice of b', h', m' , and the implied default decisions B^* and f^* .
 - C. Compute the new value functions, W^1 , by maximization given $\mathbb{E}_{\delta', y', z'} V(b', h', m', y', \delta', y')$
 - D. Compute the foreclosure, bankruptcy and portfolio policy functions
 - E. If $\|W^1 - W^0\| < \epsilon_W$ end **Loop 4**, otherwise set $W^0 = W^1$ and go to B.
 - iii. Given the default decisions $B^*(b', h', m', y', \delta', z')$ and $f^*(b', h', m', y', \delta', z')$, use Equations 1.4 & 1.2 to compute the new implied price schedules q_b^0 and q_m^0 .
 - iv. If $\|q^1 - q^0\| < \epsilon_q$ end **Loop 3**, otherwise set $q^0 = \nu q^0 + (1 - \nu)q^1$ and go to (ii).

- (b) Compute the invariant distribution μ over $A \times Z \times Y\mathcal{S}$.
 - (c) Compute the housing services supplied S^S and demanded S^D from the policy functions and invariant distribution.
 - (d) If $\|S^D - S^S\| < \epsilon_S$ end **Loop 2**.
 - (e) If $S^D < S^S$, pick $p_s^1 < p_s^0$ and repeat **Loop 3**
 - (f) Repeat until $S^D > S^S$, then use a bisection until $\|S^D - S^S\| < \epsilon_S$ end **Loop 2**.
2. Compute model moments $\mathcal{M}^{\text{MODEL}}$.
 3. If $\sum w_i (\mathcal{M}_i^{\text{MODEL}} - \mathcal{M}_i^{\text{DATA}})^2 < \epsilon_{\mathcal{M}}$ end **Loop 1**. Otherwise, return to 1.

A.6 Foreclosure and Bankruptcy Information by State

Table A.5: Foreclosure Deficiency and Homestead Bankruptcy Exemption by State

| State | Foreclosure Deficiency | Max Homestead Exemption | Federal Allowed |
|-------------|---------------------------|----------------------------|--------------------|
| Alabama | Yes | 5,000* | No |
| Alaska | No | 54,000 | No |
| Arizona | No | 150,000 | No |
| Arkansas | Yes | 17,425* | Yes |
| California | No | 50,000 [†] | No |
| Colorado | Yes | 45,000 | No |
| Connecticut | Yes | 75,000 | Yes |
| Delaware | Yes | 50,000 | No |
| D.C. | Yes | 17,425* | Yes |
| Florida | Yes | ∞ | No |
| Georgia | Yes | 10,000* | No |
| Hawaii | Yes | 17,425* | Yes |
| Idaho | Yes | 104,471 | No |
| Illinois | Yes | 7,500* | No |
| Indiana | Yes | 7,500 | No |
| Iowa | No | ∞ | No |
| Kansas | Yes | ∞ | No |
| Kentucky | Yes | 5,000 | No |
| Louisiana | Yes | 25,000 | No |
| Maine | Yes | 35,000 | No |

Continued on Next Page. . .

Table A.5 – Continued

| State | Foreclosure Deficiency | Max Homestead Exemption | Federal Allowed |
|----------------|-----------------------------------|------------------------------------|----------------------------|
| Maryland | Yes | 0 | No |
| Massachusetts | Yes | 100,000 | Yes |
| Michigan | Yes | 17,425* | Yes |
| Minnesota | No | 200,000 | Yes |
| Mississippi | Yes | 75,000 | No |
| Missouri | Yes | 15,000 | No |
| Montana | No | 100,000 | No |
| Nebraska | Yes | 12,500 | No |
| Nevada | Yes | 550,000 | No |
| New Hampshire | Yes | 100,000 | No |
| New Jersey | Yes | 17,425* | Yes |
| New Mexico | Yes | 30,000* | Yes |
| New York | Yes | 50,000 | No |
| North Carolina | No | 18,500 | No |
| North Dakota | No | 80,000 | No |
| Ohio | Yes | 5,000 | No |
| Oklahoma | Yes | ∞ | No |
| Oregon | Yes | 25,000 [‡] | No |
| Pennsylvania | Yes | 17,425* | Yes |
| Rhode Island | Yes | 200,000 | Yes |
| South Carolina | Yes | 17,425* | Yes |
| South Dakota | Yes | 30,000 | No |

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Table A.5 – Continued

| State | Foreclosure Deficiency | Max Homestead Exemption | Federal Allowed |
|---------------|-----------------------------------|------------------------------------|----------------------------|
| Tennessee | Yes | 5,000 [†] | No |
| Texas | Yes | ∞ | Yes |
| Utah | Yes | 20,000* | No |
| Vermont | Yes | 75,000 | Yes |
| Virginia | Yes | 5,000* | No |
| Washington | No | 40,000 | Yes |
| West Virginia | Yes | 25,000 | No |
| Wisconsin | Yes | 40,000* | Yes |
| Wyoming | Yes | 10,000* | No |

*Can be doubled for couples

[†]Can be multiplied by 1.5 for couples

[‡]33,000 for couples

Appendix B

Appendices to Chapter 2

B.1 Theoretical Appendix

B.1.1 Characterization of Equilibrium Mortgage Interest Rates

In this section we will construct a proof of Proposition 9 in the main text.

Proof. In equilibrium equation (2.6) becomes (by dividing both sides by mortgage size $m' > 0$):

$$\begin{aligned} P_m(g', m') &= \frac{1}{m'} \left[\frac{m' F(\delta^*(m', g')) + \gamma g' \int_{\delta^*(m', g')}^{\infty} (1 - \delta') dF(\delta')}{(1 + r_b)(1 + r_w + \theta - \phi)} \right] \\ &= \left(\frac{1}{(1 + r_b)(1 + r_w + \theta - \phi)} \right) \left\{ F(\delta^*(\kappa')) + \frac{\gamma}{\kappa'} \int_{\delta^*(\kappa')}^{\infty} (1 - \delta') dF(\delta') \right\} \\ &= P_m(\kappa') \end{aligned}$$

which proves the mortgages are priced exclusively on leverage. The second point follows from the definition of the CDF of δ' and the optimal default choice $\delta^*(\kappa')$. To prove the final point, note that for all $\delta' > \delta^*(\kappa')$ we have $\frac{\gamma}{\kappa'}(1 - \delta') < 1$ and thus the term in $\{\}$ -brackets is strictly less than 1. \square

B.1.2 Endogenous Upper Bound on Leverage

In this section we will construct a proof of Proposition 10 in the main text.

Proof. In order to prove the statement, we will first show that there exists a leverage κ^* that maximizes the contemporaneous resources available to the household. Then we will argue that in equilibrium households will only chose values of leverage less than κ^* and that the value κ^* is strictly less than the leverage which leads to certain default.

First, consider the period budget constraint:

$$c + bP_b + hP_l + g - mP_m(g, m) = a + gP_l \quad (\text{B.1})$$

This equation can be rewritten as:

$$g[1 - P_l - \kappa P_m(g, m)] = a - c - hP_l - bP_b \quad (\text{B.2})$$

For a fixed amount of housing $g > 0$, we can calculate the value of mortgages m that will generate the maximal amount of resources available today:

$$m^* \in \arg \min_{0 \leq m \leq g(1-\underline{\delta})} [g[1 - P_l - \kappa P_m(g, m)]] \quad (\text{B.3})$$

$$\Leftrightarrow m^* \in \arg \min_{0 \leq m \leq g(1-\underline{\delta})} -mP_m(g, m) \quad (\text{B.4})$$

Note that $g(1 - \underline{\delta})$, the upper bound on m , corresponds to a leverage that will result in default for sure in the second period. Borrowing above this level does not increase resources available today since an extra dollar borrowed beyond this limit will be defaulted on for sure, and thus no additional resources will be advanced today by the financial intermediary against the promise to pay nothing back tomorrow. Furthermore, this upper bound compactifies the choice space and guarantees that the pricing function is differentiable on the interior of that space. The first order conditions for this program is:

$$-P_m(\kappa) - m \frac{\partial P_m(\kappa)}{\partial \kappa} \frac{\partial \kappa}{\partial m} + \lambda = 0 \quad (\text{B.5})$$

where $\lambda \geq 0$ is the Lagrange multiplier on the upper constraint (the lower bound trivially is not binding as long as $\mathbb{E}[\delta] < 1$ and thus $P_m > 0$). The second order condition (which is well-defined due to the differentiability of $f(\delta)$) is:

$$-\frac{1}{g} \left[2 \frac{\partial P_m(\kappa)}{\partial \kappa} + \kappa \frac{\partial^2 P_m(\kappa)}{\partial \kappa^2} \right] \quad (\text{B.6})$$

In order to simplify these conditions, consider the mortgage pricing function $P_m(\frac{m}{g})$ given by:

$$P_m(\kappa) = \frac{1}{(1+r_b)(1+r_w+\theta-\phi)} \left\{ F(1-\kappa) + \frac{\gamma}{\kappa} \int_{1-\kappa}^{\bar{\delta}} (1-\delta) dF(\delta) \right\} \quad (\text{B.7})$$

As long as δ has a continuous pdf (guaranteed because $F \in \mathcal{C}^2$), we can apply Leibnitz's rule to obtain:

$$\begin{aligned} \frac{\partial P_m(\kappa)}{\partial \kappa} &= \frac{1}{(1+r_b)(1+r_w+\theta-\phi)} \times \\ &\quad \left\{ -f(1-\kappa) - \frac{\gamma}{\kappa^2} \int_{1-\kappa}^{\bar{\delta}} (1-\delta) dF(\delta) + \frac{\gamma}{\kappa} (-1)(-1)(1-(1-\kappa)) f(1-\kappa) \right\} \\ &= \frac{1}{(1+r_b)(1+r_w+\theta-\phi)} \left\{ (\gamma-1)f(1-\kappa) - \frac{\gamma}{\kappa^2} \int_{1-\kappa}^{\bar{\delta}} (1-\delta) dF(\delta) \right\} \end{aligned}$$

We can simplify the first order conditions by substituting in our prior calculations

to obtain:

$$\begin{aligned}
\lambda &= P_m(\kappa^*) + \frac{\kappa^*}{(1+r_b)(1+r_w+\theta-\phi)} \left\{ (\gamma-1)f(1-\kappa^*) - \frac{\gamma}{\kappa^{*2}} \int_{1-\kappa^*}^{\bar{\delta}} (1-\delta)dF(\delta) \right\} \\
&= F(1-\kappa^*) + \frac{\gamma}{\kappa^*} \int_{1-\kappa^*}^{\bar{\delta}} (1-\delta)dF(\delta) + (\gamma-1)\kappa^*f(1-\kappa^*) - \frac{\gamma}{\kappa^*} \int_{1-\kappa^*}^{\bar{\delta}} (1-\delta)dF(\delta) \\
&= F(1-\kappa^*) + (\gamma-1)\kappa^*f(1-\kappa^*)
\end{aligned}$$

We want to show that κ^* is an interior choice and thus that $\lambda = 0$. Consider otherwise, that is $\kappa^* = 1 - \underline{\delta}$ and $\lambda \geq 0$:

$$F(1-\kappa^*) + (\gamma-1)\kappa^*f(1-\kappa^*) - \lambda = \underbrace{F(\underline{\delta})}_{=0} + \underbrace{(\gamma-1)(1-\underline{\delta})f(\underline{\delta})}_{\leq 0} - \underbrace{\lambda}_{\geq 0}$$

Since $f(\underline{\delta}) > 0$ (from the definition of the support of F), if foreclosure is inefficient $\gamma < 1$, then the above equation will be strictly less than 0, implying that $\kappa^* = 1 - \underline{\delta}$ cannot satisfy the first order conditions, thus guaranteeing an interior optimal choice. Note that when foreclosure is efficient ($\gamma = 1$) choosing $\kappa^* = 1 - \underline{\delta}$ maximizes the resources received today (by the same argument in the text, since this is the point at which the household defaults for sure). The multiplier λ is still zero in this case, since $\kappa^* = 1 - \underline{\delta}$ is the global maximizer of the mortgage receipts.

Thus, we can characterize interior value of leverage which satisfies the first order conditions by the implicit equation:

$$\kappa^* = \frac{F(1-\kappa^*)}{(1-\gamma)f(1-\kappa^*)} \tag{B.8}$$

A solution to this implicit equation exists and is unique on $(0, \bar{\kappa})$. To see this rewrite

the implicit equation as:

$$\frac{1}{1-x} = (1-\gamma) \frac{f(x)}{F(x)} \quad (\text{B.9})$$

for $x \in (\underline{\delta}, 1)$. The right hand side is strictly increasing in x , and takes values from $[1/(1-\underline{\delta}), \infty)$. The left hand side is decreasing and also unbounded above (both coming from log-concavity of F). Thus, from a standard fixed-point theorem in \mathbb{R} , there exists an x in that interval which satisfies the equation and it is unique.

Now that we have found an interior solution to the first order conditions, we must check the second order condition, which simplifies to:

$$-\frac{1}{g(1+r_b)(1+r_w+\theta-\phi)} \{(\gamma-2)f(1-\kappa) + (1-\gamma)\kappa f'(1-\kappa)\} \quad (\text{B.10})$$

If the second order conditions is strictly positive at κ^* , the first order condition will be necessary and sufficient for a minimum, and thus will characterize the leverage which yields the maximal amount of contemporaneous resources. Log-concavity of $F(\delta)$ is sufficient for the SOC to be strictly positive. To see this, first note that log-concavity implies $f'^2 < 0$. Using this fact we can show:

$$\begin{aligned} f' &< \frac{f}{F} f \\ \Rightarrow f'(1-\kappa^*) &< \frac{f(1-\kappa^*)}{F(1-\kappa^*)} f(1-\kappa^*) \\ \Rightarrow (1-\gamma)\kappa^* f'(1-\kappa^*) &< f(1-\kappa^*) \end{aligned}$$

where the last inequality comes from equation (B.8). Now, this last inequality, along with the fact that $\gamma < 1$ and $f \geq 0$ implies that the second order condition at κ^* will be strictly positive. Thus, we have shown that our interior κ^* is indeed a maximum.

Now that we have shown the existence of κ^* to prove the first statement, suppose by way of contradiction that a household has chosen an affordable and convec-

tured optimal allocation $\{c, h, b, g, m\}$ such that $\kappa > \kappa^*$. Consider another allocation $\{c', h', b', g', m'\}$, where $h' = h$, $b' = b$, $g' = g$ and m' is such that $\frac{m'}{g'} = \kappa^*$ and $c' = c + m'P_m(\kappa^*) - mP_m(\kappa)$. Note that this new allocation is affordable, and that $m'P_m(\kappa^*) > mP_m(\kappa)$ implies that $c' > c$ (from above). Furthermore cash-at-hand in the next period will be weakly greater in all possible states under the primed allocation than the original (since $b = b'$, $g = g'$ and $m' < m$, $b + \max((1 - \delta)g - m, 0) \leq b' + \max((1 - \delta)g' - m', 0)$). Thus, from the strict monotonicity of the utility function, the primed allocation yields strictly higher period utility and weakly higher continuation value, and thus is strictly preferred to the original hypothesized optimum. \square

B.1.3 Existence, Uniqueness and Characterization of the Value Function

Definitions

First we need some definitions. Let the $M \subset \mathbb{R}_+$ mortgage choice set, $B \subset \mathbb{R}_+$ be the bond choice set, $G \subset \mathbb{R}_+$ be the housing choice set, $C \subset \mathbb{R}_+$ the consumption expenditure choice set. The state variable, cash-at-hand lies in $a \in A \subset \mathbb{R}_+$. Income resides in $y \in Y$, where Y is a finite set. We define the budget correspondence $\Gamma : A \rightarrow C \times B \times G \times M$ as:

$$\Gamma(a) = \{(c, b, g, m) \in C \times B \times G \times M : c + bP_b + g[1 - P_l] - mP_m(g, m) \leq a, m \leq g\kappa^*\} \quad (\text{B.11})$$

where κ^* is the endogenous maximal leverage characterized above.

We can write down our Bellman equation as:*

$$v(a, y) = \max_{x \in \Gamma(a)} u(c; P_l) + \beta \sum_{y' \in Y} \pi(y'|y) \int v(\phi(b', g', m', \delta', y'), y') dF(\delta') \quad (\text{B.12})$$

*We will show in the next section that Γ is compact valued, so that the maximum of the program will be obtained, justifying our use of the max-operator as opposed to the sup-operator.

where $x = (c, b', g', m')$ and $a(b', g', m', \delta', y') = b' + \max((1 - \delta')g' - m', 0) + (1 - \tau)y'$ is cash at hand tomorrow. We can now define our operator, $T : A \times Y \rightarrow A \times Y$ as:

$$Tv(a, y) = \max_{x \in \Gamma(a)} u(c; P_l) + \beta \sum_{y' \in Y} \pi(y'|y) \int v(\phi(b', g', m', \delta', y'), y') dF(\delta') \quad (\text{B.13})$$

With our definitions in hand, we proceed to discuss the properties of the budget correspondence Γ and the operator T .

Properties of Γ and T

We begin by establishing properties of Γ . First, it is non-empty (since $0 \in \Gamma(a)$) and monotone. Given prices that satisfy[†] $1 - P_l - \kappa P_m(\kappa) > 0 \forall \kappa \in [0, \kappa^*]$, we can show that Γ is also continuous and compact valued. To prove this we want to apply Theorems 3.4 and 3.5 from Stokey and Lucas (1989). We will show that the conditions for these two theorems are met by proving two lemmas.

Lemma 14. *The graph of Γ , $G = \{(a, c, b, g, m) \in A \times C \times B \times G \times M : (c, b, g, m) \in \Gamma(a)\}$ is closed, and for any bounded set $\hat{A} \subset A$, $\Gamma(\hat{A})$ is bounded.*

Proof. To show that the graph is closed, take a sequence $\{(a_n, c_n, b_n, g_n, m_n)\}_{n=0}^{\infty}$ such that $(c_n, b_n, g_n, m_n) \in \Gamma(a_n)$ for all n that converges to (a, c, b, g, m) . Suppose that $(c, b, g, m) \notin \Gamma(a^*)$. This implies either $c + bP_b + g[1 - P_l] - mP_m(g, m) > a$ or $m > g\kappa^*$. However, since all functions involved are continuous, there exists some $N > 0$ such that ones of the inequalities is also violated for $(a_N, c_N, b_N, g_N, m_N)$, which implies that $(c_N, b_N, g_N, m_N) \notin \Gamma(a_N)$, a contradiction.

To show that $\Gamma(\hat{A})$ is bounded, let $\hat{a} = \sup \hat{A}$. Since Γ is monotone, if $\Gamma(\hat{a})$ is bounded, $\Gamma(\hat{A})$ will be bounded. Now, observe that $0 \leq c \leq a$, $0 \leq b \leq a/P_b$. To

[†]This is a no-arbitrage condition on the relation between the interest rate and rental rate, and thus will be true in any equilibrium. If this condition is violated the household can buy one unit of housing with leverage κ at a positive cash flow today (and due to the default option the cash flow tomorrow from this transaction is nonnegative, and strictly positive as long as the household does not default with probability 1).

prove that g is bounded above is equivalent to showing $\forall a \in \mathbb{R}_+ \exists \bar{g} \geq 0$ s.t. $\forall g > \bar{g}, (c, b, g, m) \notin \Gamma(a)$. We will construct such a candidate \bar{g} . We propose $\bar{g}(a)$ such that $\bar{g}(a) = a/[1 - P_l - \kappa^* P_m(\kappa^*)]$, where κ^* is the endogenous leverage limit. Now, suppose by way of contradiction that there was an allocation $(c, b, g, m) \in \Gamma(a)$ with $g > \bar{g}(a)$. This implies that:

$$c + bP_b + g[1 - P_l - \kappa P_m(g, m)] \leq a \quad (\text{B.14})$$

$$\Rightarrow c + bP_b + g[1 - P_l - \kappa^* P_m(g, m^*)] \leq a \quad (\text{B.15})$$

$$\Rightarrow g \leq \bar{g} - \frac{c + bP_b}{1 - P_l - \kappa^* P_m(g, m^*)} \quad (\text{B.16})$$

$$\Rightarrow g \leq \bar{g}, \quad (\text{B.17})$$

a contradiction. Thus, for any a , $\Gamma(a)$ is bounded, thus $\Gamma(\hat{a})$ is bounded and therefore $\Gamma(\hat{A})$ is bounded. \square

Lemma 15. *The graph of Γ, G , is convex, and for any bounded set $\hat{A} \subset A$, there exists a bounded set $\hat{X} \subset C \times B \times G \times M$ such that $\Gamma(a) \cap \hat{X} \neq \emptyset$ for all $a \in \hat{A}$.*

Proof. The second part of the lemma is trivially satisfied by letting $\hat{X} = \{(0, 0, 0, 0)\}$.

In order to show convexity we need to establish that $-mP_m(m, g)$ is convex, which will make $c + bP_b + g[1 - P_l] - mP_m(g, m)$ convex in c, b, g, m , guaranteeing that the inequality constraint will hold for convex combinations. Consider the Hessian for $-mP_m(m, g)$:

$$\mathcal{D}^2(-mP_m(m, g)) = \begin{bmatrix} -\frac{1}{g}(2P'_m + \kappa P''_m) & \frac{\kappa}{g}(2P'_m + \kappa P''_m) \\ \frac{\kappa}{g}(2P'_m + \kappa P''_m) & -\frac{\kappa^2}{g}(2P'_m + \kappa P''_m) \end{bmatrix} \quad (\text{B.18})$$

Since the Hessian is singular, in order to show that the matrix is positive semi-definite, and hence that $-mP_m(m, g)$ is convex, we only need to show that the two diagonal

elements are positive. Thus, we need to show that $2P'_m + \kappa P''_m \leq 0$. From before we know that:

$$2P'_m + \kappa P''_m = \frac{1}{(1+r_b)(1+r_w+\theta-\phi)} \{(\gamma-2)f(1-\kappa) + (1-\gamma)\kappa f'(1-\kappa)\} \quad (\text{B.19})$$

Focusing on:

$$(\gamma-2)f(1-\kappa) + (1-\gamma)\kappa f'(1-\kappa) \quad (\text{B.20})$$

We again employ the maintained assumption of log-concavity of $F(\delta)$ to show:

$$\frac{f(1-\kappa^*)}{F(1-\kappa^*)} \geq \frac{f(1-\kappa)}{F(1-\kappa)} \quad \forall \kappa \in [0, \kappa^*] \quad (\text{B.21})$$

$$\Rightarrow f'(1-\kappa) < \frac{f(1-\kappa^*)}{F(1-\kappa^*)} f(1-\kappa) \quad \forall \kappa \in [0, \kappa^*] \quad (\text{B.22})$$

$$\Rightarrow f'(1-\kappa) < \frac{1}{(1-\gamma)\kappa^*} f(1-\kappa) \quad \forall \kappa \in [0, \kappa^*] \quad (\text{B.23})$$

$$\Rightarrow f'(1-\kappa) < \frac{1}{(1-\gamma)\kappa} f(1-\kappa) \quad \forall \kappa \in [0, \kappa^*] \quad \text{since } f > 0 \quad (\text{B.24})$$

$$(1-\gamma)\kappa f'(1-\kappa) < f(1-\kappa) \quad \forall \kappa \in [0, \kappa^*] \quad (\text{B.25})$$

$$(\text{B.26})$$

which guarantees that (B.19) is negative. This implies that the diagonal elements are non-negative, combined with the fact that the determinant is zero, yields that the Hessian is positive semi-definite on $\kappa \in [0, \kappa^*]$ (this follows from Debreu 1952). Now, recall our definition of $\bar{g}(a) = a/[1 - P_l - \kappa^* P_m(\kappa^*)]$ which is the maximum size house that could be purchased by a household with cash-at-hand a . Take any $g \in [0, \bar{g}(a)]$, then for any $m \in [0, g\kappa^*]$, the function $-mP_m(m, g)$ will be convex, since $\kappa \in [0, \kappa^*]$. Thus, we have established the convexity of G . \square

These two lemmas, combined with theorems 3.4 and 3.5 in Stokey and Lucas (1989), guarantee that Γ is compact valued, u.h.c. and l.h.c. Since we are analyzing

the simplified recursive household problem (with the solution of the static expenditure allocation problem substituted in), we need to show some properties of the indirect utility function over consumption expenditures, $u(c, P_l)$.

Lemma 16. $u(c; P_l)$ is continuous, strictly concave and strictly increasing in c , for all $P_l > 0$.

Proof. Take $c_1, c_2 > 0$ and $c_\theta = \theta c_1 + (1 - \theta)c_2$ for $\theta \in (0, 1)$. Let $u(c_i; P_l) \equiv U(\tilde{c}_i, h_i)$ where \tilde{c}_i and h_i are the maximizers of the static problem. From the strict concavity of U , we know that

$$\begin{aligned} \theta U(\tilde{c}_1, h_1) + (1 - \theta)U(\tilde{c}_2, h_2) &< U(\theta\tilde{c}_1 + (1 - \theta)\tilde{c}_2, \theta h_1 + (1 - \theta)h_2) \\ &\leq U(\tilde{c}_\theta, h_\theta) \end{aligned}$$

where the first inequality comes from the strict concavity of U . The second inequality follows from the fact that $\theta\tilde{c}_1 + (1 - \theta)\tilde{c}_2 + P_l(\theta h_1 + (1 - \theta)h_2) = \theta c_1 + (1 - \theta)c_2 = c_\theta$, thus it is a feasible choice for the maximization for $u(c_\theta; P_l)$, and by definition of a maximum. Continuity and strict monotonicity follow from the properties of U . \square

Since we have assumed that the utility function is unbounded from below, we use a similar argument to Chatterjee et al. (2007) to establish the existence and uniqueness of the value function. Let \mathcal{V} be the set of all continuous functions $v : A \times Y \rightarrow \mathbb{R}$, such that:

$$v(a, y) \in \left[\frac{u((1 - \tau)y_{\min}; P_l)}{1 - \beta}, \frac{\bar{u}}{1 - \beta} \right] \quad (\text{B.27})$$

$$u((1 - \tau)y_{\min}; P_l) + \beta \sum_{y' \in Y} \pi(y'|y)v((1 - \tau)y', y') > u(0; P_l) + \frac{\beta \bar{u}}{1 - \beta} \quad (\text{B.28})$$

Lemma 17. \mathcal{V} is non-empty and $(\mathcal{V}, \|\cdot\|)$ is a complete metric space, where $\|\cdot\|$ is the sup-norm.

Proof. Take any constant function v_0 satisfying (B.27). v_0 is continuous and satisfies (B.28) by the assumption that u is unbounded below. In order to show that $(\mathcal{V}, \|\cdot\|)$ is complete, first note that $(\mathcal{C}, \|\cdot\|)$ is complete, where \mathcal{C} is the set of continuous functions from $A \times Y \rightarrow \mathbb{R}$. First note that $\mathcal{V} \subset \mathcal{C}$, and thus it is sufficient to show[‡] that \mathcal{V} is a closed subset of \mathcal{C} . So take any sequence of functions $\{v_n\}_{n=0}^\infty \in \mathcal{V}$ such that $v_n \rightarrow v^*$. We need to show that $v^* \in \mathcal{V}$. Suppose not, i.e. $v^* \notin \mathcal{V}$. Then either v^* is not continuous, or (B.27) or (B.28) was violated. Continuity is preserved because v_n converges to v^* uniformly given the sup-norm. If (B.27) is violated, then there must exist some N such that it is also violated for v_N , contradicting that $v_N \in \mathcal{V}$. Finally, given (B.27), (B.28) is satisfied by the assumption of unboundedness of u from below. \square

Now we need to show that for all $v \in \mathcal{V}$, $Tv \in \mathcal{V}$. Thus, we need to establish that T preserves continuity, and that (B.27) and (B.28) hold. To show that T preserves continuity, first note that $a(b', g', m', \delta', y')$ is a continuous function. Thus $v(a(\cdot), y)$ is also continuous, because the composition of continuous functions is continuous. Further, continuity is preserved by integration, and thus $\sum_{y' \in Y} \pi(y'|y) \int v(a(b', g', m', \delta', y'), y') dF(\delta')$ is also continuous. This implies that:

$$u(c; P_l) + \beta \sum_{y' \in Y} \pi(y'|y) \int v(a(b', g', m', \delta', y'), y') dF(\delta') \quad (\text{B.29})$$

is a continuous function in c, b', g', m' on $C \times B \times G \times M$. That, combined with the previously established fact that Γ is compact valued and continuous allows us to assert the continuity of Tv from the Theorem of the Maximum. To show that (B.27) is preserved, note that $u(c; P_l)$ is bounded above by \bar{u} , thus $Tv \leq \bar{u} + \beta\bar{u}/(1 - \beta) = \bar{u}/(1 - \beta)$. Further, choosing a consumption expenditure of $c = (1 - \tau)y_{min}$ is feasible in all periods, thus $Tv \geq u((1 - \tau)y_{min}; P_l) + \beta u((1 - \tau)y_{min}; P_l)/(1 - \beta) = u((1 -$

[‡]Corollary 1 on p. 52 of Stokey, Lucas and Prescott 1989, establishes that any closed subspace of a complete metric space is also complete

$\tau)y_{min}; P_l)/(1 - \beta)$. This result, combined with the assumption that $u(0; P_l) = -\infty$ guarantees that Tv satisfies (B.28). Thus $T\mathcal{V} \subset \mathcal{V}$.

The final lemma necessary to prove our main result is:

Lemma 18. *The operator T is a contraction with modulus β .*

Proof. To prove this we will show that T satisfies monotonicity and discounting and then apply Blackwell's sufficient conditions (see Stokey and Lucas (1989), Theorem 3.3[§]).

a) Monotonicity: Take $v, w \in \mathcal{V}$ such that $v(a, y) \leq w(a, y)$ for all $(a, y) \in A \times Y$. We want to show that $Tv \leq Tw$. By the definition of T and the fact that

$$\sum_{y' \in Y} \pi(y'|y) \int v(a', y') dF(\delta') \leq \sum_{y' \in Y} \pi(y'|y) \int w(a', y') dF(\delta'), \quad Tv \leq Tw.$$

b) Discounting: Take any $\gamma \in \mathbb{R}_+$, $T(v + \gamma) = Tv + \beta \sum_{y' \in Y} \pi(y'|y) \int \gamma dF(\delta') = Tv + \beta\gamma$.

Thus, from Blackwell's theorem it follows that T is a contraction mapping with modulus β . □

Proposition 13. *Under the maintained assumptions on u and the assumption that $F(\delta)$ is \mathcal{C}^2 and log-concave, there exists a unique $v^* \in \mathcal{V}$ such that $Tv^* = v^*$. Furthermore, v^* is strictly increasing in a .*

Proof. From Lemmas 17, 18 above and the contraction mapping theorem it follows that there exists a unique $v^* \in \mathcal{V}$ such that $Tv^* = v^*$. In order to show that v^* is increasing in a we appeal to the monotonicity of Γ and the strict monotonicity of

[§]Note that all functions in \mathcal{V} are bounded.

$u(c; P_L)$. Take $a, a' \in A$ such that $a < a'$. We want to show $v^*(a, y) < v^*(a', y)$.

$$v^*(a, y) = \max_{x \in \Gamma(a)} u(c; P_L) + \beta \sum_{y' \in Y} \pi(y'|y) v^*(a(b', g', m', \delta', y'), y') dF(\delta') \quad (\text{B.30})$$

$$= u(c^*; P_L) + \beta \sum_{y' \in Y} \pi(y'|y) v^*(a(b'^*, g'^*, m'^*, \delta', y'), y') dF(\delta') \quad (\text{B.31})$$

$$< u(c^* + a' - a; P_L) + \beta \sum_{y' \in Y} \pi(y'|y) v^*(a(b'^*, g'^*, m'^*, \delta', y'), y') dF(\delta') \quad (\text{B.32})$$

$$\leq \max_{x \in \Gamma(a')} u(c; P_L) + \beta \sum_{y' \in Y} \pi(y'|y) v^*(a(b', g', m', \delta', y'), y') dF(\delta') \quad (\text{B.33})$$

$$= v^*(a', y) \quad (\text{B.34})$$

where the third line comes from the strict monotonicity of u . The fourth line comes from the fact that $a' - a > 0$ and the fact that if $(c^*, b'^*, g'^*, m'^*) \in \Gamma(a)$, then $(c^* + a' - a, b'^*, g'^*, m'^*) \in \Gamma(a')$. \square

Characterization

In this section we prove Proposition 12. It is a direct consequence of Theorem 3 in Clausen and Strub (2012).

Proof. We seek to apply theorem 3 of Clausen and Strub (2012). Consider re-writing the value function as follows:

$$V(b, g, m, \delta, d, y) = \max_{x \in \Gamma(a), d' \in \{0,1\}} u(c; P_L) + \beta \sum_{y' \in Y} \pi(y'|y) V(b', g', m', \delta', d', y') dF(\delta') \quad (\text{B.35})$$

where x and Γ are defined as before, but now

$$a = b + y + (1 - d') [(1 - \delta)g - m] \quad (\text{B.36})$$

where we explicitly model the foreclosure decision with d' . Note, that there is a

slight abuse of timing here, the d' denotes the choice to default in the current period, whereas d denotes the foreclosure choice in the previous period. As a result, V does not depend on d since the default decision in the previous period is not relevant for the current period's optimization.

In order to apply Theorem 3 of Clausen and Strub, we need to show that the choices satisfy what they call "one-period interior choice." The fact that the utility function is unbounded below guarantees that consumption will always be strictly interior. By assuming, as we did in proposition 12 that $g', b', m', g'', b'', m'' > 0$ guarantees that the choice of c, h, g', b', m' satisfies the "one-period interior choice" condition.

Therefore, since, as we showed above, the value function is finite and as long as the utility function is differentiable, then it will also be differentiable with respect to b, g, m , holding g', b', m', d, d' constant, and is differentiable with respect to g', b', m' , holding b, g, m, d, d' constant (based on how it is defined above). Then, we can conclude that if (g', b', m', d') is an optimal choice at b, g, m, d, δ and $g', b', m' > 0$, then V will be differentiable in g', b', m' for all δ' . Taking first order conditions and rearranging them yields the characterization in Proposition 12. \square

B.1.4 A Lower Bound for the Equilibrium Rental Price of Housing P_l

In the main text we established a lower bound for the equilibrium rental rate,

$$P_l \leq \frac{r_b + r_w + r_b r_w + \gamma E(\delta') + 1 - \gamma}{(1 + r_b)(1 + r_w)}.$$

We now discuss a lower bound for the rental rate; whose existence we can be sure of, but for which we have no closed-form characterization. Due to the presence of idiosyncratic house price shocks, the housing asset is an inherently risky asset. Households, however, can effectively choose the risky returns to housing by taking on different levels of leverage. Since households are risk averse, for them to purchase the housing asset, at some leverage the expected return to housing (which includes the

“dividend” P_l), weighted by the stochastic discount factor of the household, must be greater than the return of the risk-free bond. This in turn implies a lower bound on the rental price P_l .

Although we do not have an analytical characterization of that lower bound, we found in our quantitative analysis that the equilibrium rental price P_l was such that the expected return of housing *at zero leverage* was always at least as high as the risk free interest rate. This implies that in our numerical analysis the following relationship holds:

$$\left(\frac{1}{1+r_b} \right) \int_{\underline{\delta}}^1 (1-\delta') dF(\delta') \geq 1 - P_l$$

which can be rewritten as

$$\begin{aligned} \left(\frac{1}{1+r_b} \right) (1 - E(\delta')) &\geq 1 - P_l \text{ or} \\ P_l &\geq \frac{r_b + E(\delta')}{1+r_b}. \end{aligned}$$

This result states that the rental price of housing was not smaller than the (expected) user cost of housing in equilibrium.

Combining these results, with $\gamma = 1$ and $r_w = 0$ we would immediately obtain that the rental price of housing P_l equals its user cost $\frac{r_b + E(\delta')}{1+r_b}$. In fact, what happens in an equilibrium under this parameterization ($\gamma = 1, r_w = 0$) is that households purchase houses, lever up such that they default for sure tomorrow and the houses end up in the hand of the banks. Since these are risk-neutral, and since default is fully priced into the mortgage and banks receive the full (but depreciated) value of the house, banks rather than households (which are risk averse) should (from a normative perspective) and will effectively end up owning the real estate. This equilibrium in effect replicates the equilibrium, described in section 2.5.2 of the paper, in the version of the model in which a housing mutual fund can diversify all idiosyncratic house price risk.

B.2 Computational Appendix

B.2.1 Simplification of the Household Problem

For the computation of the household problem it will be convenient to split the household maximization problem into a portfolio choice problem in which the household chooses how much to invest in bonds and houses and how much of the house to finance, and into a standard intertemporal consumption-saving problem. Define

$$x' = b'P_b + g'[1 - P_l] - m'P_m(\kappa').$$

Then the consumption-savings problem reads as

$$v(a, y) = \max_{0 \leq x' \leq a} \{u(a - x'; P_l) + \beta w(x', y)\}$$

where the value of saving x' units is given by

$$\begin{aligned} w(x', y) &= \max_{b', g', m' \geq 0} \sum_{y'} \pi(y'|y) \int_{\underline{\delta}}^{\infty} v(a', y') dF(\delta') \\ &\text{s.t.} \\ x' &= b'P_b + g'[1 - P_l] - m'P_m(\kappa') \\ a' &= b' + \max\{0, (1 - \delta')g' - m'\} + (1 - \tau)y' \end{aligned}$$

This last problem can be conveniently expressed as a choice problem of just bond b' and leverage $\kappa' = m'/g'$. Note that if $g' = 0$ the household cannot borrow and thus $\kappa' = 0$. First, we can write the last two equations in terms of κ' instead of m' :

$$\begin{aligned} x' &= b'P_b + g' \{1 - P_l - \kappa'P_m(\kappa')\} \\ a' &= b' + g' \max\{0, (1 - \delta') - \kappa'\} + (1 - \tau)y' \end{aligned}$$

Now we solve the first equation for g' to obtain

$$g' = \frac{x' - b'P_b}{1 - P_l - \kappa'P_m(\kappa')}$$

$$a' = b' + \frac{x' - b'P_b}{1 - P_l - \kappa'P_m(\kappa')} \max\{0, (1 - \delta') - \kappa'\} + (1 - \tau)y'$$

and thus the portfolio choice problem boils down to a choice of b' and κ' :

$$w(x', y) = \max_{\substack{0 \leq b' \leq x'/P_b \\ 0 \leq \kappa'}} \sum_{y'} \pi(y'|y)$$

$$\int_{\underline{\delta}}^{\infty} v \left\{ b' + \frac{x' - b'P_b}{1 - P_l - \kappa'P_m(\kappa')} \max\{0, (1 - \delta') - \kappa'\} + (1 - \tau)y', y' \right\} dF(\delta')$$

B.2.2 Labor Income Process

From the Tauchen procedure we obtain (after de-logging) the five labor productivity shock realizations $y \in \{0.3586, 0.5626, 0.8449, 1.2689, 1.9909\}$ and the following transition matrix:

$$\pi = \begin{bmatrix} 0.7629 & 0.2249 & 0.0121 & 0.0001 & 0.0000 \\ 0.2074 & 0.5566 & 0.2207 & 0.0152 & 0.0001 \\ 0.0113 & 0.2221 & 0.5333 & 0.2221 & 0.0113 \\ 0.0001 & 0.0152 & 0.2207 & 0.5566 & 0.2074 \\ 0.0000 & 0.0001 & 0.0121 & 0.2249 & 0.7629 \end{bmatrix}$$

which in turn implies the stationary distribution $\Pi = (0.1907, 0.2066, 0.2053, 0.2066, 0.1907)$ and an average labor productivity of one.

B.3 Sensitivity Analysis Appendix

B.3.1 The Economy with Capital

Details of the Model

The economy with capital is identical to the Aiyagari (1994) economy, augmented by risky housing assets and housing services, as in the benchmark economy. Instead of labor income, households now receive idiosyncratic labor endowments $y \in Y$ in each period. These endowments follow a finite state Markov chain with transition probabilities $\pi(y'|y)$ and unique invariant distribution $\Pi(y)$, as does labor income in the benchmark model. A household's labor income in a given period is then given by wy , where w is the economy-wide wage. We denote by $\bar{y} = \sum_{y \in Y} y\Pi(y)$ the average labor endowment and normalize it to 1. We will use the terms labor endowment and labor income interchangeably throughout the remainder of this appendix, and as before assume that a law of large number applies, so that π and Π also denote deterministic fractions of households receiving a particular labor income shock y .

In addition to consumption and housing services the household spends income to purchase three types of assets, one-period pure discount bonds b' , perfectly divisible houses g' (as before) and physical capital \tilde{k}' . Capital pays a net return $r - \delta_k$ where r is the rental rate on capital and δ_k its depreciation rate. The recursive problem of the households now reads as

$$v(a, y) = \max_{c, h, b', m', g', \tilde{k}' \geq 0} \left\{ U(c, h) + \beta \sum_{y'} \pi(y'|y) \int_{\underline{\delta}}^1 v(a', y') dF(\delta') \right\} \quad (\text{B.37})$$

subject to

$$c + b'P_b + hP_l + g'P_h + \tilde{k}' - m'P_m(g', m') = a + g'P_l \quad (\text{B.38})$$

$$a'(\delta', y', m', g') = (1 + r - \delta_k)\tilde{k}' + b' + \max\{0, P_h(1 - \delta')g' - m'\} + (1 - \tau)wy' \quad (\text{B.39})$$

On the production side, a representative firm rents labor and capital and produces the final good which can be used for consumption and physical capital investment purposes. The production technology is given by

$$Y = AK^\alpha L^{1-\alpha}$$

where K is the physical capital stock, L is the labor input used by the representative firm and Y is aggregate output. The parameter $\alpha \in [0, 1)$ measures the capital share. Note that $\alpha = 0$ corresponds to our endowment economy. The real estate construction sector and the financial intermediary sector works as before. The same is true for the government who levies income taxes at a flat rate τ on households to finance the mortgage interest rate subsidy. The tax revenues of the government are now given by τw , recalling that aggregate labor supply is normalized to 1. For a loan of type (m', g') the subsidy by the government is given by

$$sub(m', g') = \theta m' P_m(g', m'; \phi = \theta)$$

and the total economy-wide subsidy is

$$G = \int sub(m', g') d\mu \tag{B.40}$$

The income tax rate then has to satisfy

$$\tau = \frac{G}{w}. \tag{B.41}$$

Definition of Competitive Equilibrium

We are now ready to define a stationary recursive Competitive Equilibrium for the benchmark economy. Let $S = \mathbb{R}_+ \times Y$ denote the individual state space.

Definition Given a government subsidy policy ϕ a **Stationary Recursive Competitive Equilibrium** are value and policy functions for the households, $v, c, h, b', m', g' : S \rightarrow \mathbb{R}$, policies for the production sector K, L , for the real estate construction sector I, C_h , prices P_l, P_b , wages and rental rates w, r , a mortgage pricing function $P_m : \mathbb{R}_+ \times \mathbb{R}_+ \rightarrow \mathbb{R}$, a government tax rate τ and government spending G , as well as a stationary measure μ such that

1. (Household Maximization) Given prices P_l, P_b, P_m and government policies the value function solves (B.37) and c, h, b', m', g' are the associated policy functions.
2. Production Firm Maximization

$$\begin{aligned} w &= (1 - \alpha)A \left(\frac{K}{L}\right)^\alpha \\ r &= \alpha A \left(\frac{K}{L}\right)^{\alpha-1} \end{aligned}$$

3. (Real Estate Construction Company Maximization) Policies I, C_h solve (2.4).
4. (Loan-by-Loan Competition) Given P_b and P_m , (2.6) holds with equality for all m', g' .
5. (Government Budget Balance) The tax rate function τ satisfies (B.41) and government spending G satisfies (B.40), given the functions m', P_m .
6. (Market Clearing in Rental Market)

$$\int g'(s)d\mu = \int h(s)d\mu$$

7. (Market Clearing in the Bond Market)

$$P_b \int b'(s)d\mu = (1 + r_w + \theta - \phi) \int P_m(g', m'; \phi)m'(s)d\mu$$

8. (Market Clearing in the Capital Market)

$$\int \tilde{k}'(s)d\mu = K$$

9. (Market Clearing in the Labor Market)

$$\int yd\mu = L$$

10. (Market Clearing in the Goods Market)

$$\int c(s)d\mu + C_h + \delta_k K + (r_w + \theta - \phi) \int P_m(g', m'; \phi)m'd\mu + G = AK^\alpha L^{1-\alpha}$$

where

$$C_h = I = \int g'(s) \left[1 - \int_{\underline{\delta}}^{\delta^*(\kappa'(s))} (1 - \delta')dF(\delta') - \gamma \int_{\delta^*(\kappa'(s))}^1 (1 - \delta')dF(\delta') \right] d\mu$$

is gross investment in the housing stock.

11. (Invariance of Distribution μ). The measure μ is invariant with respect to the Markov process induced by the exogenous Markov process π and the policy functions m', g', b' .

When we derive the welfare consequences of removing the mortgage interest subsidy, as before we measure aggregate economy-wide welfare via a Utilitarian social welfare function in the steady state, defined as

$$\mathcal{WEL} = \int v(s)\mu(ds)$$

where μ is the invariant measure over the state space for cash at hand and income, $s = (a, y)$.

Theoretical Results

Simplification of the Household Problem First, we note that bonds and capital are both risk-free assets, and for either to be demanded in positive but finite amounts, it needs to be the case that both assets command the same returns. Thus in any equilibrium where both assets are traded

$$P_b = \frac{1}{1 + r - \delta_k}.$$

Define a new variable $k' = \tilde{k}' + P_b b'$. Then the household problem can be written as

$$v(a, y) = \max_{c, h, m', g', k' \geq 0} \left\{ U(c, h) + \beta \sum_{y'} \pi(y'|y) \int_{\underline{\delta}}^1 v(a', y') dF(\delta') \right\}$$

subject to

$$c + k' + hP_l + g'P_h - m'P_m(g', m') = a + g'P_l \quad (\text{B.42})$$

$$a'(\delta', y', m', g') = (1 + r - \delta_k)k' + \max\{0, P_h(1 - \delta')g' - m'\} + (1 - \tau)wy' \quad (\text{B.43})$$

As before the household problem can be separated into a static and dynamic problem, with end result:

$$\begin{aligned} v(s) &= \max_{c, b', m', g' \geq 0} \left\{ u(c; P_l) + \beta \sum_{y'} \pi(y'|y) \int_{\underline{\delta}}^1 v(s') dF(\delta') \right\} \\ a &= c + k' + g' [1 - P_l] - m' P_m(\kappa') \\ a'(\delta', h', m', g') &= (1 + r - \delta_k)k' + \max\{0, (1 - \delta')g' - m'\} + (1 - \tau)wy' \end{aligned}$$

and the same properties of the household problem go through as before go through.

Simplification of the Recursive Competitive Equilibrium Trivially $L = 1$ from the labor market clearing condition, and thus

$$\begin{aligned} w &= (1 - \alpha)AK^\alpha \\ r &= \alpha AK^{\alpha-1} \end{aligned}$$

Adding the bond and capital market clearing conditions yields

$$P_b \int b'(s)d\mu + \int \tilde{k}'(s)d\mu = K + (1 + r_w + \theta - \phi) \int P_m(g', m'; \phi)m'(s)d\mu$$

and thus

$$\int k'(s)d\mu = K + (1 + r_w + \theta - \phi) \int P_m(g', m'; \phi)m'(s)d\mu$$

Consequently the only changes the shift from the endowment to the production economy entails is that now the risk-free interest rate in the economy is tied to the marginal product of labor, and that the market clearing conditions for risk-free assets now equates household demand for these assets to the *sum* of real assets (the physical capital stock) and financial assets (mortgages), rather than just financial assets, as in the endowment economy.

Calibration

Our objective is to calibrate the steady state equilibrium of the production economy with a 30bp subsidy to the same targets as we did for the endowment economy. We retain the same parameters for the idiosyncratic income process (since the common wage w just adds an aggregate constant to the log-income equation) as well as for the idiosyncratic house price depreciation process. Parameters governing the foreclosure technology and the government subsidy remain the same as well.

The production side of the economy is characterized by the three parameters A, α, δ_k . We normalize $A = 0.9232$ such that $w = 1$ in the benchmark equilibrium

which facilitates comparisons with the endowment economy and choose a capital share of $\alpha = 0.3$ and a depreciation rate of $\delta_k = 9\%$. With these choices and a target capital-to-output ratio of $K/Y = 3$ (achieved by judicious choice of the preference parameters below) the model delivers the same risk-free interest rate of 1% as in the benchmark endowment economy.

The time discount parameter β and the CRRA parameter σ are endogenously calibrated to match an equilibrium risk free rate of 1% (equivalently, given the other parameters discussed above, a capital-output ration of 3) and a median household leverage of 61% in the benchmark economy. In order to simultaneously match these targets we find that we need a much higher coefficient of relative risk aversion and a much lower time discount rate. The calibrated parameters are $(\beta, \sigma) = (0.893, 7.512)$. In order to understand the intuition, increasing the value of σ has a two-fold effect - first, it increases precautionary saving demand, helping to match a capital-output of 3 (rather than zero, as in the endowment economy). However, the higher contemporaneous risk-aversion also makes households more willing to "borrow-to-save" because they value the increased insurance. Lowering the time discount factor then allows us to then match the risk-free interest rate. For comparison we also report results obtained for the production economy under the original, endowment economy, preference specification with $(\beta, \sigma) = (0.919, 3.912)$.

Quantitative Results with Physical Capital

The results of our experiment in the model with physical capital are presented in Table ???. The main text contains a shortened version of this table in which only results from the re-calibrated economy with capital are presented.

From the table we observe that the introduction of physical capital leaves the results of the policy analysis qualitatively, and to a large extent quantitatively unchanged *if we re-calibrate the model* to be consistent with the same targets as was

| Variable | Baseline | | With Capital | | With Capital (Recalibrated) | |
|--------------------|----------|--------|--------------|--------|--------------------------------|--------|
| σ | 3.912 | | 3.912 | | 7.512 | |
| β | 0.919 | | 0.919 | | 0.893 | |
| % Sub | 30bp | 0bp | 30bp | 0bp | 30bp | 0bp |
| Median Leverage | 61.5% | 0.0% | 0.0% | 0.0% | 61.5% | 0.0% |
| r_b | 1.0% | 0.518% | 2.841% | 2.840% | 1.0% | 0.676% |
| Sub/\bar{y} | 0.97% | 0% | 0.006% | 0% | 0.96% | 0% |
| P_l | 0.0281 | 0.0278 | 0.0450 | 0.0450 | 0.0296 | 0.0294 |
| GDP | 1.150 | 1.151 | 1.430 | 1.430 | 1.585 | 1.587 |
| H/GDP | 4.633 | 4.737 | 2.491 | 2.491 | 3.332 | 3.404 |
| M/GDP | 2.810 | 0.269 | 0.012 | 0.0001 | 2.018 | 0.003 |
| K/GDP | 0.0 | 0.0 | 2.353 | 2.355 | 2.702 | 2.830 |
| w | 1 | 1 | 0.93 | 0.93 | 1 | 1.014 |
| Default share | 0.51% | 0.41% | 0.28% | 0.15% | 0.49% | 0.30% |
| Mean Net Worth/GDP | 4.633 | 4.737 | 4.844 | 4.846 | 6.034 | 6.234 |
| Median Bond Share | 60.7% | 7.2% | 48.8% | 48.6% | 72.2% | 47.8% |
| $\mu(g' > 0)$ | 96.79% | 96.66% | 97.6% | 97.6% | 100% | 100% |
| $\mu(g' > h)$ | 43.00% | 39.77% | 47.6% | 48.2% | 45.7% | 45.9% |
| CEV^* | 0 | 0.81% | 0% | 0.04% | 0% | 2.17% |

the model without capital. Under the *old calibration*, but in the model with capital, households save predominantly in riskless capital, the demand for riskless assets and mortgages collapses and the equilibrium interest rate rises significantly (from 1% in the model without capital to 2.8% in the model with capital). Median leverage, one of the calibration targets falls from 61% in the benchmark model to zero in the model with capital (both in the presence of the subsidy). Since the mortgage market almost completely collapses the removal of the subsidy has essentially no effect on allocations and welfare. We don't think that the economy with capital, under the no-capital calibration, is a useful laboratory to analysis the hypothetical policy reform since it results in the counterfactual absence of any meaningful mortgage market. And of course, if there are no mortgages traded in equilibrium, a policy that subsidizes these mortgages has no effect.

Therefore we would argue that, in order to assess the sensitivity of our benchmark results to the inclusion of capital, one should re-calibrate the capital economy to be

consistent with the same targets as the no-capital economy, and especially a risk-free interest rate of 1% as well as a median leverage of 61%. As discussed above, in order to induce households to borrow more (and saving households to save more) in the model we have to make the precautionary savings motive more potent by increasing the risk aversion and prudence parameter σ from 3.9 to 7.5. In addition, the required discount factor β falls from 0.92 to 0.89. The changes in these parameters resurrect the quantitative importance of the borrow to save motive and results in median leverage equal to the empirical target of 61% as well as a risk free rate of 1%, as in the economy without capital.

With this parameterization, both in terms of aggregate allocations, and specifically the equilibrium allocation of mortgages, houses and financial assets, the tax rate to finance the subsidy, and the rental price, as well as in terms of the welfare consequences, the endowment economy and the re-calibrated economy with capital display qualitatively, and to a large part quantitatively, the same consequences of a removal of subsidy. The one quantitative exception are the welfare gains from the removal of the subsidy, which are significantly *larger* in the economy with capital, thus reinforcing the normative point we wish to make. The key difference to the economy without capital is a larger value of the risk aversion (prudence) parameter σ , which induces larger curvature in the utility and thus value function of households. Thus a policy reform (such as the removal of the subsidy) that redistributes from rich (high income and cash at hand) to poor households constitutes larger aggregate welfare gains, under our utilitarian social welfare function.

B.3.2 The Economy with Housing Mutual Fund

Now, instead of introducing physical, suppose there exists a housing mutual fund that can purchase an entire portfolio (with positive measure) of housing assets and thus exploit the law of large numbers to perfectly diversify the idiosyncratic house price

risk. Since the mutual fund is a risk-free asset it has to earn the same return r_b as risk-free bonds.

For each dollar invested, the mutual fund buys one unit of housing (recall that the price of housing was normalized to 1), rents it out immediately at price P_l and tomorrow sell the non-depreciated part $(1 - E(\delta))$, again at price 1. Note the fact that the mutual fund can perfectly diversify idiosyncratic depreciation risk explains why a deterministic fraction $1 - E(\delta)$ of the fund's housing stock depreciates. Implicit in this discussion is that the mutual fund cannot default on part of its portfolio.

Equilibrium Rental Price

Thus the gross return of the fund's investment strategy tomorrow is

$$(1 + r_b)P_l + 1 - E(\delta)$$

which has to be equal to the return on bonds and capital, or

$$(1 + r_b)P_l + 1 - E(\delta) = 1 + r_b$$

and thus in the mutual fund economy the rental price is given by the user cost of housing:

$$P_l = \frac{r_b + E(\delta)}{1 + r_b} \tag{B.44}$$

At this rental price the housing mutual fund is a perfect substitute for the risk-free bond and thus the mutual fund is a redundant asset *from the perspective of the household*. Thus the existence of the mutual fund does not alter the household decision problem[¶], relative to the benchmark economy, but it pins down the equilibrium rental price P_l in equation (B.44).

[¶]The risk-free asset position is now a composite of risk-free bonds and risk-free housing mutual funds, both earning the same return.

Asset Market Clearing Condition

The housing position of the housing mutual fund is then given by

$$M = \int h(s)d\mu - \int g'(s)d\mu$$

and the asset market clearing condition that determines the still endogenous risk-free interest rate r_b now reads as

$$P_b \int b'(s)d\mu = M + (1 + r_w + \theta - \phi) \int P_m(g', m'; \phi)m'(s)d\mu.$$

Note that in this economy households can still buy individual houses carrying idiosyncratic risk using mortgages, and might opt to do so given the option-like mortgage cum foreclosure contract. But if in fact $\int g'(s)d\mu \equiv 0$, this economy collapses to one in which the entire housing stock is owned by the housing mutual fund, and individual households have neither houses nor mortgages in their asset portfolio. Table 2.4 shows that this is indeed what happens in the benchmark economy to a good first approximation. As a consequence this economy cannot reproduce the empirically observed median level or distribution of mortgage leverage in the economy, and the removal of the mortgage subsidy is inconsequential for allocations and welfare.

Appendix C

Appendices to Chapter 3

C.1 Implementation of Iterative Two-Stage Estimator

The following is a brief description of the algorithm implementing our iterative two-stage estimator.

1. Start with a guess for α , say α_1 .
2. At each iteration ξ , do the following:
 - (a) given α_ξ , for each p , construct $v_{p,t} = \Delta x_{p,t} - \beta(1 - s_t)\Delta x_{p,t+1} - \alpha_j \Delta b_{p,t}$.
Then, $v_{p,t} = \lambda'_p F_t$ is a pure factor model and can be estimated consistently using principal components.*
 - (b) Given the estimates for λ_p and F_t , estimate equation (3.14) via OLS and update the guess to obtain $\alpha_{\xi+1}$.
3. Repeat 2 until α_ξ converges.[†]

*The exposition of the estimator assumes that there are no missing observations. We use the generalized procedure described in Bai (2009) and allow for missing observations.

[†]We have conducted a number of Monte Carlo simulations with sample sizes similar to our sample. The estimator described here is found to converge to the true parameter. Results are available upon request.

C.2 Inadmissibility of State Unemployment Differences in Testing for Endogeneity

In this section we elucidate why controlling for the difference in state unemployment does not constitute a valid exogeneity test. To illustrate our point, we simulate data from our calibrated model where we impose exogeneity - i.e. we assume the productivity processes at the county and state level are independent. In Figure C.1 we plot the time series for state unemployment, county unemployment and weeks of benefits available. Notice that both state and county level unemployment are smooth moving variables, whereas the weeks of benefits jumps when a benefit extension is triggered on. The correlation between state and county unemployment is significantly higher than between county unemployment and benefits, and controlling for state unemployment completely takes out the effect of benefits. However, it is important to note that the only channel through which the state economy affects the county economy is through the benefit policy (because in this example the productivity processes are orthogonal). Thus, controlling for state unemployment is not a valid test for exogeneity.

C.3 County Economy, Detailed Specification

The law of motion for county employment is:

$$L_{t+1}^C(\Omega_t^C) = (1 - \delta)L_t^C + f(\theta_t^C)(1 - L_t^C). \quad (\text{C.1})$$

and $u_t^C = 1 - L_t^C$.

Value Functions. The flow value for a firm employing a worker is

$$J_t^C(\Omega_t^C) = z_t^C - w_t^C + \beta(1 - \delta)\mathbb{E}J_{t+1}^C(\Omega_{t+1}^C), \quad (\text{C.2})$$

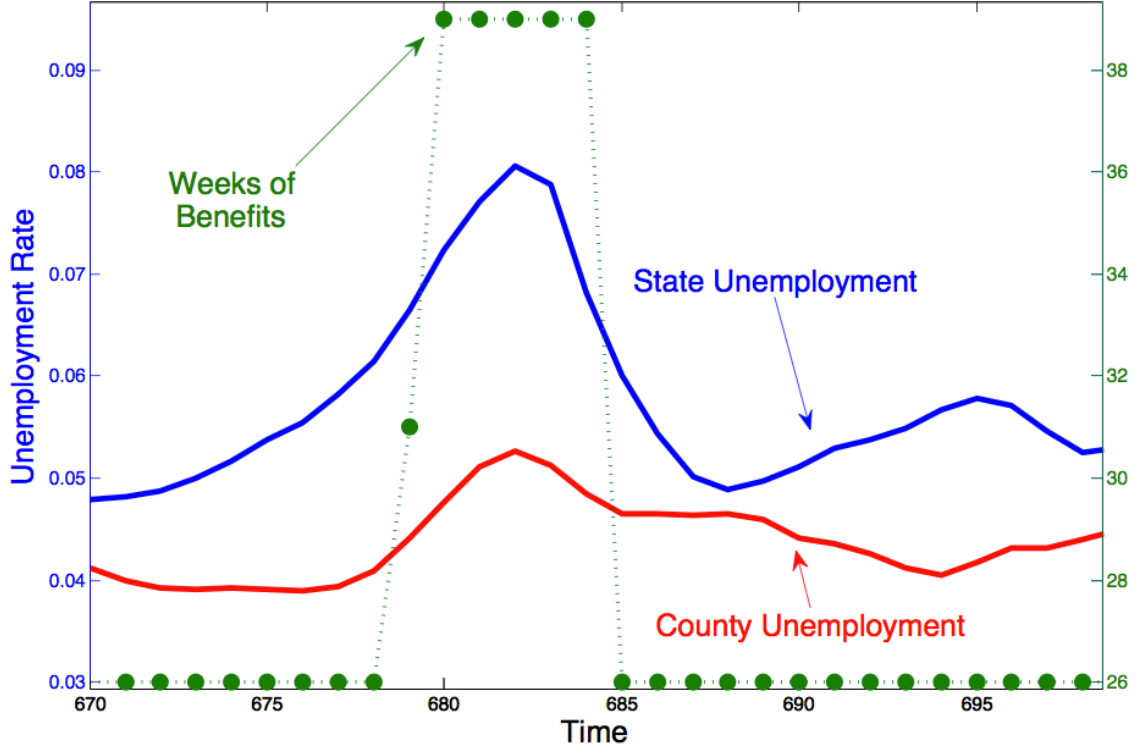


Figure C.1: County and State Unemployment: Model.

and the flow value of a vacant firm is:

$$V_t^C(\Omega_t^C) = -k + \beta q(\theta_t^C) \mathbb{E}J_{t+1}^C(\Omega_{t+1}^C). \quad (\text{C.3})$$

The surplus for a firm employing a worker is thus $J_t^C - V_t^C$.

The value functions for workers can be written as:

$$\begin{aligned} W_t^C(\Omega_t^C) &= w_t^C + \beta(1 - \delta) \mathbb{E}W_{t+1}^C + \beta\delta(1 - e_t(\Omega_t^C)) \mathbb{E}U_{t+1}^{C,E}(\Omega_{t+1}^C) \\ &\quad + \beta\delta e_t(\Omega_t^C) \mathbb{E}U_{t+1}^{C,I}(\Omega_{t+1}^C), \end{aligned} \quad (\text{C.4})$$

$$\begin{aligned} U_t^{C,E}(\Omega_t^C) &= h + b + \beta f(\theta_t^C) \mathbb{E}W_{t+1}^C(\Omega_{t+1}^C) + \beta(1 - f(\theta_t^C))(1 - e_t(\Omega_t^C)) \mathbb{E}U_{t+1}^{C,E}(\Omega_{t+1}^C) \\ &\quad + \beta(1 - f(\theta_t^C)) e_t(\Omega_t^C) \mathbb{E}U_{t+1}^{C,I}(\Omega_{t+1}^C), \end{aligned} \quad (\text{C.5})$$

$$U_t^{C,I}(\Omega_t^C) = h + \beta f(\theta_t^C) \mathbb{E}W_{t+1}^C(\Omega_{t+1}^C) + \beta(1 - f(\theta_t^C)) \mathbb{E}U_{t+1}^{C,I}(\Omega_{t+1}^C). \quad (\text{C.6})$$

Define the surplus of being employed as $\Delta_t^{C,E} = W_t^C - U_t^{C,E}$. Also define the surplus for an unemployed worker of being eligible: $\Phi_t^C = U_t^{C,E} - U_t^{C,I}$. The laws of motion for these quantities are:

$$\begin{aligned} \Delta_t^{C,E}(\Omega_t^C) &= w_t^C - h - b + \beta (1 - \delta - f(\theta_t^C)) \mathbb{E} \Delta_{t+1}^{C,E}(\Omega_{t+1}^C) \\ &\quad + \beta (1 - \delta - f(\theta_t^C)) e_t(\Omega_t^C) \mathbb{E} \Phi_{t+1}^C(\Omega_{t+1}^C), \end{aligned} \quad (\text{C.7})$$

$$\Phi_t^C(\Omega_t^C) = b + \beta (1 - f(\theta_t^C)) (1 - e_t(\Omega_t^C)) \Phi_{t+1}^C(\Omega_{t+1}^C). \quad (\text{C.8})$$

The wage is chosen to maximize:

$$\left(\Delta_t^{C,E}(\Omega_t^S) \right)^\xi \left(J_t^C(\Omega_t^S) - V_t^C(\Omega_t^S) \right)^{1-\xi}. \quad (\text{C.9})$$

County Equilibrium Definition. Taking as given an initial condition Ω_0^C , benefit expiration policy, and the joint stochastic process for state productivity and unemployment, we define an equilibrium given policy:

Definition Given a policy $(b, e_t(\cdot))$ and an initial condition Ω_0^C an equilibrium is a sequence of Ω_t^C -measurable functions for wages w_t , market tightness θ_t^C , employment L_t^C , and value functions

$$\left\{ W_t^C, U_t^{C,E}, U_t^{C,I}, J_t^C, V_t^C, \Delta_t^C \right\}$$

such that:

1. The value functions satisfy the worker and firm Bellman equations (C.2), (C.3), (C.4), (C.5), (C.6);
2. Free entry: The value V_t^C of a vacant firm is zero for all Ω_t^C ;
3. Nash bargaining: The wage satisfies equation (C.9);
4. Law of motion for employment: The employment process satisfies (C.1);

5. The joint process for (z_t^S, u_t^S) is consistent with the state equilibrium.

C.4 Appendix Figures

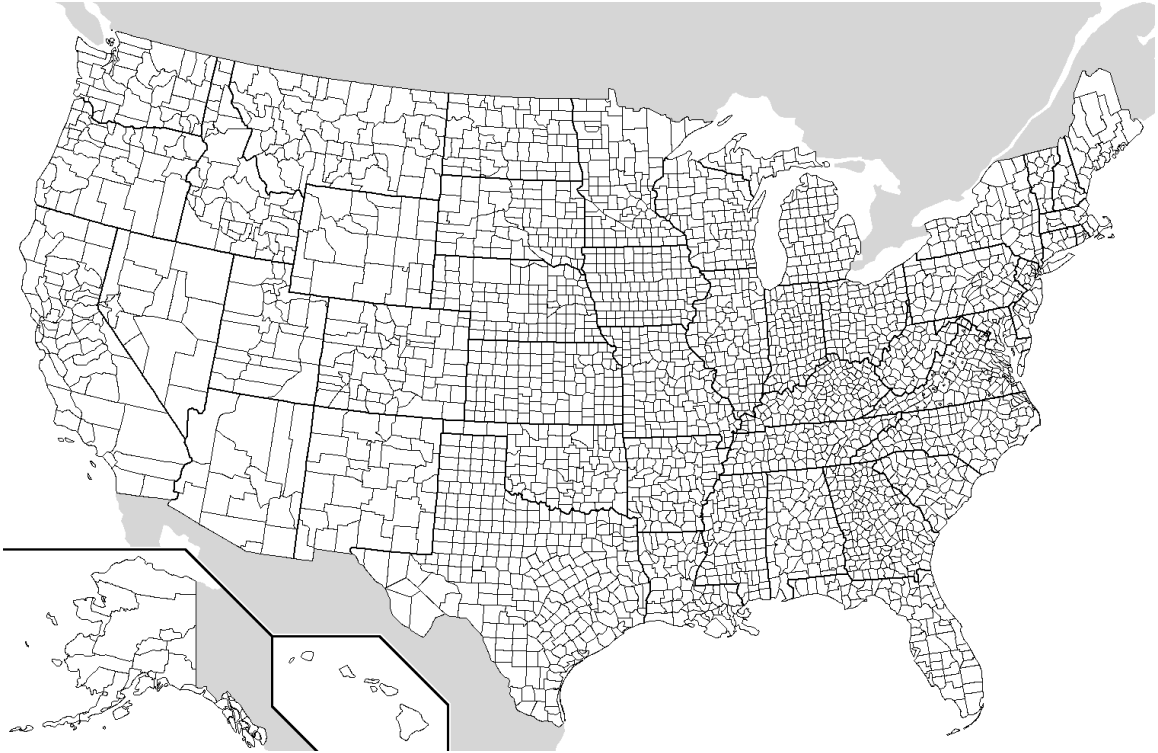


Figure C.2: Map of U.S.A. with state and county outlines.

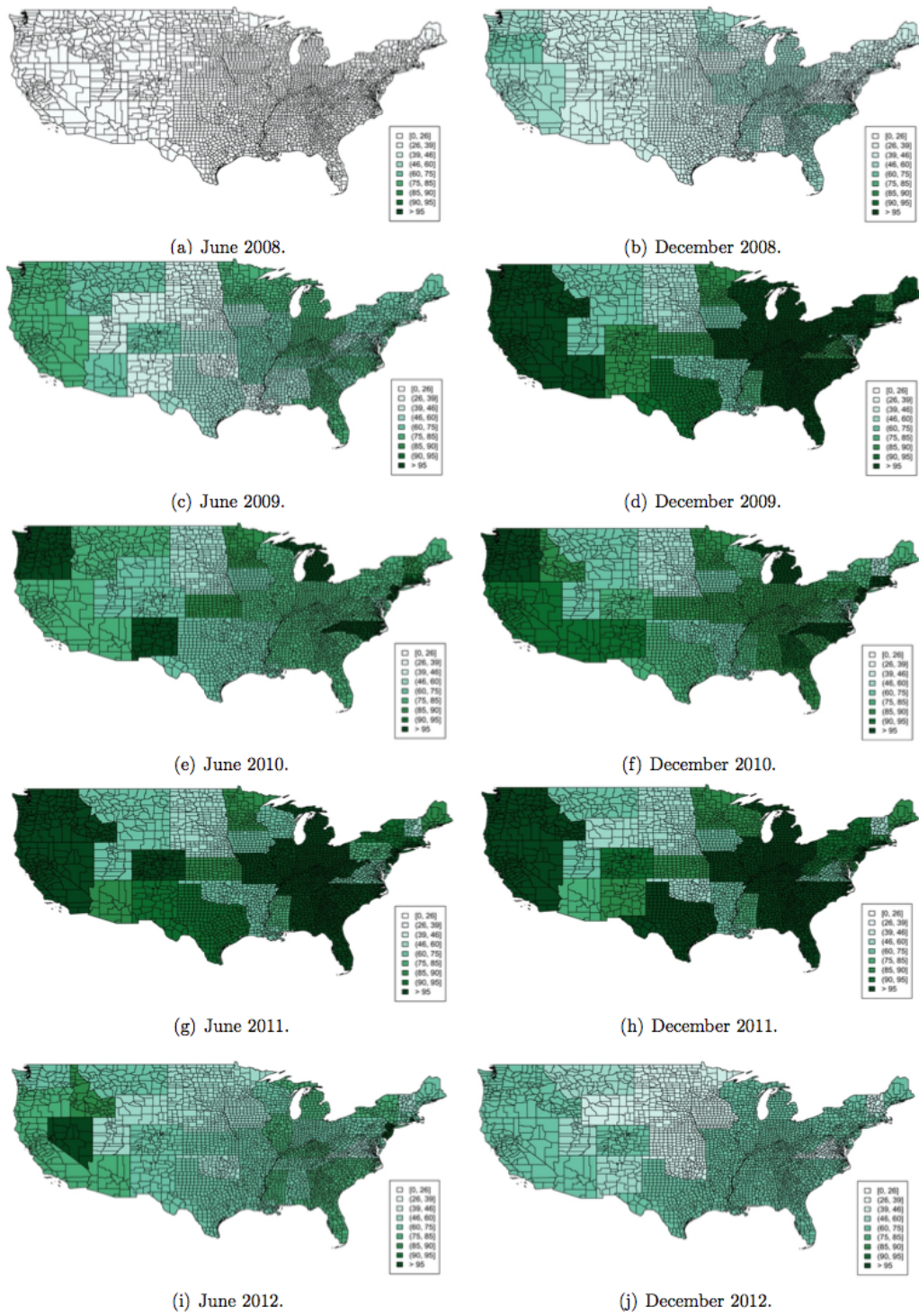


Figure C.3: Unemployment benefit duration across U.S. states during the Great Recession. Selected months.

Appendix D

Appendices to Chapter 4

D.1 The Post-War US Unemployment Insurance System: An Overview

By the late 1950s, most unemployment insurance systems in U.S. states offered 26 weeks of benefits to newly displaced workers. The deep recession of 1957-58, however, prompted the federal government to lengthen the duration of benefits available. Under the Temporary Unemployment Compensation Act (TUC), the federal government offered interest free loans to states in order to provide up to 13 additional weeks of benefits. Seventeen states opted to participate in the program, which lasted from June of 1958 until June of 1959.

The first federally financed extension of unemployment benefits occurred during the 1960-1961 recession. The federal government passed the Temporary Extended Unemployment Compensation Act (TEUC). Whereas TUC was a voluntary program, TEUC was mandatory for all states and provided up to 13 weeks of additional benefits to unemployed workers from April 1961 until June 1962. The extra weeks of benefits were entirely financed by the federal government (which raised the Federal Unemployment Tax to offset the extensions).

Guided by TUC and TEUC, the federal government sought to develop an au-

automatic system of extending unemployment benefits during recessions. In 1970 the Employment Security Amendments developed the Extended Benefits (EB) program, which would provide additional weeks of benefits to states experiencing high unemployment. The EB program is a state-federal partnership, with the costs of the extended benefits shared equally between the state and federal government. The EB program provided up to 13 weeks of additional benefits. The extended benefits can be "triggered" nationally when the unemployment rate crosses certain thresholds, or triggered within individual states when the state-level unemployment crosses certain thresholds.

Following the recession of 1969-1970, in addition to additional benefits provided by the EB program, the federal government passed the Emergency Unemployment Compensation Act of 1971 (EUCA) which provided for an additional 13 weeks of benefits to states with high unemployment financed fully by the federal government. Thus, unemployed workers could receive up to 52 weeks of benefits under the regular, EB and EUCA programs*. The EUCA provided benefits from January 1972 through March 1973.

During the 1973-1975 recession, the federal government passed the Federal Supplemental Benefits (FSB) program, which was in effect from January 1975 through October 1977. The program initially provided for 13 weeks of additional benefits financed from the federal government, but was amended to provide 26 weeks of benefits in March 1975. The EB program triggered on nationwide from February 1975 through December 1977. Thus, from March 1975 through October 1977 displaced workers could receive a total of 65 weeks of benefits (26 state + 13 EB + 26 FSB).

In 1980 and 1981, through the Omnibus Reconciliation Acts of those years, the federal government altered the EB program. It eliminated the national trigger for EB and raised the thresholds for the state level triggers. In addition, it imposed

*The triggers under EUCA were different than under the EB program. Thus some states only qualified for EB, others only for EUCA, and others for both EB and EUCA.

stricter eligibility requirements for unemployed workers to receive benefits under the EB program.

During the 1981-1982 recession, the federal government established the Federal Supplemental Compensation (FSC) program in September of 1982. The tightening of the EB program under the OBRA legislation made roughly half of states ineligible to additional benefits under that program. FSC was amended several times from 1982 through early 1985. For the majority of the program duration, it provided up to 14 additional weeks of benefits financed by the federal government. Thus, the maximum weeks of benefits that could be received were 53 (26 state + 13 EB + 14 FSC).

After the 1990-1991 recession, the federal government passed the Emergency Unemployment Compensation (EUC) Act of 1991. The extension was amended several times from 1991 through 1994 providing at various times an additional 20, 26, 33 or 15 additional weeks of benefits. The benefits were financed entirely by the federal government. The maximum weeks of benefits that an individual could have received was 72 (26 state + 13 EB + 33 EUC). In addition, the EB program was amended to increase the maximum number of weeks payable. States with unemployment rates above 8% would now receive 20 weeks of benefits instead of 13.

In March 2002, after the 2001 recession, the federal government passed the Temporary Extended Unemployment Compensation (TEUC) act. The act provided up to 26 additional weeks of federally financed unemployment benefits through March of 2004. The maximum weeks of benefits that an individual could have received was 72 (26 state + 13 EB + 26 EUC).

During the 2007-2009, the federal government passed the Emergency Unemployment Compensation (EUC08) Act of 2008. The program initially provided up to 13 weeks of additional benefits financed by the federal government. The EUC08 has been amended 8 times to day, gradually raising the maximum additional benefits provided by the federal government to 53 weeks, making to total compensation that

an unemployed worker could receive 99 weeks (26 state + 20 EB + 53 EUC08). The program is currently set to expire at the end of 2013.

Beginning in the 1950s, federal unemployment benefit extensions in recessions have become increasingly generous. This is illustrated in Figure 4.1, where we plot the time path of maximum benefit duration from 1950 to 2011. In Figure 4.2 we plot the time path of maximum benefit duration together with the time series for aggregate labor productivity. This figure illustrates that, in the recessions following the 1981-1982 recession, benefit extensions were more likely to occur *after* productivity had already begun to recover.

Appendix E

Appendices to Chapter 5

E.1

E.1.1 Characterization of Equilibrium

Proof of Lemma 1. First, observe that the necessary first-order conditions for optimal search effort are

$$\Delta_t = \frac{c'(S_t^E)}{f(\theta_t)} \quad (\text{E.1})$$

$$\Xi_t = \frac{c'(S_t^I)}{f(\theta_t)} \quad (\text{E.2})$$

Next, taking the differences of the workers' value functions from equations (5.5), (5.6), (5.7), we have

$$\begin{aligned} W_t - U_t^E &= c(S_t^E) + (1 - \delta - S_t^E f(\theta_t)) \Delta_t \\ &= c(S_t^E) + (1 - \delta - S_t^E f(\theta_t)) \frac{c'(S_t^E)}{f(\theta_t)} \end{aligned} \quad (\text{E.3})$$

$$\begin{aligned} W_t - U_t^I &= c(S_t^I) + (1 - S_t^I f(\theta_t)) \Xi_t(z^t) - \delta \Delta_t \\ &= c(S_t^I) + (1 - S_t^I(z^t) f(\theta_t)) \frac{c'(S_t^I)}{f(\theta_t)} - \delta \frac{c'(S_t^E)}{f(\theta_t(z^t))} \end{aligned} \quad (\text{E.4})$$

Next, we rearrange the expressions for worker surpluses (5.8), (5.9) to get

$$\begin{aligned} \Delta_t &= u(w_t) - u(h + b_t) \\ &\quad + \beta(1 - e_t) \mathbb{E}_t(W_{t+1} - U_{t+1}^E) + \beta e_t \mathbb{E}_t(W_{t+1} - U_{t+1}^I) \end{aligned} \quad (\text{E.5})$$

$$\Xi_t = u(w_t) - u(h) + \beta \mathbb{E}_t(W_{t+1} - U_{t+1}^I) \quad (\text{E.6})$$

Now, substituting (E.1) and (E.3) into the left and right hand sides of (E.5) gives (5.14); similarly, substituting (E.2) and (E.4) into the left and right hand sides of (E.6) gives (5.15).

Next, we derive the law of motion for the firm's surplus from hiring. By the free-entry condition, the value $V_t(z^t)$ of a firm posting a vacancy must be zero. Equations (5.10) and (5.11) then simplify to:

$$J_t = (1 - \delta) [z_t - w_t - \tau + \beta \mathbb{E}_t J_{t+1}] \quad (\text{E.7})$$

$$0 = -k + q(\theta_t) [z_t - w_t - \tau + \beta \mathbb{E}_t J_{t+1}] \quad (\text{E.8})$$

which together imply

$$J_t = (1 - \delta) \frac{k}{q(\theta_t)} \quad (\text{E.9})$$

$$\Gamma_t = \frac{k}{q(\theta_t)} \quad (\text{E.10})$$

Equations (E.7) and (E.9) imply that Γ_t follows the law of motion $\Gamma_t = z_t - w_t - \tau + \beta(1 - \delta) \mathbb{E}_t \Gamma_{t+1}$, which, by (E.10), is precisely (5.16).

Finally, the first-order condition with respect to w_t for the Nash bargaining problem (5.13) is

$$\xi u'(w_t) \Gamma_t = (1 - \xi) \Delta_t \quad (\text{E.11})$$

Substituting (E.10) and (E.1) into (E.11) and using the fact that $f(\theta) = \theta q(\theta)$ yields (5.17).

The converse of the result holds since the value functions can be recovered via the corresponding Bellman equations. \square

E.1.2 Solving for the Optimal Policy

The government is maximizing

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{l} L_t(z^t) u(w_t(z^t)) + \left(\frac{D_t(z^t)}{1-e_t(z^t)} \right) u(h + b_t(z^t)) + \left(1 - L_t(z^t) - \frac{D_t(z^t)}{1-e_t(z^t)} \right) u(h) \\ -D_{t-1}(z^{t-1}) c(S_t^E(z^t)) - (1 - L_{t-1}(z^{t-1}) - D_{t-1}(z^{t-1})) c(S_t^I(z^t)) \end{array} \right\} \quad (\text{E.12})$$

subject to the conditions (5.2), (5.3), (5.14). (5.15),(5.16),(5.17) holding for all z^t , and subject to the government budget constraint (5.4).

Let $\pi(z^t)$ be the probability of history $z^t = \{z_0, z_1, \dots, z_t\}$ given the initial condition z_{-1} . Denote by η the Lagrange multiplier on (5.4), and denote the Lagrange multipliers on (5.2), (5.3), (5.14). (5.15),(5.16),(5.17) by $\beta^t \pi(z^t) \lambda_t(z^t)$, $\beta^t \pi(z^t) \alpha_t(z^t)$, $\beta^t \pi(z^t) \mu_t(z^t)$, $\beta^t \pi(z^t) \nu_t(z^t)$, $\beta^t \pi(z^t) \gamma_t(z^t)$, $\beta^t \pi(z^t) \phi_t(z^t)$, respectively. In what follows, we suppress the dependence on z^t for notational simplicity. The first order necessary conditions with respect to $b_t, e_t, w_t, S_t^E, S_t^I, L_t, D_t, \theta_t$, respectively, are:

$$(D_t - (1 - e_t) \mu_t) u'(h + b_t) = \eta D_t \quad (\text{E.13})$$

$$D_t [u(h + b_t) - u(h) - \eta b_t - \alpha_t] = \mu_t (1 - e_t) \left[u(h + b_t) - u(h) - \frac{c'(S_t^I) - c'(S_t^E)}{f(\theta_t)} \right] \quad (\text{E.14})$$

$$\gamma_t = (L_t + \mu_t + \nu_t) u'(w_t) - \phi_t \xi u''(w_t) k \theta_t \quad (\text{E.15})$$

$$\begin{aligned} \phi_t (\xi - 1) c''(S_t^E) &= D_{t-1} [(\lambda_t - \alpha_t) f(\theta_t) - c'(S_t^E)] \\ &+ \frac{c''(S_t^E)}{f(\theta_t)} [\mu_{t-1} ((1 - e_{t-1}) (1 - S_t^I f(\theta_t)) - \delta) - \mu_t - \delta \nu_{t-1}] \end{aligned} \quad (\text{E.16})$$

$$(1 - L_{t-1} - D_{t-1}) [c'(S_t^I) - \lambda_t f(\theta_t)] = \frac{c''(S_t^I)}{f(\theta_t)} [(\mu_{t-1} e_{t-1} + \nu_{t-1}) (1 - S_t^I f(\theta_t)) - \nu_t] \quad (\text{E.17})$$

$$\begin{aligned} \lambda_t &= u(w_t) - u(h) + \eta\tau + \\ &\beta \mathbb{E}_t \{c(S_{t+1}^I) + \lambda_{t+1}(1 - \delta - S_{t+1}^I f(\theta_{t+1})) + \alpha_{t+1}\delta\} \end{aligned} \quad (\text{E.18})$$

$$\begin{aligned} \alpha_t &= u(h + b_t) - u(h) - \eta b_t \\ &+ \beta(1 - e_t) \mathbb{E}_t \{c(S_{t+1}^I) - c(S_{t+1}^E) + \lambda_{t+1} f(\theta_{t+1})(S_{t+1}^E - S_{t+1}^I) + \\ &\alpha_{t+1}(1 - S_{t+1}^E f(\theta_{t+1}))\} \end{aligned} \quad (\text{E.19})$$

$$\begin{aligned} &\phi_t \xi u'(w_t) k - f'(\theta_t) \{ \lambda_t [S_t^E D_{t-1} + S_t^I (1 - L_{t-1} - D_{t-1})] - \alpha_t S_t^E D_{t-1} \} - \\ &[\gamma_t - (1 - \delta) \gamma_{t-1}] \frac{kq'(\theta_t)}{(q(\theta_t))^2} = [\mu_t - \mu_{t-1}(1 - e_{t-1} - \delta) + \nu_{t-1}\delta] \frac{c'(S_t^E) f'(\theta_t)}{(f(\theta_t))^2} + \\ &[\nu_t - \nu_{t-1} - \mu_{t-1} e_{t-1}] \frac{c'(S_t^I) f'(\theta_t)}{(f(\theta_t))^2} \end{aligned} \quad (\text{E.20})$$

The first-order necessary condition for the optimal tax rate τ is

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \{ \eta L_t(z^t) - \gamma_t(z^t) \} = 0 \quad (\text{E.21})$$

To find the optimal policy given η and τ , we solve the above system of difference equations (E.13)-(E.20) and (5.2), (5.3), (5.14). (5.15),(5.16),(5.17) for the optimal policy vector

$$\begin{aligned} \Omega(z^t) &= \{b_t(z^t), e_t(z^t), w_t(z^t), S_t^E(z^t), S_t^I(z^t), \theta_t(z^t), L_t(z^t), D_t(z^t), \\ &\lambda_t(z^t), \alpha_t(z^t), \mu_t(z^t), \nu_t(z^t), \gamma_t(z^t), \phi_t(z^t)\} \end{aligned}$$

We then pick η and τ so that (5.4) and (E.21) are satisfied.

Observe that the only period- $t - 1$ variables that enter the period- t first-order condi-

tions are

$$L_{t-1}, D_{t-1}, e_{t-1}, \mu_{t-1}, \nu_{t-1}, \gamma_{t-1},$$

and no variables from periods prior to $t - 1$ enter the period- t first-order conditions. This implies that $(z_t, L_{t-1}, D_{t-1}, e_{t-1}, \mu_{t-1}, \nu_{t-1}, \gamma_{t-1})$ is a sufficient state variable for the history of shocks z^t up to and including period t . Specifically, fix η, τ , and let $(-)$ and $(+)$ denote the previous period's variable and the next period's variable, respectively. Let

$$\Psi : (z, L_-, D_-, e_-, \mu_-, \nu_-, \gamma_-) \mapsto (b, e, w, S^E, S^I, L, D, \theta, \lambda, \alpha, \mu, \nu, \gamma, \phi)$$

be a function that satisfies

$$(D - (1 - e) \mu) u'(h + b) = \eta D \quad (\text{E.22})$$

$$D [u(h + b) - u(h) - \eta b - \alpha] = \mu(1 - e) \left[u(h + b) - u(h) - \frac{c'(S^I) - c'(S^E)}{f(\theta)} \right] \quad (\text{E.23})$$

$$\gamma = (L + \mu + \nu) u'(w) - \phi \xi u''(w) k \theta \quad (\text{E.24})$$

$$\begin{aligned} \phi(\xi - 1) c''(S^E) = & D_- [(\lambda - \alpha) f(\theta) - c'(S^E)] \\ & + \frac{c''(S^E)}{f(\theta)} [\mu_- ((1 - e_-) (1 - S^I f(\theta)) - \delta) - \mu - \delta \nu_-] \end{aligned} \quad (\text{E.25})$$

$$(1 - L_- - D_-) [c'(S^I) - \lambda f(\theta)] = \frac{c''(S^I)}{f(\theta)} [(\mu_- e_- + \nu_-) (1 - S^I f(\theta)) - \nu] \quad (\text{E.26})$$

$$\lambda = u(w) - u(h) + \eta \tau + \beta \mathbf{E} \{ c(S^I_+) + \lambda_+ (1 - \delta - S^I_+ f(\theta_+)) + \alpha_+ \delta \} \quad (\text{E.27})$$

$$\begin{aligned}
\alpha &= u(h+b) - u(h) - \eta b \\
&+ \beta(1-e) \mathbb{E} \left\{ c(S_+^I) - c(S_+^E) + \lambda_+ f(\theta_+) (S_+^E - S_+^I) + \alpha_+ (1 - S_+^E f(\theta_+)) \right\}
\end{aligned} \tag{E.28}$$

$$\begin{aligned}
&\phi \xi u'(w) k - f'(\theta) \left\{ \lambda [S^E D_- + S^I (1 - L_- - D_-)] - \alpha S^E D_- \right\} - [\gamma - (1 - \delta) \gamma_-] \frac{k q'(\theta)}{(q(\theta))^2} \\
&= [\mu - \mu_- (1 - e_- - \delta) + \nu_- \delta] \frac{c'(S^E) f'(\theta)}{(f(\theta))^2} + [\nu - \nu_- - \mu_- e_-] \frac{c'(S^I) f'(\theta)}{(f(\theta))^2}
\end{aligned} \tag{E.29}$$

as well as

$$\begin{aligned}
L &= (1 - \delta) L_- + f(\theta) [S^E D_- + S^I (1 - L_- - D_-)] \\
D &= (1 - e) [\delta L_- + (1 - s f(\theta)) D_-]
\end{aligned} \tag{E.30}$$

$$\begin{aligned}
\frac{c'(S^E)}{f(\theta)} &= u(w) - u(h+b) + (1 - e) \beta \mathbb{E} \left(c(S_+^E) + (1 - \delta - S_+^E f(\theta_+)) \frac{c'(S_+^E)}{f(\theta_+)} \right) \\
&+ e \beta \mathbb{E} \left(c(S_+^I) + (1 - S_+^I f(\theta_+)) \frac{c'(S_+^I)}{f(\theta_+)} - \delta \frac{c'(S_+^I)}{f(\theta_+)} \right)
\end{aligned} \tag{E.31}$$

$$\frac{c'(S^I)}{f(\theta)} = u(w) - u(h) + \beta \mathbb{E} \left(c(S_+^I) + (1 - S_+^I f(\theta_+)) \frac{c'(S_+^I)}{f(\theta)} - \delta \frac{c'(S_+^E)}{f(\theta_+)} \right) \tag{E.32}$$

$$\frac{k}{q(\theta)} = z - w - \tau + \beta(1 - \delta) \mathbb{E} \frac{k}{q(\theta_+)} \tag{E.33}$$

$$\xi u'(w) k \theta = (1 - \xi) c'(S^E) \tag{E.34}$$

Then the sequence defined by

$$\Omega(z^t) = \Psi(z_t, L_{t-1}(z^{t-1}), D_{t-1}(z^{t-1}), e_{t-1}(z^{t-1}), \mu_{t-1}(z^{t-1}), \nu_{t-1}(z^{t-1}), \gamma_{t-1}(z^{t-1}))$$

satisfies the system (E.13)-(E.20) and (5.2), (5.3), (5.14). (5.15),(5.16),(5.17).

To find the optimal policy given η , we therefore solve the system of functional equations (E.22)-(E.34).

E.2 Supplementary Appendix

E.2.1 The Steady State Equations for the Optimal Policy

The steady-state versions of the equations characterizing the optimal policy are as follows:

The steady-state version of the first-order condition for b :

$$(D - (1 - e)\mu)u'(h + b) = \eta D \quad (\text{E.35})$$

The steady-state version of the first-order condition for e :

$$D[u(h + b) - u(h) - \eta b - \alpha] = \mu(1 - e) \left[u(h + b) - u(h) - \frac{c'(S^I) - c'(S^E)}{f(\theta)} \right] \quad (\text{E.36})$$

The steady-state version of the first-order condition for w :

$$\gamma = (L + \mu + \nu)u'(w) - \phi\xi u''(w)k\theta \quad (\text{E.37})$$

The steady-state version of the first-order condition for S^E :

$$\begin{aligned} \phi(\xi - 1)c''(S^E) = & D[(\lambda - \alpha)f(\theta) - c'(S^E)] \\ & + \frac{c''(S^E)}{f(\theta)} [\mu((1 - e)(1 - S^I f(\theta)) - \delta - 1) - \delta\nu] \end{aligned} \quad (\text{E.38})$$

The steady-state version of the first-order condition for S^I :

$$(1 - L - D)[c'(S^I) - \lambda f(\theta)] = \frac{c''(S^I)}{f(\theta)} [(\mu e + \nu)(1 - S^I f(\theta)) - \nu] \quad (\text{E.39})$$

The steady-state version of the first-order condition for L :

$$\lambda = \frac{u(w) - u(h) + \eta\tau + \beta \{c(S^I) + \alpha\delta\}}{1 - \beta(1 - \delta - S^I f(\theta))} \quad (\text{E.40})$$

The steady-state version of the first-order condition for D :

$$\alpha = \frac{u(h+b) - u(h) - \eta b + \beta(1-e) \{c(S^I) - c(S^E) + \lambda f(\theta)(S^E - S^I)\}}{1 - \beta(1-e)(1 - S^E f(\theta))} \quad (\text{E.41})$$

The steady-state version of the first-order condition for θ :

$$\begin{aligned} & \phi\xi u'(w)k - f'(\theta) \{ \lambda [S^E D + S^I(1-L-D)] - \alpha S^E D \} - \delta\gamma \frac{kq'(\theta)}{(q(\theta))^2} \\ & = [\mu(e+\delta) + \nu\delta] \frac{c'(S^E) f'(\theta)}{(f(\theta))^2} - \mu e \frac{c'(S^I) f'(\theta)}{(f(\theta))^2} \end{aligned} \quad (\text{E.42})$$

The steady-state version of the first-order condition for τ :

$$\eta L = \gamma \quad (\text{E.43})$$

The steady state government budget constraint:

$$L\tau = \frac{D}{1-e}b \quad (\text{E.44})$$

The steady-state equation for employment, L :

$$\delta L = f(\theta) [S^E D + S^I(1-L-D)] \quad (\text{E.45})$$

The steady-state equation for the measure of eligible unemployed workers, D :

$$D = \frac{\delta L(1-e)}{1 - (1 - S^E f(\theta))(1-e)} \quad (\text{E.46})$$

The steady-state version of the optimal search condition for eligible unemployed

workers:

$$\begin{aligned} \frac{c'(S^E)}{f(\theta)} = & u(w) - u(h+b) + (1-e)\beta \left(c(S^E) + (1-\delta - S^E f(\theta)) \frac{c'(S^E)}{f(\theta)} \right) \\ & + e\beta \left(c(S^I) + (1 - S^I f(\theta)) \frac{c'(S^I)}{f(\theta)} - \delta \frac{c'(S^I)}{f(\theta)} \right) \end{aligned} \quad (\text{E.47})$$

The steady-state version of the optimal search condition for the ineligible unemployed:

$$\frac{c'(S^I)}{f(\theta)} = u(w) - u(h) + \beta \left(c(S^I) + (1 - S^I f(\theta)) \frac{c'(S^I)}{f(\theta)} - \delta \frac{c'(S^E)}{f(\theta)} \right) \quad (\text{E.48})$$

The steady-state version of the firm free entry condition:

$$\frac{k}{q(\theta)} = \frac{z - w - \tau}{1 - \beta(1 - \delta)} \quad (\text{E.49})$$

The steady-state Nash bargaining equation:

$$\xi u'(w) k\theta = (1 - \xi) c'(S^E) \quad (\text{E.50})$$

E.2.2 Derivation for the Analysis of Section 5.4.2

We want to derive the bargaining power ξ such that, in steady state, the optimal tax and benefit level is zero, in the model where benefits do not expire. We set $b = e = \tau = 0$ in the system of equations (E.35-E.50). We also set $D = 1 - L$ and $S^I = S^E$ (since benefits do not expire, all unemployed workers are eligible for benefits). We can drop the government budget constraint (E.44). Since benefits do not expire, we also drop equation (E.36) (first-order condition for e), equation (E.39) (first-order condition for S^I , equation (E.41) (first-order condition for the measure of eligible workers), equation (E.46) (the law of motion for the measure of eligible workers), and equation (E.48) (the optimal search condition for workers ineligible for

benefits). These equations are meaningless if benefits do not expire. For the same reason, we also set the multipliers α (on the law of motion for D) and ν (on the optimal search condition for the ineligible) to zero. This leaves 10 equations: (E.35), (E.37), (E.38), (E.40), (E.42), (E.43), (E.45), (E.47), (E.49), (E.50), which we solve for 10 unknowns: w , S^E , θ , L , μ , γ , ϕ , λ , η , and ξ . We obtain $\xi = 0.72$. This number is the value of the bargaining power such that, in the model without expiration, the optimal benefit level and tax would be zero (taking as given the values of the other parameters). It is the closest analogue to the Hosios condition in our model.

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