Does Unemployment Risk Affect Business Cycle Dynamics?

Sebastian Graves*

September 17, 2021

Abstract

In this paper, I show that the decline in household consumption during unemployment spells depends on both liquid and illiquid asset holdings. I also provide evidence that unemployment predicts illiquid asset withdrawal, particularly when households have few liquid assets. Motivated by these findings, I embed endogenous unemployment risk in a two-asset heterogeneous-agent New Keynesian model. The model is consistent with the evidence and suggests that aggregate shocks are amplified by a flight-to-liquidity that occurs when unemployment risk rises. This mechanism implies that unemployment insurance plays an important role as an automatic stabilizer, particularly when monetary policy is constrained.

*Federal Reserve Board. Email: sebastian.h.graves@frb.gov. I am very grateful to Simon Gilchrist, Mark Gertler, and Thomas Sargent for their advice and support throughout this project. I would like to thank Corina Boar, Jaroslav Borovička, Katarína Borovičková, Francesco Ferrante, William Gamber, Nils Gornemann, Ralph Luetticke (discussant), Virgiliu Midrigan and Gaston Navarro for helpful comments as well as seminar participants at NYU, the Federal Reserve Board, and Washington University in St. Louis. The views expressed in this paper are solely those of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or any other person associated with the Federal Reserve System.

1 Introduction

Unemployment spells are the largest source of income risk that households face. Yet the majority of household wealth is held in illiquid assets, which are not well suited to smoothing consumption during unemployment. In this paper I study the implications of these facts in a model with endogenous unemployment risk in which households trade both liquid and illiquid assets. The combination of these features provides a propagation mechanism for aggregate shocks, driven by a "flight-to-liquidity" that occurs when households face higher unemployment risk. It also suggests that an important role for unemployment insurance is its ability to dampen this amplification by lessening the cyclicality of household income risk.

I begin by presenting new empirical evidence on the relationship between unemployment, the liquidity of asset holdings, and consumption. Using data from the Consumer Expenditure Survey and the Panel Study of Income Dynamics, I show that the decline in consumption that households experience during unemployment spells depends on both their liquid and illiquid asset positions. In particular, the decline is smallest for households with significant liquid asset holdings, larger for households with only illiquid assets, and largest for households with few assets of either type.[1] This finding suggests that households with illiquid wealth are at least partially able to use such assets to smooth their consumption during unemployment. I use data from the Survey of Consumer Finances to confirm that this is the case: I show that households that experience an unemployment spell are more likely to make a withdrawal from their illiquid asset holdings than those that do not, and that this effect is stronger when the unemployment spell is long or when households have few liquid assets.

Motivated by this empirical evidence, I study a heterogeneous-agent New Keynesian (HANK) model in which households trade both liquid bonds and illiquid capital and are subject to endogenous unemployment risk due to search frictions in the labor market. First, I show that this model is consistent with the above findings. I then study the response of the economy to aggregate shocks in order to answer the following questions: How does household demand for liquid and illiquid assets change when unemployment risk rises? Does this affect business cycle dynamics? Does unemployment insurance play an important role as automatic stabilizer?

[1] In the terminology of Greg Kaplan, Giovanni L. Violante and Justin Weidner (2014), the first group are non hand-to-mouth households, the second are the wealthy hand-to-mouth, and the third are the poor hand-to-mouth.

I find that the interaction of illiquid assets and endogenous unemployment risk provides a novel propagation mechanism for aggregate shocks. Higher unemployment risk triggers a flight-to-liquidity: households increase their demand for liquid assets as these are the best suited to smoothing consumption during unemployment spells. Conversely, demand for illiquid capital declines. In the presence of sticky prices, this decline in investment leads to lower output and higher unemployment, prompting a feedback loop between unemployment risk and aggregate demand. A key feature of the model is that income risk responds endogenously to aggregate shocks through changes in the unemployment rate. I use the Current Population Survey to show that this is confirmed in the data: the cyclicality of income risk is driven by changes in unemployment risk.[2]

If there is no unemployment insurance, this propagation mechanism implies that the response of unemployment or output is around 30% larger than in a version of the model with no idiosyncratic unemployment risk. Unemployment insurance provides a source of consumption smoothing during unemployment spells, and consequently dampens the flight-to-liquidity and the feedback loop between unemployment risk and aggregate demand. Quantitatively, I find that unemployment insurance removes around half of the amplification that the flight-to-liquidity mechanism provides. Unemployment insurance is even more important when monetary policy is constrained, as the feedback loop between unemployment risk and aggregate demand is significantly strengthened at such times.

The two-asset model can also be used to study policies that affect asset adjustment costs. I use the model to study the effect of a temporary reduction in the tax faced by individuals that make a withdrawal from their illiquid asset holdings. This mirrors a policy that was included in the CARES Act in response to the COVID-19 pandemic. The model implies that such a policy is contractionary: a temporary reduction in withdrawal costs leads to a synchronized withdrawal of illiquid assets and a decline in investment.

In the final section, I compare the results from this two-asset model to those from a model where households have access to one liquid asset. Even in a calibration in which the majority of households have close to zero liquid wealth, unemployment risk and unemployment insurance have no effect on business cycle volatility without the flight-to-liquidity and decline in investment demand that occurs in the two-asset model.

[2] Fatih Guvenen, Serdar Ozkan and Jae Song (2014) use Social Security Administration data to show that the skewness of the income growth distribution is strongly pro-cyclical. The role of unemployment cannot be studied in their data as it does not include a measure of time spent employed.

1.1 Literature Review

The empirical evidence on the consumption response to unemployment spells in this paper builds on previous work by Jonathan Gruber (1997), Mark Aguiar and Erik Hurst (2005), Gabriel Chodorow-Reich and Loukas Karabarbounis (2016), Jonas Kolsrud, Camille Landais, Peter Nilsson and Johannes Spinnewijn (2018) and others. These papers either estimate the average consumption decline during unemployment or focus on heterogeneity related only to liquid asset holdings. I provide evidence that illiquid asset holdings are also an important determinant of the response of household consumption to unemployment.

A number of recent papers have investigated the source of the pro-cyclical skewness of the income growth distribution documented by Guvenen, Ozkan and Song (2014). I use the Current Population Survey (CPS) to show that this is driven entirely by cyclicality in the distribution of changes in time employed. For workers that do not experience unemployment, the skewness of the income growth distribution exhibits no cyclicality. This is consistent with evidence from Italian data provided in Eran B. Hoffmann and Davide Malacrino (2019).

This paper also contributes to the literature studying the aggregate implications of unemployment risk in HANK models. Previous papers have disagreed on whether or not unemployment risk amplifies business cycle dynamics in such models. For example, Morten O. Ravn and Vincent Sterk (2017) study a one-asset model without capital. Their baseline version of the model features a degenerate wealth distribution and has the feature that unemployment risk strongly amplifies business cycle fluctuations. On the other hand, Nils Gornemann, Keith Kuester and Makoto Nakajima (2016) study a one-asset model with capital that is calibrated to match total household wealth. In their model, where households hold a large quantity of liquid assets, business cycle volatility is unaffected by unemployment risk.

One other paper that studies unemployment risk in a model with multiple assets is Wouter J Den Haan, Pontus Rendahl and Markus Riegler (2017). The key difference between my model and theirs is that both assets in their model are liquid.[3] Whether or not unemployment risk amplifies business cycles in their model depends crucially on the degree of nominal wage stickiness.

Taken together, these papers suggest that whether or not unemployment risk amplifies busi-

[3] The two-assets in their model are bonds and equity in the firms that post vacancies in the labor market.

ness cycles depends crucially on the asset structure of the economy. In this paper I provide a quantitative assessment of the amplification provided by unemployment risk in a model that matches the distribution of both liquid and illiquid asset holdings, as well as new evidence on the consumption response to unemployment spells and the relationship between unemployment and illiquid asset adjustment. I find that unemployment risk does significantly amplify business cycle fluctuations.

By studying a HANK model with liquid and illiquid assets, my paper is closely related to the burgeoning literature following Greg Kaplan, Benjamin Moll and Giovanni L Violante (2018). Previous papers in this area have focused on models with competitive labor markets. My paper introduces search frictions in the labor market of such models.

The flight-to-liquidity mechanism in the two-asset model in my paper is related to that studied by Christian Bayer, Ralph Lütticke, Lien Pham-Dao and Volker Tjaden (2019). In a two-asset model with a competitive labor market, they show that uncertainty shocks to households' idiosyncratic productivity can lead to a decline in investment and output. The mechanism in their model is operative in response to exogenous uncertainty shocks to idiosyncratic productivity. In this paper, income risk is endogenous as any shock that affects the unemployment rate also affects household income risk. The fact that income risk is endogenous is crucial for the propagation mechanism in this paper: if income risk is exogenous there is no feedback loop between income risk and aggregate demand.

Finally, this paper contributes to the literature studying the role of unemployment insurance as an automatic stabilizer, such as Rohan Kekre (2016) and Alisdair McKay and Ricardo Reis (2016*b*). The latter paper uses a one-asset HANK model and finds that automatic stabilizers have little effect on business cycle volatility when monetary policy is not constrained, as in the one-asset model studied in this paper. My contribution to this strand of the literature is to show that unemployment insurance can affect business cycle volatility in a model with liquid and illiquid assets, through its ability to dampen the flight-to-liquidity that occurs when unemployment rise.

The rest of the paper is organized as follows. Section 2 shows that the consumption response to unemployment spells depends on both liquid and illiquid asset holdings. Section 3 documents the relationship between unemployment and the withdrawal of illiquid assets. Section 4 describes the two-asset model and Section 5 shows that it is consistent with the empirical evidence. Section 6 studies the impact of an aggregate productivity shock in different versions of the two-asset model. Section 7 compares these results with those from a one-asset model. Section 8 concludes.

2 Consumption Response to Unemployment Spells

In this section I show that the decline in household consumption during unemployment spells depends on both liquid and illiquid asset positions.

Methodology As in Kaplan, Violante and Weidner (2014), I classify households as non hand-to-mouth if they have significant liquid asset holdings, wealthy hand-to-mouth if they have few liquid assets but significant illiquid asset holdings, and poor hand-to-mouth if they have few liquid or illiquid assets. I then estimate the response of consumption to unemployment spells using the following specification:

$$\log C_{i,t} = \boldsymbol{\beta X_{i,t}} + \gamma_N U_{i,t}\mathbb{1}\{\text{N-HTM}\} + \gamma_W U_{i,t}\mathbb{1}\{\text{W-HTM}\} + \gamma_P U_{i,t}\mathbb{1}\{\text{P-HTM}\} + \epsilon_{i,t} \quad (2.1)$$

where $C_{i,t}$ denotes household consumption, $\boldsymbol{X_{i,t}}$ is a vector of control variables, and $U_{i,t} \in [0,1]$ denotes the fraction of the year that the household spent unemployed. The indicator variables denote the liquid/illiquid asset status of the household.[4] The coefficients γ_N, γ_W, and γ_P measure the decline in log consumption during unemployment for households that are either non-hand-to-mouth, wealthy-hand-to-mouth, or poor-hand-to-mouth. Using cross-sectional variation to identify the consumption decline during unemployment relies on the assumption that the set of control variables is large enough to eliminate any omitted variable bias coming from a correlation between unemployment spells and unobservables. As a cross-check, I estimate the following panel regressions based on within-household variation in consumption:[5]

$$\log \Delta C_{i,t} = \alpha_t + \gamma_N \Delta U_{i,t}\mathbb{1}\{\text{N-HTM}\} + \gamma_W \Delta U_{i,t}\mathbb{1}\{\text{W-HTM}\} + \gamma_P \Delta U_{i,t}\mathbb{1}\{\text{P-HTM}\} + \Delta\epsilon_{i,t} \quad (2.2)$$

[4] The following variables are included in the vector of controls: region-year fixed effects, race of the household head, age and age squared of the household head, family size and family size squared, education of the household head, housing tenure, number of cars, rental value of the home (split into deciles by region and year), hand-to-mouth status, and the fraction of the year spent out of the labor force.

[5] Chodorow-Reich and Karabarbounis (2016) use the same two specifications to estimate the average consumption response to unemployment spells, without conditioning on household's asset positions.

Data To estimate equation 2.1, I use data from the Consumer Expenditure Survey (CEX) for the period from 1996 to 2017, restricting the sample to households whose head is between the ages of 25 and 55. I measure consumption spending on non-durables and services by excluding spending on automobiles, housing, health expenses, and education. The CEX measures liquid asset holdings well, but has little information on illiquid asset holdings. I therefore use home-ownership as a proxy for positive illiquid asset holdings.[6] I define households as hand-to-mouth if they are in the bottom 50% of the liquid asset distribution in a given year.[7] I then define them as wealthy hand-to-mouth if they are also homeowners, and as poor hand-to-mouth if they are not.

To estimate equation 2.2, I use data from the Panel Study of Income Dynamics (PSID) for the period from 2005 to 2017. As in the CEX, I restrict the sample to households whose head is between the ages of 25 and 55. As well as having a shorter sample than the CEX, the PSID also includes less information on consumption: the measure I use is spending on food, clothing, recreation and vacations. On the other hand, the PSID does have more accurate information on illiquid wealth holdings: I measure illiquid wealth as housing equity plus the value of retirement accounts and define households as wealthy if their illiquid wealth is greater than zero. Appendices B.1 and B.2 contain further details on the construction of the datasets.

Results The results of estimating equations 2.1 and 2.2 are shown in Table 1. The estimated consumption declines are very similar using both the cross-sectional variation in the CEX and the within-household variation in the PSID. Columns 1 and 4 show estimates of the average response of consumption to unemployment without interacting unemployment with the asset indicator variables. I find that on average consumption is 20-25% lower during unemployment, in line with previous estimates.[8]

Columns 2 and 5 show the estimates when I split households only on the basis of their

[6] In Appendix C I use data from the Survey of Consumer Finances to show that home-ownership is a good proxy for illiquid asset holdings.

[7] Kaplan, Moll and Violante (2018) report that 15% of households have negative liquid asset holdings and a further 30% of households have liquid asset holdings close to zero.

[8] A large literature has studied the average response of consumption to unemployment. Chodorow-Reich and Karabarbounis (2016) find similar estimates in both the CEX and PSID. Aguiar and Hurst (2005) use the Continuing Survey of Food Intake of Individuals (CSFII) to estimate that food expenditure falls by 19% during unemployment.

Table 1: Consumption Response to Unemployment Spells

	CEX			PSID		
	(1)	(2)	(3)	(4)	(5)	(6)
$U_{i,t}$	-0.22			-0.26		
	(0.015)			(0.051)		
$U_{i,t}\mathbb{1}\{\text{N-HTM}\}$		-0.14	-0.14		-0.14	-0.14
		(0.026)	(0.026)		(0.069)	(0.069)
$U_{i,t}\mathbb{1}\{\text{HTM}\}$		-0.26			-0.32	
		(0.019)			(0.065)	
$U_{i,t}\mathbb{1}\{\text{W-HTM}\}$			-0.23			-0.28
			(0.027)			(0.131)
$U_{i,t}\mathbb{1}\{\text{P-HTM}\}$			-0.30			-0.34
			(0.026)			(0.074)
$H0 : \gamma_N = \gamma_H$		0.00			0.02	
$H0 : \gamma_N = \gamma_W = \gamma_P$			0.00			0.11
$H0 : \gamma_W = \gamma_P$			0.06			0.71

Notes: Robust standard errors in parentheses. PSID standard errors are clustered by household head. Regressions weighted using sampling weights. Final three rows of the table report the p-values for different Wald tests. CEX uses 31638 observations from 1996-2017. PSID uses 17892 observations from 2005-2017.

liquid asset holdings. The estimated consumption decline during unemployment is strongly influenced by a household's liquid asset position. Non hand-to-mouth households are able to use their liquid assets to smooth consumption during unemployment, and their consumption declines by around 15% on average. Hand-to-mouth households are less able to smooth their consumption, which declines by 25-30% on average.

Columns 3 and 6 estimate the regressions in full, now splitting hand-to-mouth households into two groups on the basis of their illiquid asset holdings. When liquid asset holdings are low, illiquid asset holdings appear to significantly affect the consumption decline during unemployment: the consumption of poor hand-to-mouth households declines by at least 30%, double the decline of non hand-to-mouth households. For the wealthy hand-to-mouth, the decline is around 25%, suggesting that illiquid assets provide households with at least some ability to smooth consumption during unemployment.

To formally test the hypothesis that the size of the consumption decline depends on liquid and illiquid asset positions, Table 1 also reports the p-values of Wald tests that (1) the decline is the same for hand-to-mouth and non hand-to-mouth households, (2) the decline is the same for all three groups, and (3) that the decline for the hand-to-mouth does not depend on illiquid asset holdings. In the cross-sectional regressions using the CEX, all hypotheses can be rejected at the 10% level, confirming that both liquid and illiquid asset positions are important for determining the size of the consumption decline during unemployment. Due to the shorter sample in the PSID, the second and third hypothesis cannot be rejected in the regressions using within-household variation.

One concern with the approach used here is that differences in the consumption response to unemployment spells may reflect heterogeneity in the effect of unemployment spells on household labor income, rather than heterogeneity in the effect of a given decline in labor income on household consumption. In Appendix F I show that this is not the case: there is no evidence that the effect of a given unemployment spell on household labor income differs across the three groups.

3 Illiquid Asset Response to Unemployment Spells

The findings in the previous section suggest that illiquid assets can play a role in smoothing consumption during unemployment spells. I now turn to data from the Survey of Consumer Finances (SCF) to understand the relationship between unemployment spells and illiquid asset holdings. I find that unemployment is a strong predictor of illiquid asset withdrawal, and that this effect is stronger when the unemployment spell is long or when households have few liquid assets.

Data I use data from the SCF from 2004 to 2019. To measure the withdrawal of illiquid assets, I focus on early withdrawals from tax-deferred individual retirement accounts (IRAs).[9] Such withdrawals are generally subject to a 10% penalty, making them a clear example of illiquid asset adjustment.[10] Along with housing equity, retirement accounts are one of the key components of household's illiquid asset holdings, making up around a fifth of all household wealth. I restrict the sample to households whose head is at most 55 years of age and has an IRA. More details on the sample are included in Appendix B.3.

[9]The SCF question about withdrawals from retirement accounts is specifically asked in relation to IRA/Keogh accounts, and does not relate to employer-sponsored accounts such as a 401(k).

[10]For Roth IRAs this penalty applies to earnings but not contributions. I obtain very similar results if I remove households with Roth IRAs from the sample.

Table 2: Illiquid Asset Withdrawal Probabilities

	Data	95% C.I.	p-value
Full Sample	0.046	(0.039, 0.054)	
No Unemployment Spell	0.040	(0.033, 0.048)	0.000
Unemployment Spell	0.105	(0.073, 0.138)	
Short Unemployment Spell	0.058	(0.026, 0.096)	0.007
Long Unemployment Spell	0.159	(0.103, 0.220)	
Unemployment Spell & Non-HTM	0.048	(0.010, 0.096)	0.007
Unemployment Spell & HTM	0.134	(0.084, 0.190)	

Notes: Probabilities constructed using sampling weights from households in the 2004 to 2019 waves of the SCF. I define an unemployment spell as short for households whose head was unemployed for 12 weeks or less. I define a household as hand-to-mouth if they have less than the median level of liquid assets. The first three sections use a sample of 4863 households. The last section uses a sample of 3649 households. Bootstrapped confidence intervals in parentheses. p-values calculated using Fisher's exact test.

Results Table 2 reports the annual probability of an early withdrawal for different groups of households. The first row shows that between four and five percent of households make an early withdrawal from their retirement account in a given year. The next two rows split the sample depending on whether or not the household head experienced an unemployment spell that year. Households whose head had an unemployment spell are between two and three times as likely to have made an early withdrawal from their retirement account as those whose head was employed for the whole year. This provides evidence that the withdrawal of such illiquid assets is an important way that households smooth their consumption in the face of unemployment shocks.

Next, I further divide the sample of households whose head was unemployed into two groups, based on the length of the unemployment spell. Households whose head was unemployed for more than 12 weeks were nearly three times as likely to make an early withdrawal than those whose head was unemployed for 12 weeks or less.

Finally, I split the sample of unemployed households based on their liquid asset holdings. As in Section 2, I define households as being hand-to-mouth if they are in the bottom 50% of the liquid asset distribution. The last two rows of Table 2 show that households with low liquid asset holdings were almost three times as likely to make an early withdrawal than those who had high liquid asset holdings if their head had an unemployment spell. Overall, these results are consistent with the idea that liquid assets are the primary source of consumption smoothing for unemployed households, but that illiquid assets are also used when households have depleted their liquid asset holdings.

The second column of Table 2 provides bootstrapped confidence intervals for each of these probabilities, while the third column reports the p-value for tests that the probability of withdrawal does not depend on employment status, the length of the unemployment spell, or liquid asset holdings. In all cases, the null hypothesis that withdrawal probabilities are the same across the two groups can be rejected at the 1% level.

The withdrawal probabilities in Table 2 do not control for other observable variables that may be correlated with an individual's employment status and their withdrawal probability. In Appendix E I show that the results are unaffected by the addition of controls for age, education, race, family size and year.

4 Two-Asset Model

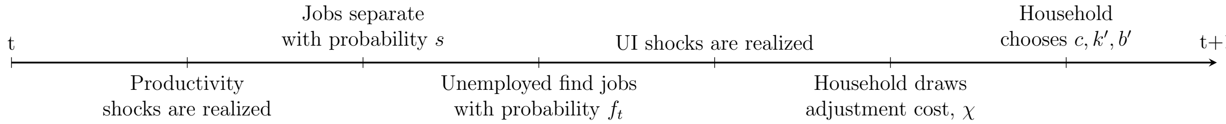
Motivated by this empirical evidence, I now study the role of endogenous unemployment risk in a heterogeneous-agent New Keynesian model with both liquid and illiquid assets. As in Kaplan, Moll and Violante (2018), households trade both liquid assets (nominal bonds) and illiquid assets (physical capital).[11] Search frictions in the labor market render unemployment, and consequently income risk, endogenous to aggregate shocks.

In the model, households face a trade-off when choosing their asset portfolio. Bond holdings can be adjusted without cost, but offer a low rate of return. Capital offers a higher return, but is costly to adjust. As bonds are liquid, they are well suited to smoothing consumption in response to transitory income shocks, such as unemployment spells. The key mechanism in this model is that a household's optimal asset portfolio depends on the level of unemployment risk in the economy, leading to a time-varying preference for holding liquid assets.

Households Time is discrete. There is a continuum of infinitely-lived households that supply labor inelastically, derive utility from consumption, and trade both liquid and illiquid

[11] I follow Kaplan, Moll and Violante (2018) in calibrating the model assuming that housing, business equity, and durables are illiquid assets. In Section J.7, I show that the main results are the same if the illiquid asset in the model is housing rather than productive capital.

Figure 1: Model Timeline



assets. Households' idiosyncratic labor productivity follows an exogenous Markov process. Households are also subject to shocks to their employment status. In each period, households that choose to adjust their illiquid asset position pay a random adjustment cost, described in more detail below. In order to study the effect of the CARES Act in Section 6.3, I also assume that households that withdraw from their illiquid asset holdings are required to pay a tax, τ_k. Within a period, the timing of events is shown in Figure 1.

For households that choose to adjust their illiquid asset holdings, the recursive problem is:

$$V_t^A(b,k,z,e) = \max_{c,b',k'} \frac{c^{1-\gamma}}{1-\gamma} + \beta \mathbb{E}_{e',z'} V_{t+1}(b',k',z',e') \tag{4.1}$$

$$\text{subject to}$$

$$k' + b' + c + \tau_k \mathbb{1}\{k' < k\}(k-k') = \mathbb{1}\{e=1\}w_t z(1-\tau_l) + \mathbb{1}\{e=0\}w_t\phi(z)(1-\tau_l) + R_t^b(b)b + R_t^k k + T_t$$

$$b' \geqslant -\underline{\mathrm{b}}$$

$$k' \geqslant 0$$

$$z' = \Gamma(z)$$

where b denotes bond holdings, z is the household's idiosyncratic productivity, and e is the household's employment status, equal to 1 if employed, 0 if unemployed and receiving unemployment insurance, and -1 if unemployed and not receiving unemployment insurance. If employed, the household receives wage w_t per unit of labor productivity. If unemployed and receiving unemployment insurance, households receive benefits equal to $w_t\phi(z)$. Both sources of labor income are subject to a linear tax, τ_l. T_t denotes a lump-sum transfer which is received by all households.[12]

Households face borrowing constraints on their holdings of both liquid and illiquid assets. Illiquid asset holdings must be non-negative. Household are able to borrow up to $\underline{\mathrm{b}}$ units

[12] This transfer is included primarily for computational reasons. It is chosen to be large enough that the lowest productivity household with no illiquid assets and liquid assets equal to $-\underline{\mathrm{b}}$ is able to cover the interest payments on their liquid debt and still have a positive level of consumption.

of the liquid asset. However, there is an exogenous wedge, κ, between the borrowing and lending rates on the liquid asset:[13]

$$R^b(b) = \begin{cases} \frac{1+i_t}{\Pi_t} & \text{if } b \geqslant 0 \\ \frac{1+i_t}{\Pi_t} + \kappa & \text{if } b < 0 \end{cases} \tag{4.2}$$

where i_t is the nominal interest rate set by the central bank, and Π_t is the gross rate of inflation. The return on the illiquid asset is derived from supplying capital services to the intermediate good producers at rate r_t^k. Capital services provided are the product of the utilization rate, u_t, and the household's holding of the illiquid asset, k. The rate of depreciation of capital is increasing in the utilization rate, as in Jeremy Greenwood, Zvi Hercowitz and Gregory W Huffman (1988).[14] Thus, the rate of return on the illiquid asset is:

$$R_t^k = 1 + r_t^k u_t - \delta_0 u_t^{\delta_1} \tag{4.3}$$

If the household doesn't adjust their illiquid asset holdings, their problem is:

$$\begin{aligned} V_t^{NA}(b, k, z, e) = \max_{c, b'} \frac{c^{1-\gamma}}{1-\gamma} + \beta \mathbb{E}_{z', e'} V_{t+1}(b', k, z', e') \quad \quad (4.4) \\ \text{subject to} \\ k + b' + c = \mathbb{1}\{e = 1\} w_t z (1 - \tau_l) + \mathbb{1}\{e = 0\} w_t \phi(z)(1 - \tau_l) + R_t^b(b) b + R_t^k k + T_t \\ b' \geqslant -\underline{\mathrm{b}} \\ z' = \Gamma(z) \end{aligned}$$

Illiquid Asset Adjustment Costs Each period, household's draw an iid adjustment cost, χ, from the uniform distribution on $[0, \bar{\chi}]$, denominated in units of utility. They then decide whether or not to adjust their capital holdings. Consequently, the value of the household's problem, conditional on a draw of χ is:

$$V_t(b, k, z, e; \chi) = \max\{V_t^A(b, k, z, e) - \chi, V_t^{NA}(b, k, z, e)\} \tag{4.5}$$

[13] This assumption helps to ensure a realistic distribution of liquid asset holdings: a large mass of households with close to zero liquid assets, and a share of around 15% of households with negative liquid asset holdings.

[14] Without variable capital utilization, the marginal product of labor, and thus the wage, would rise after a negative productivity shock that leads to an increase in unemployment.

The value before the draw of χ is:

$$V_t(b, k, z, e) = \mathbb{E}_\chi V_t(b, k, z, e; \chi) \tag{4.6}$$

Such random adjustment costs have been used in the household context by Bayer et al. (2019) and in the firm context by Aubhik Khan and Julia K Thomas (2008). When calibrating the model I discipline the size of these adjustment costs using data on liquid and illiquid wealth holdings.

Idiosyncratic Shocks Households face idiosyncratic shocks to their employment status and to their productivity. Each period, employed households are separated to unemployment with exogenous probability s. Unemployed households find employment with endogenous probability f_t. If unemployed, the probability that households receive unemployment insurance is independent across periods and equal to ξ.[15] I assume that households whose employment is terminated may immediately re-enter employment.

Previous research has shown that having a realistic income process is crucial if models are to generate a realistic wealth distribution. A key feature of the data is the high level of kurtosis of the income growth distribution. By introducing infrequent large income changes, idiosyncratic unemployment risk helps to provide high kurtosis of income growth. However, to match the level seen in the data I also assume that idiosyncratic productivity shocks are infrequent. Specifically:

$$\log z' = (1 - \rho_z)\mu_z + \rho_z \log z + \epsilon_z \tag{4.7}$$

$$\epsilon_z = \begin{cases} N(0, \sigma_z^2) & \text{with prob } \lambda_z \\ 0 & \text{with prob } 1 - \lambda_z \end{cases} \tag{4.8}$$

I introduce the normalization μ_z to ensure that the mean value of idiosyncratic productivity is equal to 1.

[15] I assume that recipiency is random as there is no evidence in the SCF that recipiency is related to liquid asset holdings: 48% of households that have unemployment spells report receiving unemployment insurance, while the proportion is 50% for households with low liquid asset holdings and 45% for households with high liquid asset holdings.

Final Good Producers There is a representative final good producer, which aggregates a continuum of intermediate goods according to the production function:

$$Y_t = \left(\int_0^1 y_{j,t}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{4.9}$$

Their profit maximization problem leads to the following demand curve for intermediate goods:

$$y_{j,t}(p_{j,t}) = \left(\frac{p_{j,t}}{P_t} \right)^{-\epsilon} Y_t \tag{4.10}$$

$$P_t = \left(\int_0^1 p_{j,t}^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}} \tag{4.11}$$

Intermediate Good Producers Intermediate goods are produced using both capital services, $k_{j,t}$, and labor, $n_{j,t}$, using the production function:

$$y_{j,t} = A_t k_{j,t}^{\alpha} n_{j,t}^{1-\alpha} \tag{4.12}$$

where A_t is the level of aggregate productivity. Intermediate good producers rent capital from households at rate r_t^k and labor from a representative labor agency at rate h_t. Their cost minimization problem implies the following value for their marginal cost of production:

$$m_t = \frac{1}{A_t} \left(\frac{r_t^k}{\alpha} \right)^{\alpha} \left(\frac{h_t}{1-\alpha} \right)^{1-\alpha} \tag{4.13}$$

I assume that intermediate good producers are owned by risk-neutral entrepreneurs who consume all profits each period.[16] Price adjustment is subject to quadratic costs.[17] Given these assumptions, the recursive form of their price-setting problem is:

$$V_t^I(p_{j,t-1}) = \max_{p_{j,t}} Y_t \left\{ \left(\frac{p_{j,t}}{P_t} - m_t \right) \left(\frac{p_{j,t}}{P_t} \right)^{-\epsilon} - \frac{\theta_P}{2} \log \left(\frac{p_{j,t}}{p_{j,t-1}} \right)^2 \right\} + \beta V_{t+1}^I(p_{j,t}) \tag{4.14}$$

where θ_P governs the size of price adjustment costs. The solution to this problem implies

[16] In Appendix J I show that the results are similar if instead profits are distributed lump-sum to households.
[17] As in Julio J Rotemberg (1982).

the following New Keynesian Phillips Curve:

$$\log(\Pi_t) = \beta \frac{Y_{t+1}}{Y_t} \log(\Pi_{t+1}) + \frac{\epsilon}{\theta_P}(m_t - m^*) \tag{4.15}$$

where $m^* = \frac{\epsilon - 1}{\epsilon}$ is the inverse of the steady-state mark-up.

Labor Agency Intermediate good producers hire labor from a representative labor agency. This agency hires households in a frictional labor market by posting vacancies. I assume that the labor agency is also owned by risk-neutral entrepreneurs. The labor agency's recursive problem is:

$$J_t(N) = \max_{N',V} (h_t - w_t)N' - cV + \beta J_{t+1}(N') \tag{4.16}$$

$$\text{subject to}$$

$$N' = (1-s)N + q(\theta_t)V$$

where N is the number of employed households, V is the number of vacancies, c is the cost of posting a vacancy, $q(\theta_t)$ is the job-filling probability, and $\theta_t \equiv \frac{V_t}{U_t}$ is labor market tightness.

There are two wages in the model: h_t is the wage paid by intermediate good producers to the labor agency, and w_t is the wage paid by the labor agency to employed households. Due to the search frictions in the model, there is a range of household wages that is between the reservation wages of households and the labor agency. I assume the following wage rule, which implies that the wage paid to households responds to the wage paid to the labor agency with elasticity ϵ_w:[18]

$$w_t = \bar{w}\left(\frac{h_t}{\bar{h}}\right)^{\epsilon_w} \tag{4.17}$$

Labor Market The labor market is characterized by search and matching frictions. Given U_t unemployed households and V_t vacancies, $M(U_t, V_t)$ new employment relationships are

[18] The complexity of the problem precludes a Nash bargaining solution for wages. Similar wage rules are used in Gornemann, Kuester and Nakajima (2016) and Den Haan, Rendahl and Riegler (2017). In Appendix J.1, I show that the main results of the paper are robust to a wide range of values of ϵ_w.

formed according to the following matching function:[19]

$$M(U_t, V_t) = \frac{U_t V_t}{(U_t^l + V_t^l)^{\frac{1}{l}}} \tag{4.18}$$

The job-finding and job-filling rates are functions of labor market tightness:

$$f(\theta_t) = (1 + \theta_t^{-l})^{-\frac{1}{l}} \tag{4.19}$$

$$q(\theta_t) = (1 + \theta_t^{l})^{-\frac{1}{l}} \tag{4.20}$$

Fiscal and Monetary Policy The central bank sets nominal interest rates according to the following Taylor rule:

$$i_{t+1} = \bar{r}^b + \psi \log(\Pi_t) \tag{4.21}$$

Unemployment insurance provides a replacement rate ϕ_0 and is capped at a fraction ϕ_1 of the average wage:

$$\phi(z) = \min\{\phi_0 z, \phi_1\} \tag{4.22}$$

The government receives revenue from the labor income tax and the illiquid asset withdrawal tax, distributes unemployment insurance and the lump-sum transfer, issues nominal bonds, and undertakes government spending. The government budget constraint is:

$$G_t + r_t^b B_t^g + T_t + \xi(1-N_t) w_t \int \phi(z) d\mu_t = \tau_l N_t w_t + \tau_l \xi (1-N_t) w_t \int \phi(z) d\mu_t + \tau_k \int \mathbb{1}\{k' < k\}(k-k') d\mu_t \tag{4.23}$$

Equilibrium An equilibrium in this model consists of paths for household decision rules $\{c_t, b_t, k_t, u_t\}_{t=0}^{\infty}$, firm decision rules $\{L_t, K_t, N_t, V_t\}_{t=0}^{\infty}$, prices and returns $\{w_t, h_t, r_t^b, r_t^k\}_{t=0}^{\infty}$, inflation $\{\Pi_t\}_{t=0}^{\infty}$, the job finding rate $\{f_t\}_{t=0}^{\infty}$, fiscal variables $\{G_t, T_t, B_t\}_{t=0}^{\infty}$, and the distribution of households $\{\mu_t\}_{t=0}^{\infty}$ such that:

1. Decision rules solve household and firm problems, taking as given aggregate variables
2. The government budget constraint holds
3. The distribution satisfies aggregate consistency conditions

[19] As in Wouter J Den Haan, Garey Ramey and Joel Watson (2000). This matching function ensures that job-finding and job-filling rates are well defined for any value of $\theta_t > 0$.

4. All markets clear

Market Clearing The following market clearing conditions must hold in equilibrium:

1. Bonds:
$$B_t^g = B_t^h = \int b \, d\mu_t \tag{4.24}$$

2. Capital:
$$K_t = K_t^h = u_t \int k \, d\mu_t \tag{4.25}$$

3. Labor:
$$L_t = N_t = \int \mathbb{1}\{e = 1\} \, d\mu_t \tag{4.26}$$

4. Goods:
$$Y_t = C_t + I_t + G_t + \Theta_t + \kappa \int \max\{-b, 0\} \, d\mu_t + cV_t \tag{4.27}$$

The goods market clearing condition takes into account price adjustment costs, Θ_t, as well as the borrowing costs and costs of posting vacancies.

4.1 Calibration

Table 3 summarizes the calibration of the model. The model period is one quarter. Below I provide further details on the calibration process.

Labor Market The quarterly job separation rate is 0.1, in line with the Job Openings and Labor Turnover Survey (JOLTS). I target a steady-state unemployment rate of 6%, and a quarterly job-filling rate of 0.71, as in Den Haan, Ramey and Watson (2000). These values imply a matching function elasticity of $l = 1.68$. I set the vacancy cost equal to 5% of the quarterly wage. Combined with the job-filling probability, this implies a hiring cost per worker of around 7% of the quarterly wage, as in Lawrence J Christiano, Martin S Eichenbaum and Mathias Trabandt (2016). With this assumption, I calibrate the steady-state wage to generate an unemployment rate of 6%. I set ϵ_w to 0.45, the elasticity of wages to labor productivity estimated by Marcus Hagedorn and Iourii Manovskii (2008).[20]

Income Process I set the values of ρ_Z, σ_Z, and λ_Z in order to target the variance and kurtosis of the annual income growth distribution, as well as the variance of the level of income. Table 4 reports these moments in the model and the data. While the high kurtosis of the income growth distribution implies that idiosyncratic productivity shocks occur infrequently, unemployment spells provide income shocks that are both more frequent and more transitory.

Wealth Distribution The key parameters affecting the liquid and illiquid wealth distributions are the coefficient of relative risk aversion, the discount factor, the borrowing wedge, and the parameter governing the degree of illiquid asset adjustment costs. I set the coefficient of relative risk aversion, γ, to 2. I calibrate the other parameters to target the total quantity of liquid and illiquid assets relative to output, as well as the fraction of households with negative liquid asset holdings. Table 4 provides various moments of the wealth distribution. The model is also close to matching the proportion of hand-to-mouth households, defined as those with liquid asset holdings close to zero.

The model slightly under-predicts the Gini coefficient for total wealth inequality. The bottom two panels of Table 4 provide further details on the share of the liquid and illiquid wealth distributions held by different quantiles. The model fails to match the wealth holdings of the top 1% of households, and instead over-predicts the share of wealth held by the rest of the top 50% of the distribution. In terms of adjustment probabilities, 3% of employed households and 11% of unemployed households adjust their illiquid asset holdings each period. The total adjustment costs that households pay are equivalent to 1.5% of aggregate output.[21]

Fiscal and Monetary Policy The particular details of unemployment insurance vary across US states. I set the cap on unemployment insurance, ϕ_1, to two-thirds of the average wage, and the replacement rate, ϕ_0, to 50%. These values are the most common across

[20]Due to movements in the mark-up, this calibration leads to wages that are more responsive to labor productivity than in the data. This ensures that the results of the model are not driven by the stickiness of real wages, as further shown in Appendix J.1.

[21]See Appendix I.4 for the derivation of this value. Kaplan, Moll and Violante (2018) report that illiquid asset adjustment costs in their model total less than 4% of GDP.

Table 3: Parameter Values

Parameter		Value	Source/Target
Separation Rate	s	0.1	JOLTS
Vacancy Cost	c	0.11	5% of Quarterly Wage
Steady-state Wage	$\bar{w}$	2.1	6% Unemployment Rate
Wage Elasticity	ϵ_w	0.45	Elasticity of Wages to Labor Productivity
Matching Function Elasticity	l	1.68	Quarterly Job-Filling Probability
Prod. Persistence	ρ_z	0.964	Variance of Annual Income
Prod. Variance	σ_z	3.2	Variance of Annual Income Growth
Prod. Shock Probability	λ_z	0.007	Kurtosis of Annual Income Growth
Risk Aversion	γ	2	Standard value
Discount Factor	β	0.973	Illiquid Assets/Output
Adjustment Cost Limit	$\bar{\chi}$	2	Liquid Assets/Output
Borrowing Limit	$\underline{b}$	1	50% of Average Quarterly Labor Income
Borrowing Wedge	κ	0.019	% Negative Liquid Assets
UI Replacement Rate	ϕ_0	0.5	Department of Labor (2018)
UI Cap	ϕ_1	0.67	Department of Labor (2018)
UI Probability	ξ	0.45	Employment & Training Administration
Income Tax	τ_l	0.3	Kaplan, Moll and Violante (2018)
Withdrawal Tax	τ_k	0.1	IRA Withdrawal Penalty
Transfer	T	0.15	Computational requirement
Return on Liquid Assets	$\bar{r}^b$	0.0025	1% Annual Rate of Return
Taylor Rule Coefficient	ψ	1.5	Kaplan, Moll and Violante (2018)
Capital Share	α	0.33	Standard value
Steady-State Depreciation Rate	δ_0	0.014	6% Annual Rate of Depreciation
Depreciation Elasticity	δ_1	2.05	Steady-State Utilization Rate of 1
Elasticity of Substitution	ϵ	20	Mark-up of 5%
Price Adjustment Cost	θ_P	250	Slope of New Keynesian Phillips Curve

Table 4: Income and Wealth Distributions

Moment	Data	Model
Variance: Annual Log Earnings	0.70	0.71
Variance: 1-year change	0.23	0.23
Kurtosis: 1-year change	17.8	18.5
Liquid Assets to Output	0.26	0.28
Illiquid Assets to Output	2.92	2.85
% Poor Hand-to-Mouth	0.1	0.08
% Wealthy Hand-to-Mouth	0.2	0.16
% Negative Liquid Assets	0.15	0.16
Gini Coefficient (Total Wealth)	0.81	0.74
Top 1% share (Liquid)	47	15
Top 1%-10% share (Liquid)	39	57
Top 10%-50% share (Liquid)	18	31
Bottom 50% share (Liquid)	-4	-3
Top 1% share (Illiquid)	33	9
Top 1%-10% share (Illiquid)	37	46
Top 10%-50% share (Illiquid)	27	44
Bottom 50% share (Illiquid)	3	1

Notes: Income moments are based on Social Security Administration data on male earnings, reported by Fatih Guvenen, Fatih Karahan, Serdar Ozkan and Jae Song (2015). Wealth moments are from the 2004 SCF, reported by Kaplan, Moll and Violante (2018). Moments from the model are calculated by simulating 1 million households until the steady-state of the model is reached, and aggregating income to an annual frequency. In the model I define household as hand-to-mouth if the absolute value of their liquid asset holdings is less than 10% of the average quarterly wage. I define households as wealthy if their illiquid asset holdings exceed 60% of average quarterly labor earnings.

states, as reported in Department of Labor (2018). The parameter ξ governs the probability that unemployed households receive unemployment insurance. Figure 11 in Appendix A shows that a large fraction of unemployed individuals do not actually receive unemployment insurance, even if their unemployment spell is short enough to qualify for benefits. I set ξ equal to 0.45, the average UI recipiency rate for the short-term unemployed. I set the illiquid asset withdrawal tax to 10%, equal to the standard penalty for early withdrawals from retirement accounts. I set the linear income tax to 30%, and the value of the transfer to 0.15, equal to around 8% of the average wage. I set the steady-state real return on bonds to 1% on an annual basis. I assume that the Taylor rule coefficient on inflation is 1.5.

Remaining Parameters I calibrate the remaining parameters of the model to standard values in the New Keynesian literature. The coefficient on capital in the intermediate good production function is set to 0.33. I choose δ_0 such that the depreciation rate on capital is 6% at an annual frequency and δ_1 such that the steady-state utilization rate is equal to 1. I set the elasticity of substitution, ϵ, to 20, implying a steady-state mark-up of 5%. I choose a low mark-up to ensure that profits are small, given that I assume that all profits are consumed by risk-neutral entrepreneurs. I then set the value of the price-adjustment cost, θ_P, to 250, which implies that the slope of the New-Keynesian Phillips curve is 0.08. If price-adjustment was of the Calvo form, this would be equivalent to prices lasting four quarters on average.

5 Model Validation

Before turning to the effect of aggregate shocks in the model, I start by checking that the model is consistent with the empirical findings in Sections 2 and 3. To do this, I simulate a large panel of households in the steady-state of the model and aggregate to an annual frequency. Using this panel, I then run the same consumption regressions as in Section 2, and calculate illiquid asset withdrawal probabilities as in Section 3.

Table 5: Consumption Response to Unemployment Spells

	Data (CEX)			Two-Asset Model		
	(1)	(2)	(3)	(4)	(5)	(6)
$U_{i,t}$	-0.22			-0.20		
	(0.015)					
$U_{i,t}\mathbb{1}\{\text{N-HTM}\}$		-0.14	-0.14		-0.11	-0.11
		(0.026)	(0.026)			
$U_{i,t}\mathbb{1}\{\text{HTM}\}$		-0.26			-0.28	
		(0.019)				
$U_{i,t}\mathbb{1}\{\text{W-HTM}\}$			-0.23			-0.19
			(0.027)			
$U_{i,t}\mathbb{1}\{\text{P-HTM}\}$			-0.30			-0.35
			(0.026)			

Notes: Robust standard errors in parentheses. Regressions weighted using CEX sampling weights, with 31638 observations from 1996 to 2017. In both the model and the data households are defined as hand-to-mouth if their liquid asset holdings are below the median. In the CEX I define households as wealthy if they are homeowners. In the model I define households as wealthy if their illiquid asset holdings exceed 60% of average quarterly labor earnings.

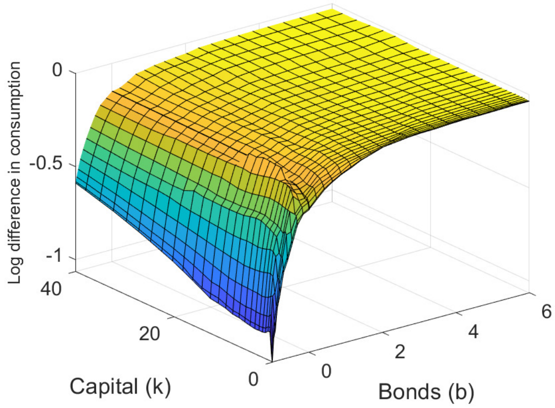
5.1 Consumption Response to Unemployment Spells

Table 5 compares the regression results in the model and the data. Column (4) shows that the average consumption decline during unemployment in the model is close to that estimated in the data. Columns (5) and (6) show that the model also matches the ranking seen in the data, including the important role for illiquid asset holdings within the hand-to-mouth group.

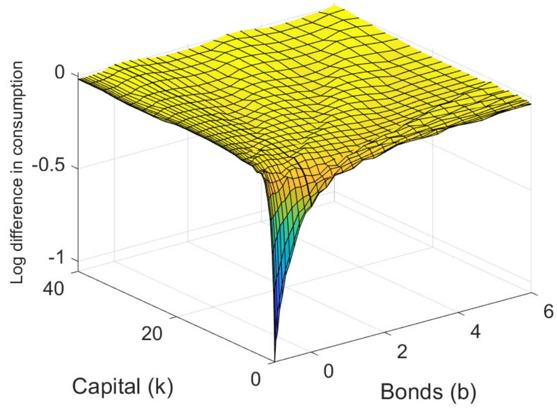
To understand how the two-asset model generates these patterns, Figure 2 plots the log difference between the consumption of employed and unemployed households across the liquid and illiquid wealth distributions. The left panel shows the decline in consumption if the household does not adjust their illiquid asset holdings. The right panel shows the decline in consumption if they do adjust their illiquid asset holdings.

The left panel shows that liquid assets are the primary determinant of the consumption decline during unemployment for households that do not adjust their illiquid asset holdings. Thus, the consumption decline for wealthy hand-to-mouth households that do not adjust is similar to that of poor hand-to-mouth households. On the other hand, the right panel shows

Figure 2: Consumption Declines and Illiquid Asset Adjustment



(a) Not Adjusting k



(b) Adjusting k

Notes: These figures plot the log difference in consumption between employed and unemployed households at the median level of productivity. The mean (median) value of k in the steady-state of the model is 34 (6). The mean (median) value of b is 3.4 (0.5). These figures are shown at the median level of idiosyncratic productivity.

that if wealthy hand-to-mouth households do adjust their illiquid asset holdings, then the consumption decline during unemployment is negligible. The consumption decline during unemployment for this group is similar to that of non hand-to-mouth households.

Overall, the model is able to generate a realistic consumption decline for wealthy hand-to-mouth households because only a fraction of wealthy hand-to-mouth households choose to liquidate capital during unemployment. Consequently, the average consumption decline for the wealthy hand-to-mouth is between that of the poor hand-to-mouth and the non hand-to-mouth, as in the data.

5.2 Illiquid Asset Response to Unemployment Spells

Table 6 compares the illiquid asset withdrawal probabilities in the model and the data. As individual retirement accounts are only one type of illiquid asset, there is no direct comparability between the levels of the withdrawal probabilities in the model and the data.[22] The true withdrawal probabilities in the data are higher when including withdrawals from

[22] Also, household decisions regarding retirement accounts are intimately tied up with life-cycle considerations, from which the model abstracts.

Table 6: Illiquid Asset Withdrawal Probabilities

	Probability	Model
Full Sample	0.046	0.132
No Unemployment Spell	0.040	0.114
Unemployment Spell	0.105	0.225
Short Unemployment Spell	0.058	0.177
Long Unemployment Spell	0.159	0.319
Unemployment Spell & Non-HTM	0.048	0.096
Unemployment Spell & HTM	0.134	0.343

Notes: Probabilities constructed using sampling weights from the 2004 to 2019 waves of the SCF. The first three sections use a sample of 4863 households. The last section uses a sample of 3649 households. I define an unemployment spell as short for households whose head was unemployed for 12 weeks or less. I define a household as hand-to-mouth if they have less than the median level of liquid assets.

other illiquid assets, such as housing.[23] However, it is possible to validate the model by considering the relative effect of unemployment and liquid asset holdings on withdrawal probabilities.

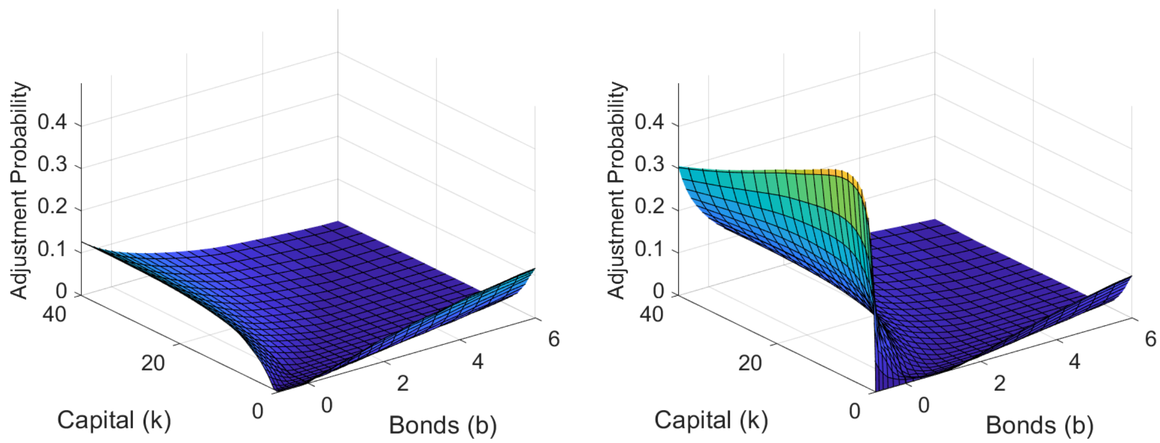
The model matches the patterns seen in the data. In the model, the withdrawal probability for households who experienced an unemployment spell is significantly higher than that of households who did not. As in the data, this is driven particularly by households who experienced long unemployment spells and those who became unemployed when they had few liquid assets.

Figures 3a and 3b plot illiquid asset adjustment probabilities across the liquid and illiquid wealth distributions for employed and unemployed households to highlight the importance of employment status for illiquid asset adjustment in the model. In both cases, adjustment probabilities are highest when households hold unbalanced portfolios: households with high illiquid asset holdings but low liquid asset holdings would like to shift their portfolio towards liquid assets, while households with low illiquid asset holdings and high liquid asset holdings would like to shift their portfolios in the opposite direction.

Comparing the two figures shows how employment status affects adjustment probabilities.

[23]For example, Neil Bhutta and Benjamin J Keys (2016) find that an average of 11% of households extracted equity from their home each year between 1999 and 2010.

Figure 3: Adjustment Probabilities and Employment Status



(a) Employed

(b) Unemployed

Notes: The mean (median) value of k in the steady-state of the model is 34 (6). The mean (median) value of b is 3.4 (0.5). These figures are shown at the median level of idiosyncratic productivity.

Relative to employed households, unemployed households are much more likely to withdraw from their illiquid asset holdings when their liquid asset holdings are low. Figure 2 showed that such households can only smooth their consumption during unemployment if they liquidate their illiquid asset holdings. Unemployed households are also less likely to increase their illiquid asset holdings when their liquid asset holdings are high, as they are aware that they may need to use their their liquid assets to smooth consumption if the unemployment spell is persistent.

6 Response of the Economy to Aggregate Shocks

In this section, I consider the response of the economy to an unanticipated negative shock to aggregate productivity.[24] To understand whether or not unemployment risk affects business cycle dynamics, and if unemployment insurance is an important automatic stabilizer, I compare the impulse responses of three different versions of the model: the baseline model, a model with no unemployment insurance, and a model with no unemployment insurance but in which households pool their idiosyncratic unemployment risk perfectly.

[24] I consider a shock which lowers aggregate productivity by 0.1% on impact, and has a quarterly persistence equal to 0.9.

In these alternate versions of the model, I adjust $\bar{w}$ so that the unemployment rate remains at 6% in the steady-state. I also assume that the steady-state real interest rate remains at 1% in each version of the model. Table 8 in Appendix A shows that the steady-state wealth distributions are similar in all three versions of the model.[25]

By comparing the response to the shock in the second and third versions of the model, I am able to assess the importance of unemployment risk on aggregate fluctuations. The baseline model then shows the degree to which unemployment insurance is able to mitigate any amplification due to idiosyncratic unemployment risk. Figure 4 plots the impulse response of key variables to the aggregate productivity shock in each version of the model.

In all versions of the model, the decline in aggregate productivity causes a decline in vacancy posting and a rise in the unemployment rate. In response to an increase in unemployment risk, there is a flight-to-liquidity: demand for liquid assets increases, as these are best-suited to smoothing consumption during unemployment spells. Investment in capital falls, as employed households postpone investing in illiquid assets, and unemployed households withdraw from their illiquid asset holdings. In the presence of nominal rigidities, this decline in investment demand lowers aggregate output, raises unemployment, and initiates a feedback loop between unemployment risk and aggregate demand in the economy.

This mechanism is not operative if unemployment risk is pooled, and it is dampened if households have access to unemployment insurance. By providing a source of income during unemployment spells, unemployment insurance lessens the need for holding liquid assets to smooth consumption during such times. Figure 5 shows the response of illiquid asset adjustment probabilities in each version of the model. The key difference is that without unemployment insurance there is a much larger increase in the probability of illiquid asset withdrawal in comparison to the other two versions of the model.

The quantitative significance of this mechanism can be seen in Figure 4. The main result is that the unemployment rate rises by around 30% more in the version without unemployment insurance than in the version with no unemployment risk, and that unemployment insurance removes around half of this amplification. The more unemployment risk that households face, the larger is the decline in investment, and the sharper is the decline in the real interest

[25]In response to the aggregate shock, I assume that government spending adjusts to balance the government's budget constraint each period. Kaplan, Moll and Violante (2018) discuss the importance of assumptions regarding fiscal policy in HANK economies. In Appendix J I consider an alternative fiscal policy in which the lump-sum transfer adjusts.

Figure 4: Response to an Aggregate Productivity Shock

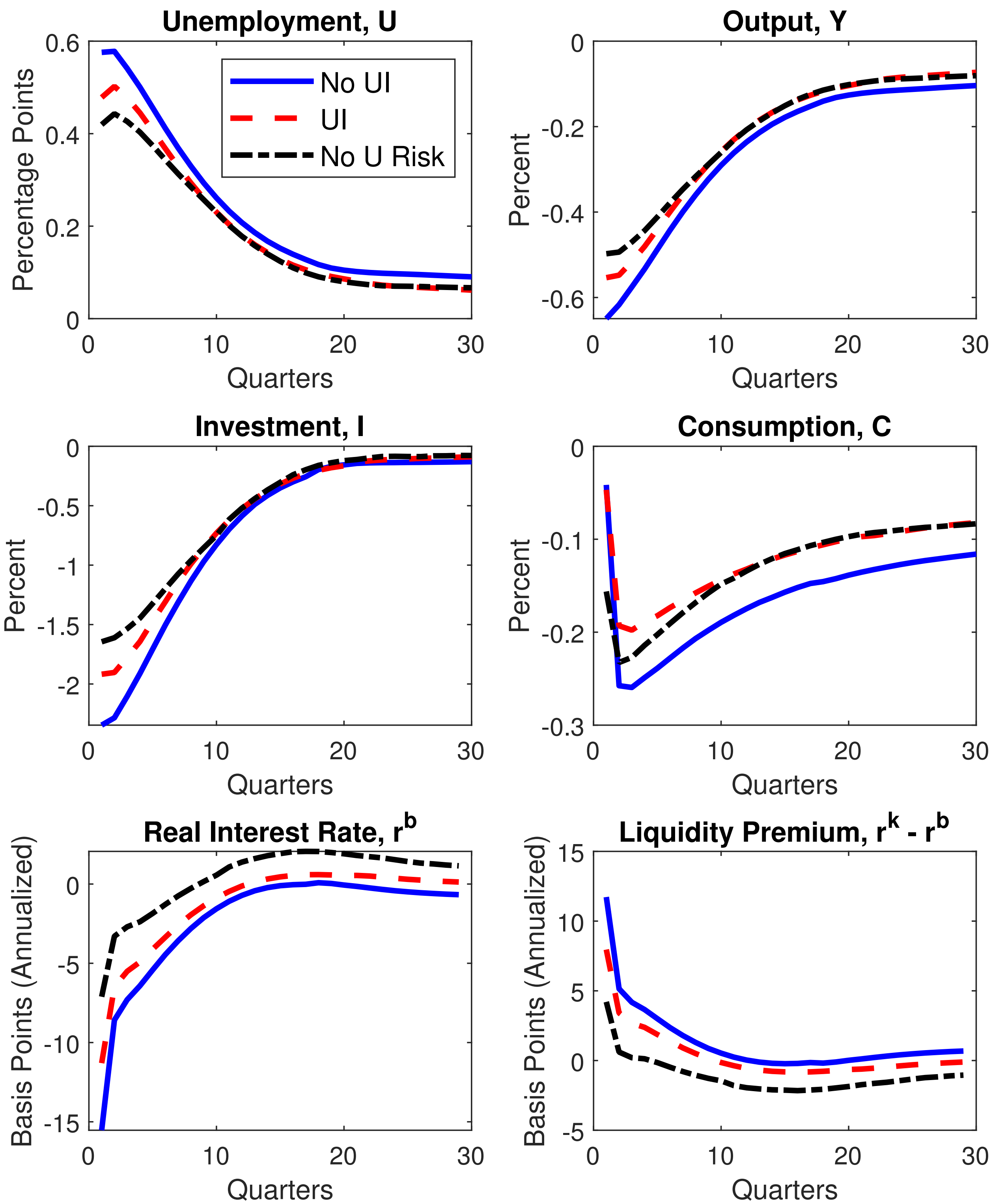
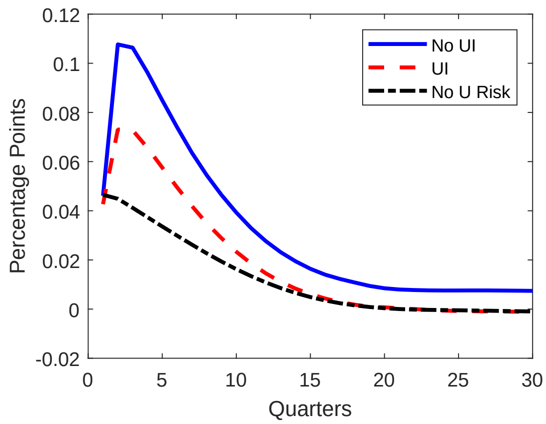
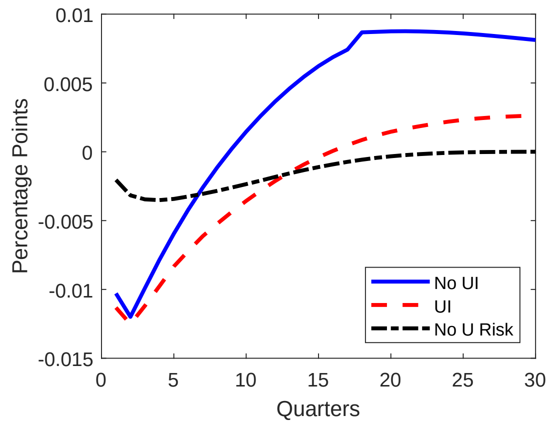


Figure 5: Response of Illiquid Asset Adjustment Probabilities



(a) Withdrawing from Illiquid Asset



(b) Investing in Illiquid Asset

rate. The bottom-right panel of Figure 4 plots the liquidity premium, the spread between the rate of return on capital and the real interest rate. In all versions of the model, the spread is counter-cyclical, but this effect is stronger the more unemployment risk households face.

Appendix J undertakes a number of robustness exercises. The amplification implied by unemployment risk is robust to heterogeneous job separation rates, alternative fiscal policy assumptions, assuming that profits are distributed directly to households, a wide range of values for the responsiveness of wages, and an alternative wage rule in which wages respond to unemployment risk.[26]

6.1 The Endogenous Response of Income Risk

In this section, I show that the endogenous response of income risk to the aggregate shock in the model is consistent with empirical evidence from the CPS. Guvenen, Ozkan and Song (2014) use Social Security Administration data to show that the skewness of the income growth distribution is strongly pro-cyclical: recessions are times when large negative income changes become much more likely. Using data from the March supplement of the CPS, I am able to break down income growth into hours growth and wage growth. Figure 6

[26]It would also be interesting to extend the model to allow for varying search effort on the part of unemployed agents. I have not undertaken this extension due to the computational complexity of the current model without this extra decision on behalf of households.

shows that the pro-cyclical skewness of income growth is entirely driven by the pro-cyclical skewness of hours growth, while the distribution of hourly wage growth doesn't vary over the business cycle. Thus, large negative income changes in recessions become more likely due to an increased likelihood of a large decline in hours worked, i.e. an unemployment spell. In Appendix G I provide more detail on the CPS data and additional evidence that the cyclicality of income growth is driven by the extensive margin, specifically the cyclicality of unemployment risk. I also estimate the response of the skewness of hours growth and wage growth to identified macroeconomic shocks.

Figure 7 shows the effect of the aggregate shock on the skewness of the hours growth, wage growth and income growth distributions in the model. As in the data, the skewness of income growth is pro-cyclical, and it is driven entirely by the skewness of hours growth, which is around twice as volatile as the skewness of income growth. In the model, the skewness of the wage growth distribution is acyclical by construction, as it depends only on the exogenous stochastic process for idiosyncratic productivity.

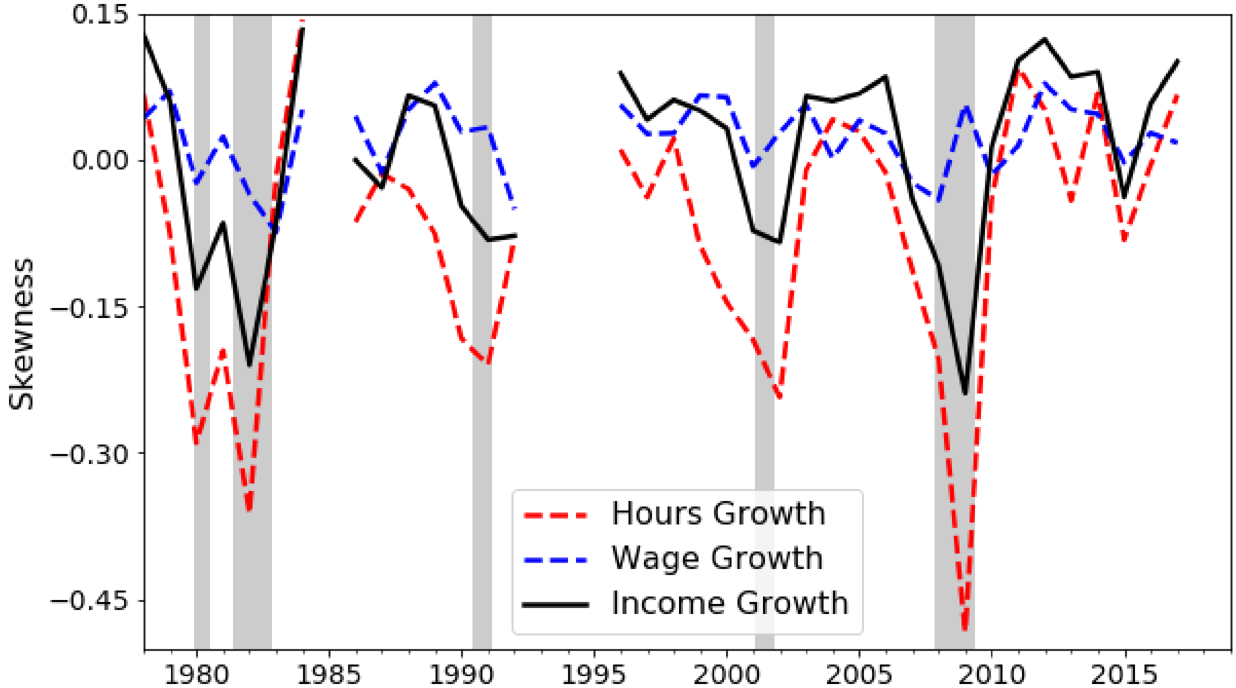
Figure 7 is also useful for understanding why the flight-to-liquidity mechanism is not operative in the version of the model where unemployment risk is pooled. In this version of the model, the only source of income risk comes from idiosyncratic productivity shocks, so the skewness of the income growth distribution is unaffected by changes in the unemployment rate.

6.2 The Importance of Unemployment Insurance at the ZLB

I now consider how the importance of unemployment insurance as an automatic stabilizer depends on the responsiveness of monetary policy. I consider the response of the economy to the same aggregate productivity shock considered previously. However, I now assume that there is an exogenous lower bound on the nominal interest rate, such that monetary policy follows a truncated Taylor rule:

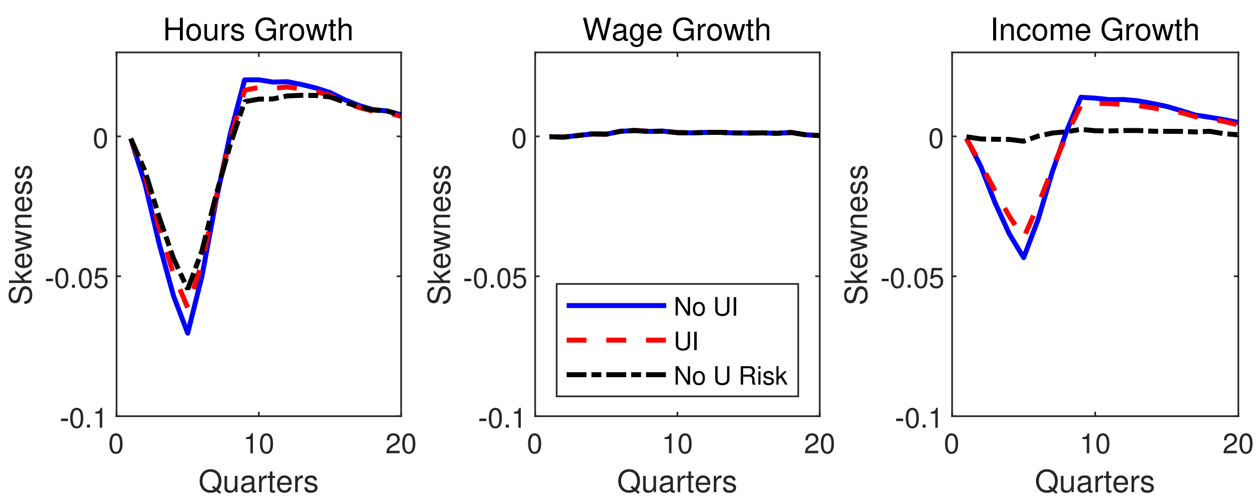
$$i_t = \max\{\bar{r}^b + \psi \log(\Pi_t), \underline{\text{i}}\} \tag{6.1}$$

Figure 6: Breakdown of Income Growth Skewness in the Data



Notes: Data from the Current Population Survey. Skewness measured using Pearson's second skewness coefficient (median skewness).

Figure 7: Model Response of Income Risk



Notes: Skewness measured using Pearson's second skewness coefficient (median skewness).

I set $\underline{i}$ such that monetary policy is constrained for 3 quarters in the baseline version of the model.[27] Figure 8 compares the impulse response functions of the baseline model with those from the versions of the model without unemployment insurance or without unemployment risk.

When monetary policy is constrained, the decline in investment demand that follows the increase in unemployment risk is not offset by lower interest rates. This strengthens the feedback loop between aggregate demand and unemployment risk, and increases the amplification coming from the flight-to-liquidity mechanism. Unemployment insurance plays a much more important role than in normal times: without unemployment insurance, unemployment rises by around 60% more than in the baseline model. Monetary policy is constrained for longer, and both investment and inflation decline by almost twice as much as they do with the baseline level of unemployment insurance.

The COVID-19 pandemic has pushed nominal interest rates back to the zero lower bound in almost all advanced economies. The message provided by this section is that unemployment insurance is particularly important as an automatic stabilizer at this time.

6.3 Tax-Free Illiquid Asset Withdrawals in the CARES Act

In response to the COVID-19 pandemic, the CARES Act removed the 10% early withdrawal penalty on retirement accounts until the end of 2020 for individuals that experience adverse financial consequences due to the pandemic. The two-asset model in this paper is a useful laboratory for studying the effect of such a policy.

In this section, I investigate the implications of this policy in the baseline calibration of the model. Specifically, I assume that the withdrawal tax on illiquid assets is reduced from 10% to 5% for three quarters for individuals that are unemployed. I do not remove the tax entirely as in reality retirement accounts are only a fraction of total illiquid asset holdings. For simplicity, I assume that this policy occurs in the steady-state of the model, rather than layering it on top of an additional aggregate shock to mimic the COVID-19 recession.

[27] The standard method for engineering a ZLB episode in New Keynesian models is a temporary rise in the discount factor, β. This does not work in this model due to the presence of capital and labor market frictions. Increasing the discount factor leads to a decline in unemployment, both because of an increase in the capital stock, which increases labor productivity, but also because a higher discount factor raises the value of a filled vacancy to the labor agency.

Figure 8: Response to Shock with Constrained Monetary Policy

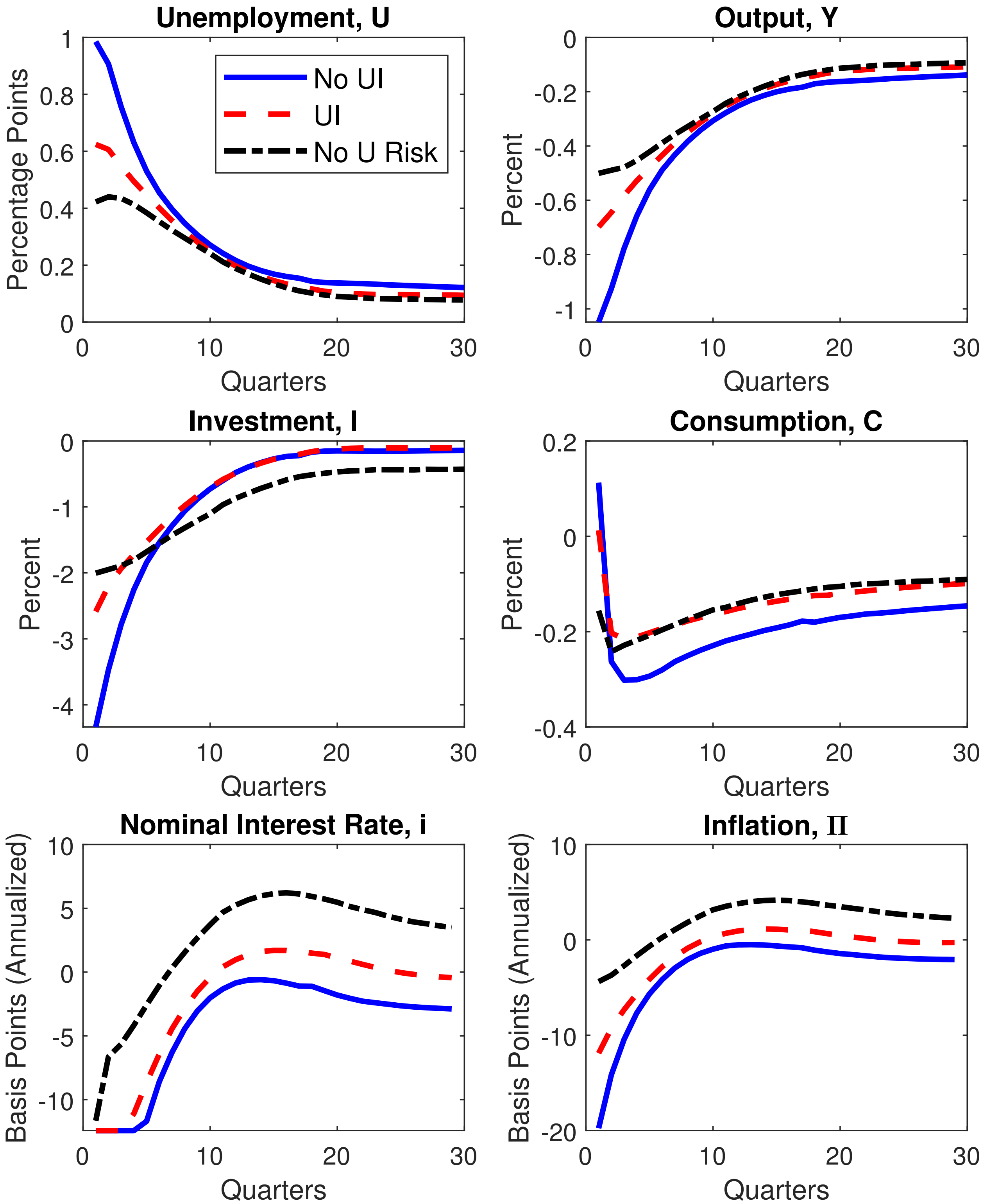


Figure 9 shows the results of this policy in the baseline version of the model. While the policy helps unemployed individuals smooth their consumption, it actually has a contractionary effect. The policy leads to a synchronized withdrawal of illiquid assets, and consequently a significant decline in investment in physical capital. This is only partially offset by an increase in consumption. The overall effect is a decline in demand, a fall in the equilibrium interest rate, and consequently a rise in unemployment.

7 Comparison with a One-Asset Model

The key contribution of the model in this paper is to provide a quantitative assessment of the amplification provided by unemployment risk in a model which matches both liquid and illiquid wealth distributions. However, it is also important to understand the exact source of this amplification.

In the previous sections I have argued that the amplification in the two-asset model is driven by the flight-to-liquidity mechanism that is a feature of such a model. However, Ravn and Sterk (2017) show that one-asset models can also exhibit amplification, driven by a more general counter-cyclical precautionary saving motive. To understand the specific importance of the flight-to-liquidity mechanism for generating amplification, I now consider the response to the same aggregate productivity shock as in Section 6 in a model with only one asset, liquid bonds.

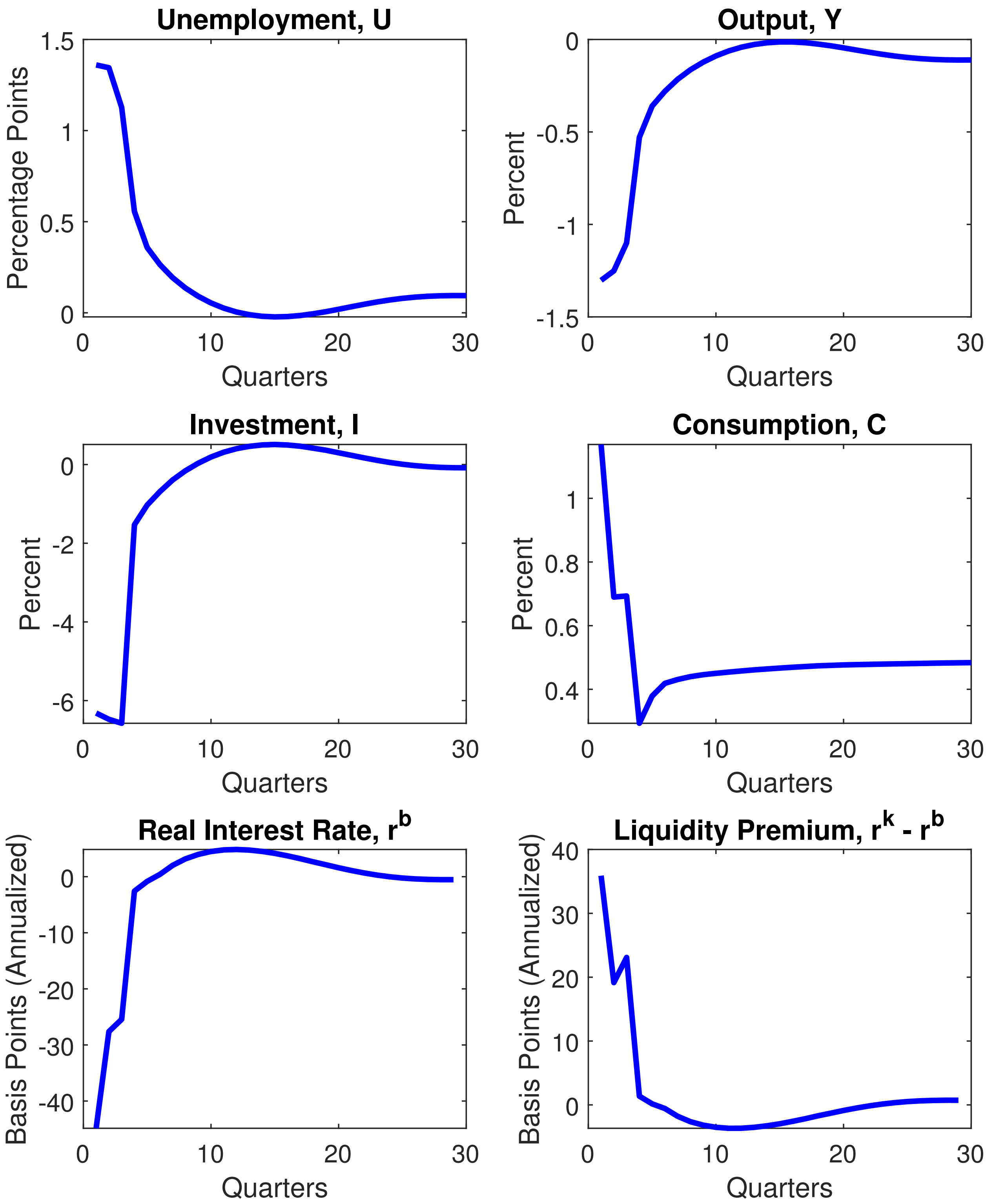
Without illiquid capital the production function for the intermediate good producers is:

$$y_{j,t} = A_t n_{j,t} \tag{7.1}$$

Their marginal cost is equal to $m_t = \frac{h_t}{A_t}$. Given this, the New Keynesian Phillip's Curve is unchanged. The household's problem simplifies to:

$$\begin{aligned} V_t(b, z, e) = \max_{c,b'} \frac{c^{1-\gamma}}{1-\gamma} + \beta \mathbb{E}_{e',z'} V_{t+1}(b', z', e') \quad (7.2) \\ \text{subject to} \\ b' + c = \mathbb{1}\{e = 1\} w_t z (1 - \tau_l) + \mathbb{1}\{e = 0\} w_t \phi(z)(1 - \tau_l) + R_t^b(b) b + T_t \\ b' \geqslant \underline{\text{b}} \\ z' = \Gamma(z) \end{aligned}$$

Figure 9: Response to Temporary Reduction of Withdrawal Tax



Notes: Response to a halving of the illiquid asset withdrawal tax for unemployed individuals for three quarters.

Table 7: Liquid Wealth Distribution

Moment	Data	One-Asset Model	Two-Asset Model
Median Liquid Assets/Average Income	0.12	-0.06	0.20
% Negative Liquid Assets	0.15	0.14	0.16
% Hand-to-Mouth	0.30	0.52	0.25
Liquid Assets/Output	0.26	2.14	0.28

Notes: Median liquid asset holdings reported relative to average quarterly wage income.

The rest of the model: the labor agency's problem and fiscal and monetary policy rules are exactly as in the two-asset model. I leave the calibration as close to the two-asset model as possible. Specifically, I leave all parameters unchanged except the following: I adjust the mean wage $\bar{w}$ to keep the unemployment rate at 6% in the steady state and then lower the values of the vacancy cost c, the transfer T, and the borrowing limit $\underline{b}$ such that they remain the same relative to $\bar{w}$.

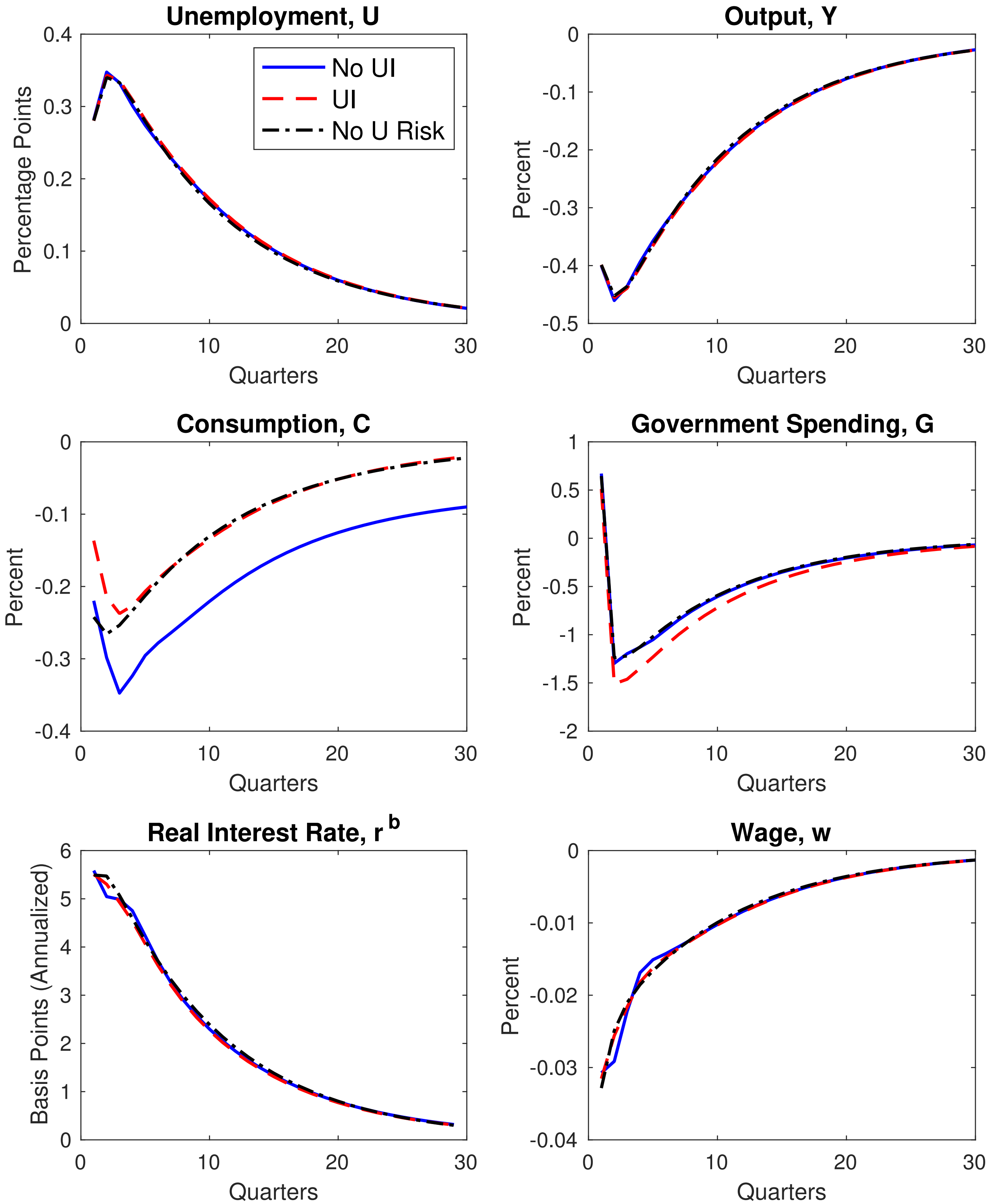
Table 7 shows that the one-asset model slightly under-predicts median liquid asset holdings and slightly over-predicts the fraction of households that hold close to zero liquid assets. The one area where the calibration of the one-asset model fails significantly is the total liquid assets to output ratio. Due to the significant income inequality in the model, it is not possible to simultaneously match both median and mean liquid asset holdings. However, despite overstating total liquid asset holdings, the model delivers a decline in consumption in response to an unemployment spell that is almost twice as large as that seen in the data or the two-asset model.[28]

Figure 10 plots the response of key variables to the aggregate productivity shock in all three versions of the one-asset model. The main result is that the path of the unemployment rate and aggregate output is almost identical in all three scenarios. Despite the fact that this is a calibration in which consumption responds strongly to unemployment, idiosyncratic unemployment risk does not affect business cycle dynamics in this model, and unemployment insurance plays no role as an automatic stabilizer.

Why does the one-asset model have such different predictions to the two-asset model? The key is in the path of the real interest rate. In the two-asset model, the version without unemployment insurance saw a substantially larger decline in the real interest rate, relative to the other two versions of the model. The one-asset model shows that the key driver of this

[28]See Table 10 in Appendix D for further details.

Figure 10: Aggregate Productivity Shock (One-Asset Model)



difference was the flight-to-liquidity caused by higher unemployment risk: In the one-asset model, the interest rate path is almost identical in all three versions of the model.

Without the flight-to-liquidity mechanism, the only forces affecting the path of the real interest rate come from household's consumption/saving decisions. On the one hand, when the unemployment rate is elevated, employed households have a greater incentive to save, as they are more likely to become unemployed in the future. However, there is an opposing force coming from the consumption smoothing motive of unemployed households, who wish to borrow while their income is temporarily low. Figure 10 implies that these forces almost exactly offset each other, such that the path of the real interest rate is unaffected by the degree of unemployment risk or generosity of unemployment insurance. In a New Keynesian model such as this, equivalence of the path of the real interest rate translates into equivalence in the path of aggregate output and employment.

The lack of amplification in the one-asset model here is in contrast to the results in Ravn and Sterk (2017) In Appendix H I consider alternative calibrations of the one-asset model in this paper and show that significant amplification of aggregate shocks does occur as liquid assets are withdrawn from the model and the wealth distribution converges towards the degenerate distribution that their model features.

8 Conclusion

This paper shows that the combination of endogenous unemployment risk and the presence of illiquid assets provides an important propagation mechanism for aggregate shocks: higher unemployment risk leads to a flight-to-liquidity and initiates a feedback loop between unemployment risk and aggregate demand. Unemployment insurance plays an important role as an automatic stabilizer, particularly if monetary policy is constrained. The presence of both liquid and illiquid assets is key: I use a model with only one liquid asset to show the importance of the flight-to-liquidity mechanism in generating amplification in the two-asset model.

The two-asset model is also consistent with new empirical evidence on the relationship between unemployment and the liquidity of asset holdings. Using data from the Consumer Expenditure Survey, I find that the consumption decline during unemployment is largest for poor hand-to-mouth households, smaller for the wealthy hand-to-mouth, and smallest for the non hand-to-mouth. The two-asset model is able to match this finding due to the costs associated with adjusting illiquid asset holdings. Some wealthy hand-to-mouth households pay these adjustment costs, and consequently are able to smooth their consumption as well as the non hand-to-mouth, while others do not pay the adjustment costs and are unable to smooth their consumption, like poor hand-to-mouth households.

In the model, unemployed households do not need to withdraw from their illiquid asset holdings until they have first run down their liquid asset holdings. However, when their liquid asset holdings are depleted, they are then likely to withdraw from their illiquid asset holdings. Consequently, unemployed households are more likely to make a withdrawal from their illiquid asset holdings than employed households, particularly if their unemployment spell is long or their liquid asset holdings are low. Using data from the Survey of Consumer Finances I show that these patterns are confirmed in the data.

The model suggests that an important role for unemployment insurance is its ability to dampen aggregate fluctuations by lessening the flight-to-liquidity that occurs when unemployment risk is heightened. However, the model has abstracted from search effort on the part of unemployed workers, or any mechanism by which unemployment insurance affects the level of wages. Consequently, there is likely an important trade-off between the effect of unemployment insurance on the volatility of the unemployment rate and the effect on the average level of unemployment. I leave an investigation of this trade-off to future work.

References

Acharya, Sushant, and Keshav Dogra. 2018. "Understanding HANK: Insights from a PRANK." *FRB of New York Staff Report*, , (835).

Aguiar, Mark, and Erik Hurst. 2005. "Consumption versus Expenditure." *Journal of Political Economy*, 113(5): 919–948.

Aiyagari, S. Rao, and Mark Gertler. 1991. "Asset returns with transactions costs and uninsured individual risk." *Journal of Monetary Economics*, 27(3): 311–331.

Auclert, Adrien, Matthew Rognlie, and Ludwig Straub. 2018. "The Intertemporal Keynesian Cross." National Bureau of Economic Research, Inc NBER Working Papers 25020.

Bayer, Christian, Ralph Lütticke, Lien Pham-Dao, and Volker Tjaden. 2019. "Precautionary savings, illiquid assets, and the aggregate consequences of shocks to household income risk." *Econometrica*, 87(1): 255–290.

Bhutta, Neil, and Benjamin J Keys. 2016. "Interest rates and equity extraction during the housing boom." *American Economic Review*, 106(7): 1742–74.

Birinci, Serdar, and Kurt Gerrard See. 2018. "How Should Unemployment Insurance vary over the Business Cycle?"

Bloom, Nicholas. 2009. "The Impact of Uncertainty Shocks." *Econometrica*, 77(3): 623–685.

Boppart, Timo, Per Krusell, and Kurt Mitman. 2018. "Exploiting MIT shocks in heterogeneous-agent economies: the impulse response as a numerical derivative." *Journal of Economic Dynamics and Control*, 89: 68–92.

Braxton, J. Carter, Gordon Phillips, and Kyle Herkenhoff. 2018. "Can the Unemployed Borrow? Implications for Public Insurance." Society for Economic Dynamics 2018 Meeting Papers 564.

Browning, Martin, and Thomas F Crossley. 2001. "Unemployment insurance benefit levels and consumption changes." *Journal of public Economics*, 80(1): 1–23.

Busch, Christopher, David Domeij, Fatih Guvenen, and Rocio Madera. 2018.

"Asymmetric Business-Cycle Risk and Social Insurance." National Bureau of Economic Research.

Challe, Edouard, and Xavier Ragot. 2015. "Precautionary saving over the business cycle." *The Economic Journal*, 126(590): 135–164.

Challe, Edouard, Julien Matheron, Xavier Ragot, and Juan F Rubio-Ramirez. 2017. "Precautionary saving and aggregate demand." *Quantitative Economics*, 8(2): 435–478.

Cho, Daeha. 2018. "Unemployment Risk and Business Cycles."

Chodorow-Reich, Gabriel, and Loukas Karabarbounis. 2016. "The cyclicality of the opportunity cost of employment." *Journal of Political Economy*, 124(6): 1563–1618.

Christiano, Lawrence J, Martin S Eichenbaum, and Mathias Trabandt. 2016. "Unemployment and business cycles." *Econometrica*, 84(4): 1523–1569.

Coibion, Olivier, Yuriy Gorodnichenko, Lorenz Kueng, and John Silvia. 2017. "Innocent Bystanders? Monetary policy and inequality." *Journal of Monetary Economics*, 88: 70–89.

Davis, Steven J., and Till Von Wachter. 2011. "Recessions and the Costs of Job Loss." *Brookings Papers on Economic Activity*, 42(2 (Fall)): 1–72.

Den Haan, Wouter J, Garey Ramey, and Joel Watson. 2000. "Job destruction and propagation of shocks." *American economic review*, 90(3): 482–498.

Den Haan, Wouter J, Pontus Rendahl, and Markus Riegler. 2017. "Unemployment (fears) and deflationary spirals." *Journal of the European Economic Association*, 16(5): 1281–1349.

Department of Labor. 2018. "Comparison of State Unemployment Laws."

Faccini, Renato, and Pontus Rendahl. 2019. "Income Risk, Asset Prices, and Labor Market Cyclicality."

Ganong, Peter, and Pascal Noel. 2019. "Consumer spending during unemployment: Positive and normative implications." *American Economic Review*, 109(7): 2383–2424.

Gilchrist, Simon, and Egon Zakrajšek. 2012. "Credit spreads and business cycle fluctuations." *American Economic Review*, 102(4): 1692–1720.

Gornemann, Nils, Keith Kuester, and Makoto Nakajima. 2016. "Doves for the rich, hawks for the poor? Distributional consequences of monetary policy."

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W Huffman. 1988. "Investment, capacity utilization, and the real business cycle." *The American Economic Review*, 402–417.

Gruber, Jonathan. 1997. "The Consumption Smoothing Benefits of Unemployment Insurance." *The American Economic Review*, 87(1): 192–205.

Guvenen, Fatih, Fatih Karahan, Serdar Ozkan, and Jae Song. 2015. "What do data on millions of US workers reveal about life-cycle earnings risk?" National Bureau of Economic Research.

Guvenen, Fatih, Serdar Ozkan, and Jae Song. 2014. "The nature of countercyclical income risk." *Journal of Political Economy*, 122(3): 621–660.

Hagedorn, Marcus, and Iourii Manovskii. 2008. "The cyclical behavior of equilibrium unemployment and vacancies revisited." *American Economic Review*, 98(4): 1692–1706.

Hoffmann, Eran B., and Davide Malacrino. 2019. "Employment time and the cyclicality of earnings growth." *Journal of Public Economics*, 169(C): 160–171.

Johnson, David S, Jonathan A Parker, and Nicholas S Souleles. 2006. "Household expenditure and the income tax rebates of 2001." *American Economic Review*, 96(5): 1589–1610.

Jordà, Òscar. 2005. "Estimation and inference of impulse responses by local projections." *American economic review*, 95(1): 161–182.

Kaplan, Greg, and Giovanni L Violante. 2014. "A model of the consumption response to fiscal stimulus payments." *Econometrica*, 82(4): 1199–1239.

Kaplan, Greg, Benjamin Moll, and Giovanni L Violante. 2018. "Monetary policy according to HANK." *American Economic Review*, 108(3): 697–743.

Kaplan, Greg, Giovanni L. Violante, and Justin Weidner. 2014. "The Wealthy Hand-to-Mouth." *Brookings Papers on Economic Activity*, 45(1 (Spring)): 77–153.

Kaplan, Greg, Kurt Mitman, and Giovanni L Violante. 2017. "The housing boom and bust: Model meets evidence." National Bureau of Economic Research.

Kekre, Rohan. 2016. "Unemployment Insurance in Macroeconomic Stabilization."

Khan, Aubhik, and Julia K Thomas. 2008. "Idiosyncratic shocks and the role of non-convexities in plant and aggregate investment dynamics." *Econometrica*, 76(2): 395–436.

Kolsrud, Jonas, Camille Landais, Peter Nilsson, and Johannes Spinnewijn. 2018. "The optimal timing of unemployment benefits: Theory and evidence from sweden." *American Economic Review*, 108(4-5): 985–1033.

Krueger, D., K. Mitman, and F. Perri. 2016. "Macroeconomics and Household Heterogeneity." Vol. 2 of *Handbook of Macroeconomics*, Chapter 0, 843–921. Elsevier.

Maggio, Marco Di, and Amir Kermani. 2016. "The Importance of Unemployment Insurance as an Automatic Stabilizer." National Bureau of Economic Research.

McKay, Alisdair, and Ricardo Reis. 2016*a*. "Optimal automatic stabilizers." National Bureau of Economic Research.

McKay, Alisdair, and Ricardo Reis. 2016*b*. "The role of automatic stabilizers in the US business cycle." *Econometrica*, 84(1): 141–194.

Ravn, Morten O., and Vincent Sterk. 2017. "Job uncertainty and deep recessions." *Journal of Monetary Economics*, 90(C): 125–141.

Romer, Christina D, and David H Romer. 2004. "A new measure of monetary shocks: Derivation and implications." *American Economic Review*, 94(4): 1055–1084.

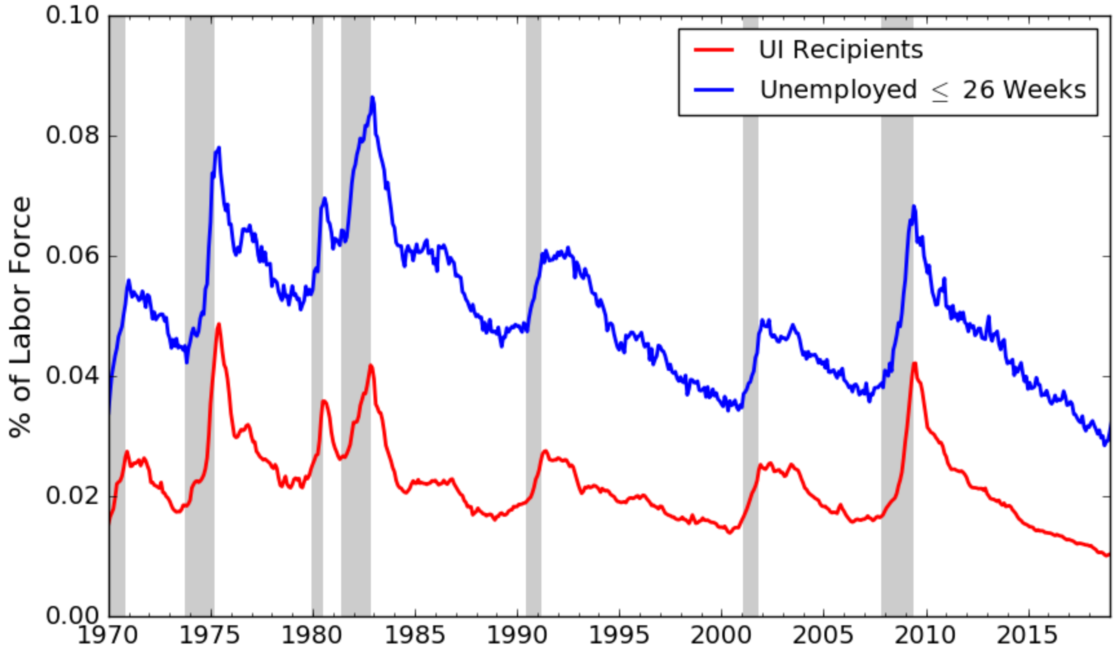
Rotemberg, Julio J. 1982. "Sticky prices in the United States." *Journal of Political Economy*, 90(6): 1187–1211.

Werning, Iván. 2015. "Incomplete markets and aggregate demand." National Bureau of Economic Research.

Appendices

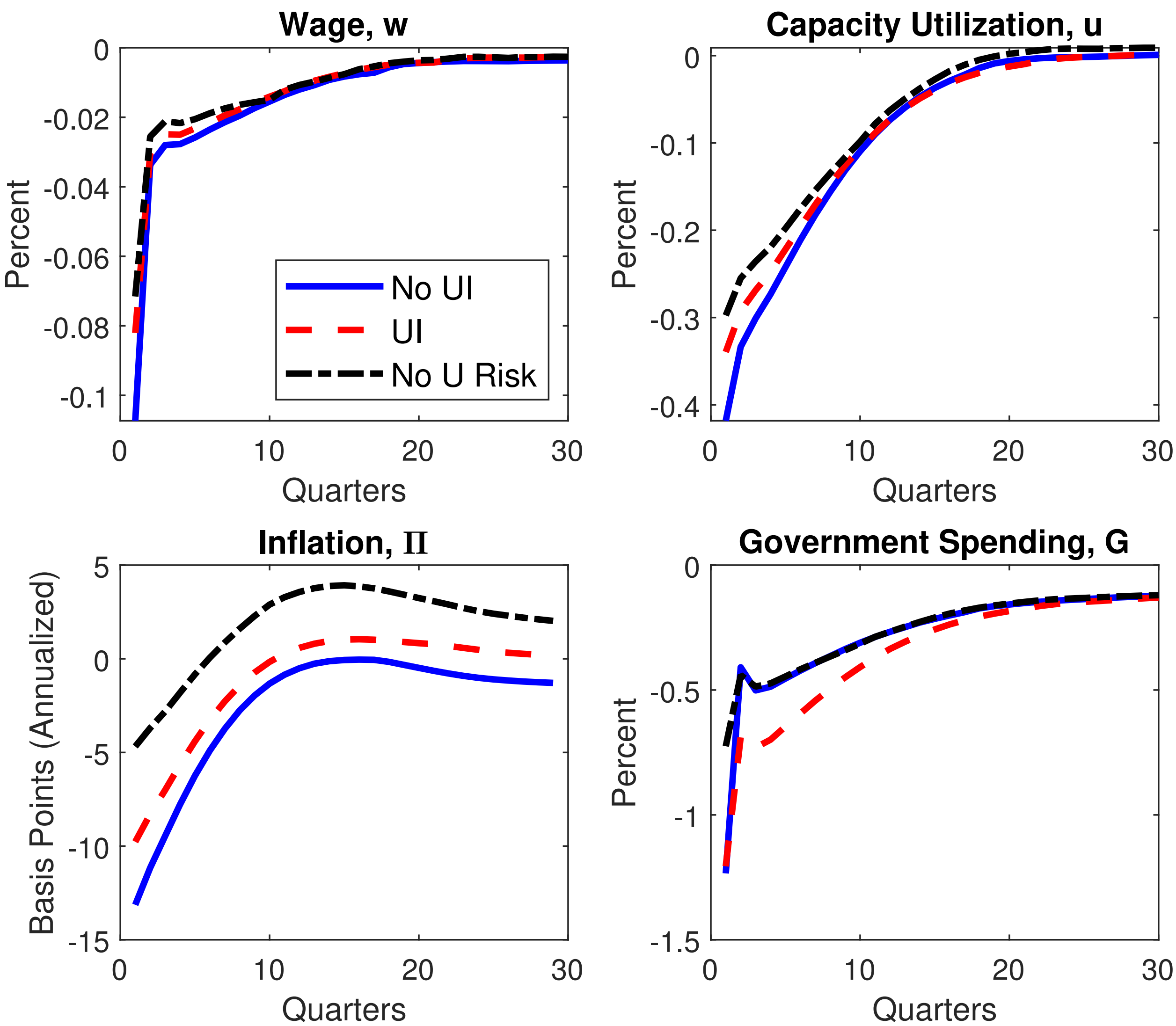
A Additional Figures and Tables

Figure 11: Low Recipiency of Unemployment Insurance



Notes: Data from the Bureau of Labor Statistics and the Employment and Training Administration.

Figure 12: Response to an Aggregate Productivity Shock



Notes: Figure shows the response of further variables to a negative aggregate productivity shock in the three versions of the model.

Table 8: Wealth Distributions in Alternative Models

Moment	Data	Baseline Model	No UI Model	No U Risk Model
Liquid Assets to Output	0.26	0.28	0.29	0.25
Illiquid Assets to Output	2.86	2.85	2.85	2.86
% Poor Hand-to-Mouth	0.1	0.08	0.04	0.24
% Wealthy Hand-to-Mouth	0.2	0.16	0.14	0.23
% Negative Liquid Assets	0.15	0.16	0.14	0.20
Gini Coefficient (Total Wealth)	0.81	0.74	0.73	0.75
Top 1% share (Liquid)	47	15	14	17
Top 1%-10% share (Liquid)	39	57	54	61
Top 10%-50% share (Liquid)	18	31	31	27
Bottom 50% share (Liquid)	-4	-3	0	-5
Top 1% share (Illiquid)	33	9	9	9
Top 1%-10% share (Illiquid)	37	46	46	45
Top 10%-50% share (Illiquid)	27	44	44	44
Bottom 50% share (Illiquid)	3	1	2	1

Notes: Data moments are from Guvenen et al. (2015) and Kaplan, Moll and Violante (2018). Moments from the model are calculated by simulating 1 million households until the steady-state of the model is reached, and aggregating income to an annual frequency. In the model I define household as hand-to-mouth if the absolute value of their liquid asset holdings is less than 10% of the average quarterly wage.

B Data Sources

B.1 Consumer Expenditure Survey (CEX)

I have constructed the CEX sample using the micro-data files provided by the BLS.

Following the previous literature on the relationship between household consumption and unemployment, I restrict attention to the consumption of non-durables and services. From total expenditure, I exclude spending on housing, health care, education, cash contributions, personal insurance, and automobiles. This is close to the definition of non-durables and services used by Chodorow-Reich and Karabarbounis (2016).

I select households whose head is between the ages of 25 and 55. As in Chodorow-Reich and Karabarbounis (2016), I drop households whose head or spouse work in farming, forestry, or the armed services.

The measurement of liquid asset holdings has changed over time in the CEX. For the most recent years, I use the variable LIQUDYRX, which measures the value of checking, savings, and money market accounts, as well as CDs, one year ago. Before 2013 this variable was not available, and I construct a similar measure using CKBKACTX (which measures the current value of checking accounts, brokerage accounts, and other similar accounts) and COMPCKGX which measures the change in checking account balances over the previous year. In all years, I define households as hand-to-mouth if their liquid asset holdings are below the median value in that given year.

The CEX contains little information on a household's illiquid asset holdings. Consequently, I use housing tenure as a proxy for illiquid asset holdings. I define households as wealthy (poor) hand-to-mouth if they are hand-to-mouth by the above definition and they are homeowners (renters).

I measure employment at the household level using the number of weeks worked by the household head or spouse. I classify individuals who do not work during the year as unemployed if they report having looked for a job and out of the labor force if not. For individuals who worked for less than 52 weeks, I measure the fraction of the year that they were unemployed as 1 - weeks worked/52.

The following variables are included in the vector of controls: region/year fixed effects, race of the household head, age and age squared of the household head, family size and family size squared, education of the household head, housing tenure, number of cars, rental value of the home (split into deciles by region and year), hand-to-mouth status, and the fraction of the year spent out of the labor force.

B.2 Panel Study of Income Dynamics (PSID)

A broad measure of consumption expenditures is only available in the PSID from 2005 onwards. Consequently, I use data from the surveys between 2005 and 2017. As in the CEX, I restrict the sample to households whose head is between the ages of 25 and 55.

The measure of liquid asset holdings that I use in the PSID is the value of checking or savings accounts, money market funds, certificates of deposit, government savings bonds, or Treasury bills. The measure of illiquid asset holdings is the value of housing equity and retirement accounts. Finally, the measure of consumption is food, clothing, recreation and vacation expenditures.

B.3 Survey of Consumer Finances (SCF)

I use micro-data from the SCF for the following survey years: 2004, 2007, 2010, 2013, 2016, and 2019. 2004 was the first year that the survey asked about withdrawals from individual retirement accounts.

The SCF uses a multiple imputation approach, given the low response rate to certain questions in the survey. To avoid any problems that could be introduced by this imputation, I restrict the sample to households who have no imputed data on the age of the household head, their weeks of unemployment in the previous 12 months, their ownership of any individual retirement accounts (IRAs), and the presence of any withdrawals from their IRA in the past year.

Generally, withdrawals from retirement accounts that occur before the age of 59.5 are subject to a 10% tax penalty. Consequently, I restrict the sample to households whose head is at most 55 years of age, consistent with the sample I use for the CEX in Section 2. I further restrict the sample to households where the household head reports having an IRA. This leaves 4863 households across the 6 survey waves. Overall, 24% of households in the SCF report ownership of an IRA.

Measurement of liquid asset holdings in the SCF requires a trade-off. On the one-hand, the survey contains questions on a relatively large number of assets that could be considered liquid. On the other hand, given my decision to not use imputed data, the larger the set of assets included, the smaller will be my final sample size. Consequently, I measure liquid asset holdings using only checking account balances. Even with this relatively crude measure, the sample size declines to 3649 households once I have removed households for whom checking account data is imputed.

B.4 Current Population Survey (CPS)

In Section 6.1 and Appendix G, I document the central role of unemployment risk in explaining cyclical changes in the income growth distribution. This is based on micro-data from the March supplement of the IPUMS CPS dataset between 1976 and 2018. Following Guvenen, Ozkan and Song (2014), I restrict the sample to men between the ages of 25 and 60, and I drop individuals who report either no weeks of work or no income in a particular year. The remaining sample size fluctuates between around 5000 and 9000 individuals per year.

I measure annual income using the IPUMS variable INCWAGE, which measures wage and salary income. I measure annual hours worked using the product of WKSWORK1, which measures the number of weeks worked during the year, and UHRSWORKLY, which measures the usual number of hours worked per week.

In Appendix G.1, I require a higher frequency measure of hours growth and wage growth, which requires using the monthly CPS sample. To construct a measure of wage growth, I use the NBER dataset on the Merged Outgoing Rotation Group (MORG), as individuals are only asked about their earnings in their fourth and eights CPS interviews. For individuals in their last interview, I measure hourly wages as EARNWKE/UHOURSE.

To construct a measure of hours growth, I use the AHRSWORKT variable from the IPUMS data, which measures hours worked in the previous week (equal to 0 if the individual was unemployed). I sum this within a quarter. Consequently, my quarterly hours growth measure is annual growth in quarterly hours worked.

Table 9: Descriptive Statistics Across Asset Groups

	Full Sample		N-HTM		W-HTM		P-HTM	
	CEX	SCF	CEX	SCF	CEX	SCF	CEX	SCF
% of Households	1	1	0.51	0.50	0.29	0.31	0.20	0.19
Average Age	41.2	39.6	41.8	40.5	41.8	40.8	38.7	35.5
% College Degree	0.45	0.39	0.59	0.53	0.37	0.30	0.22	0.17
% Homeowners	0.71	0.59	0.84	0.74	1.00	0.70	0.00	0.06
Average $U_{i,t}$	0.08	0.06	0.06	0.04	0.09	0.08	0.12	0.12
Median Income (000's)	50	54	69	80	44	48	23	23

Notes: SCF data is from Kaplan, Moll and Violante (2018) for the 2004 survey. In both surveys I define households as hand-to-mouth if their liquid asset holdings are below the median level. In the SCF, I define households as wealthy if their illiquid asset holdings are above the 25th percentile. The CEX sample uses households in the survey between 2003 and 2005. All statistics are calculated using sampling weights.

C Asset Groups: Descriptive Statistics

Table 9 reports some descriptive statistics about the CEX sample and compares it to households from the Survey of Consumer Finances, where liquid and illiquid asset holdings are measured more accurately. In the SCF, I define households as hand-to-mouth if their liquid asset holdings are below the median value. I then define them as poor hand-to-mouth if their illiquid asset holdings are also below the 25th percentile, and wealthy hand-to-mouth if their illiquid asset holdings are above the 25th percentile.

In both the CEX and SCF, poor hand-to-mouth households are slightly younger, less likely to have a college degree, and more likely to be unemployed than either non hand-to-mouth or wealthy hand-to-mouth households. Table 9 also shows that housing status is a good proxy for illiquid asset holdings: 70% of wealthy hand-to-mouth households in the SCF are homeowners, compared to only 6% of poor hand-to-mouth households. By construction these values are 100% and 0% in the CEX.

D Consumption Response to Unemployment Spells

In this section I provide further evidence on the consumption response to unemployment spells. Column (1) of Table 10 repeats the average response shown in Table 1. The second

Table 10: Consumption Response to Unemployment Spells

	Data (CEX)		One-Asset Model	
	(1)	(2)	(3)	(4)
$U_{i,t}$	-0.22	-0.31	-0.39	
	(0.015)	(0.017)		
$U_{i,t}\mathbb{1}\{\text{N-HTM}\}$				-0.09
$U_{i,t}\mathbb{1}\{\text{HTM}\}$				-0.53
Fixed effects	✓	✓		
Control variables	✓			

Notes: Robust standard errors in parentheses. Regressions weighted using CEX sampling weights, with 31638 observations from 1996 to 2017.

column removes the control variables to show their importance. Without the control variables, the consumption response to unemployment is biased due to a correlation between unemployment and other demographic characteristics that predict lower consumption. For example, even when employed, the consumption of wealthy and poor hand-to-mouth households is around 10% and 20% lower than that of non hand-to-mouth households, respectively.

Finally, columns (3) and (4) repeat the basic regressions in the one-asset model studied in Section 7. Column (3) shows that the one-asset model over-predicts the consumption decline during unemployment. Column (4) shows that this is entirely driven by the hand-to-mouth households in the model, as the one-asset model actually under-predicts the consumption decline for non hand-to-mouth households (who hold too many liquid assets relative to the data).

E Illiquid Asset Response to Unemployment Spells

In this section I show that the results in Section 3 are unaffected by the addition of control variables. Table 11 shows the results of estimating a linear probability model with an indicator for IRA withdrawal as the dependent variable. I provide results both with and without controls for age, family size, education, race and year. The first and second columns estimate the overall effect of unemployment on the withdrawal probability. The third and fourth columns split unemployed households into two on the basis of the number of weeks

Table 11: Illiquid Asset Response to Unemployment Spells

	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbb{1}\{U_{i,t} > 0\}$	0.064	0.062				
	(0.018)	(0.017)				
$\mathbb{1}\{U_{i,t} \leqslant 12 \text{ weeks}\}$			0.018	0.017		
			(0.018)	(0.018)		
$\mathbb{1}\{U_{i,t} > 12 \text{ weeks}\}$			0.119	0.116		
			(0.030)	(0.030)		
$\mathbb{1}\{U_{i,t} > 0 \text{ \& N-HTM}\}$					0.007	0.007
					(0.022)	(0.022)
$\mathbb{1}\{U_{i,t} > 0 \text{ \& HTM}\}$					0.092	0.087
					(0.027)	(0.027)
Control variables		✓		✓		✓
Observations	4863	4863	4863	4863	3649	3649

Notes: Dependent variable is an indicator for IRA withdrawal. Robust standard errors in parentheses. Regressions weighted using SCF sampling weights using data from 2004 to 2019. Control variables include age and family size as well as fixed effects for education, race, and year.

spent unemployed. The fifth and sixth columns split unemployed households into two on the basis of liquid asset holdings.

The first, third, and fifth columns are equivalent to Table 2 in that they measure the increase in withdrawal probabilities relative to a households that do not experience unemployment with no controls. The second, fourth, and sixth columns add the control variables. The estimates are unaffected by the addition of control variables.

F Income Response to Unemployment Spells

To estimate whether or not a household's asset status is related to the size of the labor income decline that they experience during an unemployment spell, I estimate equations 2.1 and 2.2 using household wage and salary income as the dependent variable. To focus on households whose primary source of labor income is wages and salaries, I restrict the sample to households whose wage and salary income is at least $7000 in 2017 prices. Table 12 reports the estimated coefficients for the three versions of the regression used in Section 2. I find that there is no significant difference in the impact of unemployment on labor income across the three groups.

As an alternative to the above, I have used data from the Displaced Worker Supplement of the CPS to estimate how the log change in weekly earnings or length of an unemployment spell after a job displacement vary with education, home ownership, and age. On average, weekly earnings decline by 7.9% after a job displacement and individuals spend 12.2 weeks unemployed before finding a new job. Table 13 shows that there is no significant effect of education or homeownership on either of the dependent variables. The one characteristic which is associated with both longer unemployment spells and larger earnings declines, is age.

Given that poor hand-to-mouth households tend to be younger than either the non hand-to-mouth or wealthy hand-to-mouth, this suggests that, if anything, the long-term impact of unemployment spells is smallest for the poor hand-to-mouth. Consequently, this cannot explain the finding that the consumption response is largest for this group.

G Unemployment and Income Risk

In this section I explain the details behind the decomposition of income growth into hours growth and wage growth used in Section 6.1. I also show that income risk responds endogenously to identified macroeconomic shocks through the effect that these shocks have on unemployment.

The March supplement of the CPS contains annual data on income and hours worked. Using this data, I can decompose income into hours worked and hourly earnings as follows:

$$y_{i,t} = \underbrace{\left(\frac{y_{i,t}}{h_{i,t}}\right)}_{w_{i,t}} h_{i,t} \tag{G.1}$$

where $y_{i,t}$ is the income of individual i in year t, and $h_{i,t}$ is the number of hours worked by individual i in year t. Consequently, $w_{i,t}$ is a measure of hourly earnings. Taking log differences, income growth can then be decomposed into wage growth and hours growth:

$$\Delta y_{i,t} = \Delta w_{i,t} + \Delta h_{i,t} \tag{G.2}$$

Table 12: Income Response to Unemployment Spells

	CEX			PSID		
	(1)	(2)	(3)	(4)	(5)	(6)
$U_{i,t}$	-0.75			-0.82		
	(0.029)			(0.044)		
$U_{i,t}\mathbb{1}\{\text{N-HTM}\}$		-0.74	-0.74		-0.81	-0.81
		(0.044)	(0.044)		(0.070)	(0.070)
$U_{i,t}\mathbb{1}\{\text{HTM}\}$		-0.76			-0.84	
		(0.038)			(0.053)	
$U_{i,t}\mathbb{1}\{\text{W-HTM}\}$			-0.75			-0.84
			(0.052)			(0.091)
$U_{i,t}\mathbb{1}\{\text{P-HTM}\}$			-0.76			-0.83
			(0.055)			(0.064)
H_0: $\gamma_N^U = \gamma_H^U$		0.83			0.74	
H_0: $\gamma_N^U = \gamma_W^U = \gamma_P^U$			0.97			0.95

Notes: Robust standard errors in parentheses. PSID standard errors are clustered by household head. Regressions weighted using sampling weights. Final three rows of the table report the p-values for different Wald tests. CEX uses 23218 observations from 1996-2017. PSID uses 22672 observations from 2005-2017.

Table 13: Effect of Job Displacement in the CPS

	Δ log Weekly Earnings	Weeks Unemployed
Intercept	0.23***	3.61***
	(0.04)	(1.20)
$\mathbb{1}\{\text{High School}\}$	-0.004	-1.26
	(0.02)	(0.78)
$\mathbb{1}\{\text{Some College}\}$	-0.010	-0.77
	(0.02)	(0.79)
$\mathbb{1}\{\text{College}\}$	0.017	-0.33
	(0.02)	(0.80)
$\mathbb{1}\{\text{Homeowner}\}$	-0.004	-0.49
	(0.01)	(0.45)
Age_i	-0.008***	0.25***
	(0.001)	(0.03)

Notes: Robust standard errors in parentheses. Asterisks denote statistical significance at the ***1 percent, **5 percent, and *10 percent levels. The sample is restricted to men between the ages of 25 and 55. Regressions use sampling weights, with 7094 observations from 1990 to 2018.

Figure 6 shows a measure of the skewness of the income growth, wage growth, and hours growth distributions over time.[29] It is clear that the skewness of hours growth drives that of income growth, while the skewness of wage growth changes little over the business cycle. Income growth becomes negatively skewed in recessions because it becomes much more likely to experience a large decline in hours, i.e. to become unemployed. Meanwhile, for those who remain employed, the skewness of the wage growth distribution is unaffected by business cycles.[30]

To show that it is the extensive margin rather than the intensive margin that drives these results (i.e. unemployment rather than average hours worked) Figure 13 plots the income growth distribution in 2006 and 2009 for two groups of individuals: those who experienced unemployment spells in either of the two years used to measure income growth, and those who did not. It is clear from these densities that the the decline in the skewness of the income growth distribution between these two years comes entirely from those households who experienced unemployment spells. In 2009 such households were far more likely to see a large decline in income than in 2006.

Figure 14 plots the skewness of income growth for the entire sample of individuals as well as the sub-samples of individuals that either did or did not experience an unemployment spell. This confirms that the group of individuals with unemployment spells drives the cyclicality of the skewness of the income growth distribution. Finally, Figure 15 plots the skewness of income growth measured in the CPS against the equivalent measure from Guvenen, Ozkan and Song (2014), which uses Social Security Administration data. There is a close correlation between the two series, although the skewness of income growth declines by more in the Social Security Administration data in the past two recessions.

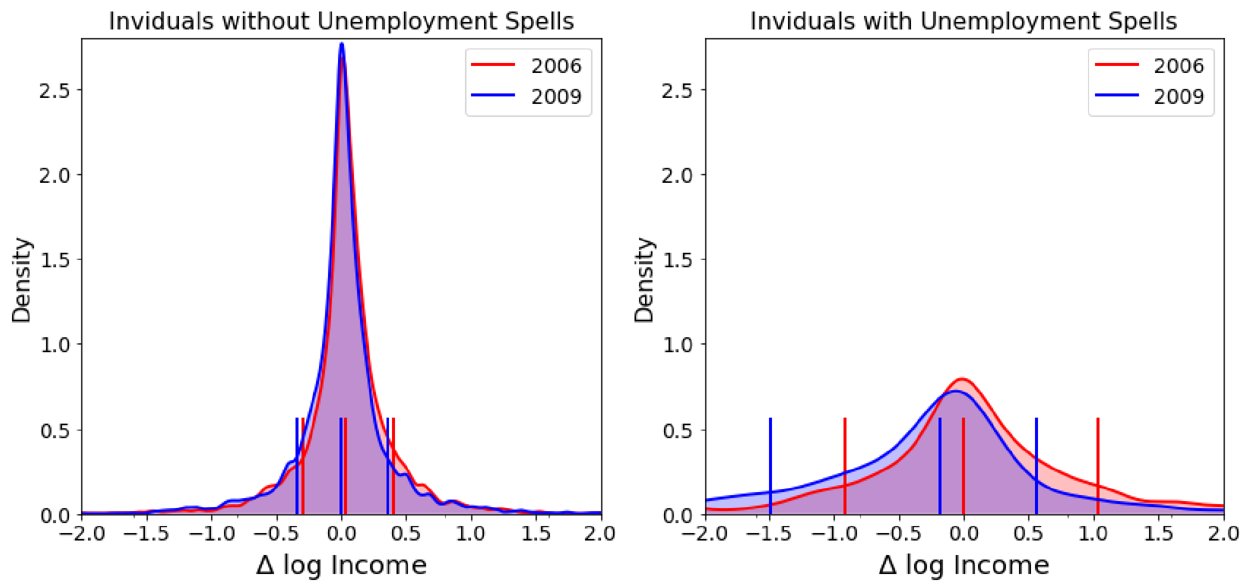
G.1 Response of Income Risk to Macroeconomic Shocks

In this section, I construct measures of hours and wage growth at a quarterly frequency and then estimate the responsiveness of the skewness of these distributions to monetary policy

[29] Due to the 4-8-4 structure of the CPS, individuals that are in the March survey for the first time in one year should also be interviewed in the March survey in the following year. There are two breaks in my skewness measures which correspond to periods where the CPS identifiers are not consistent across the two interview spells.

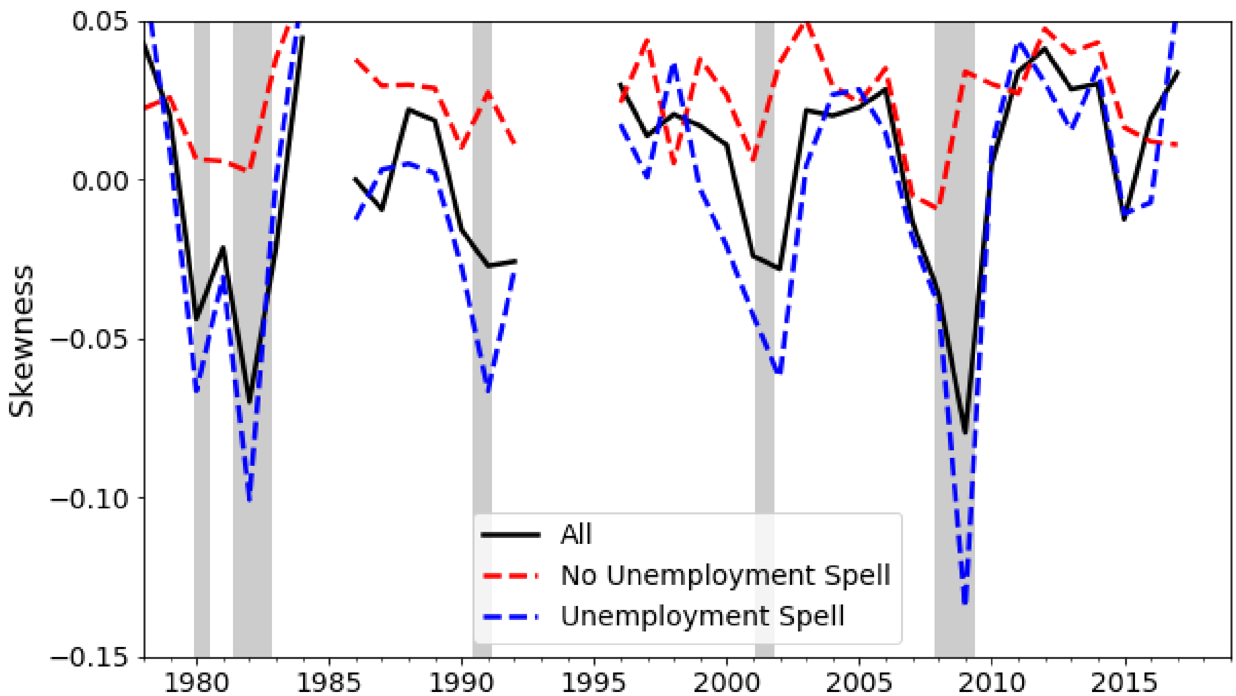
[30] Hoffmann and Malacrino (2019) shows similar results using Italian data.

Figure 13: Income Growth Densities and Unemployment Spells



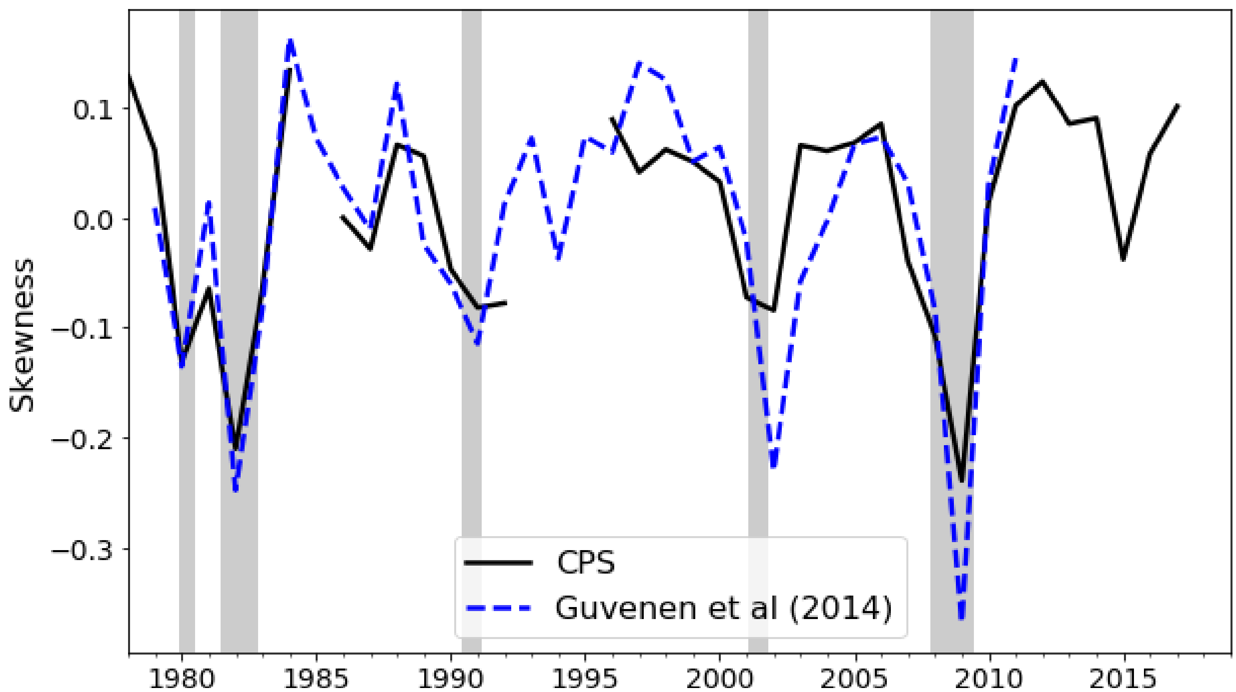
Notes: The vertical lines denote the 10th, 50th, and 90th percentiles of the distribution.

Figure 14: Unemployment Drives Skewness of Income Growth



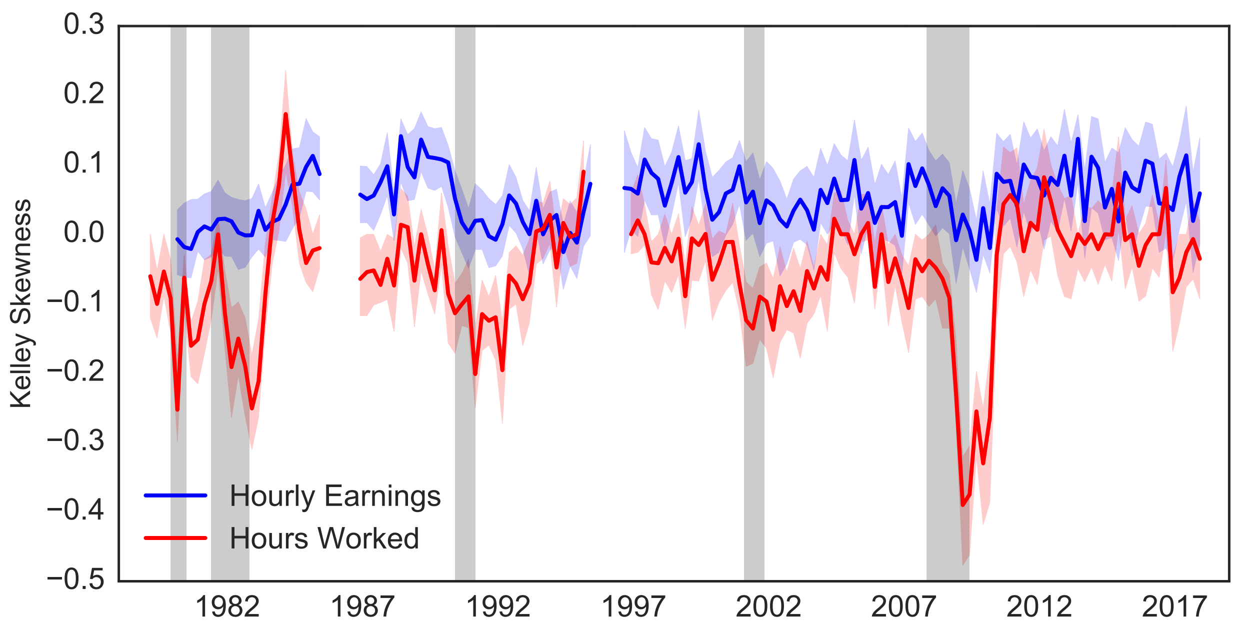
Notes: Skewness measured using Pearson's second skewness coefficient (median skewness).

Figure 15: Income Skewness: CPS vs. Social Security Data



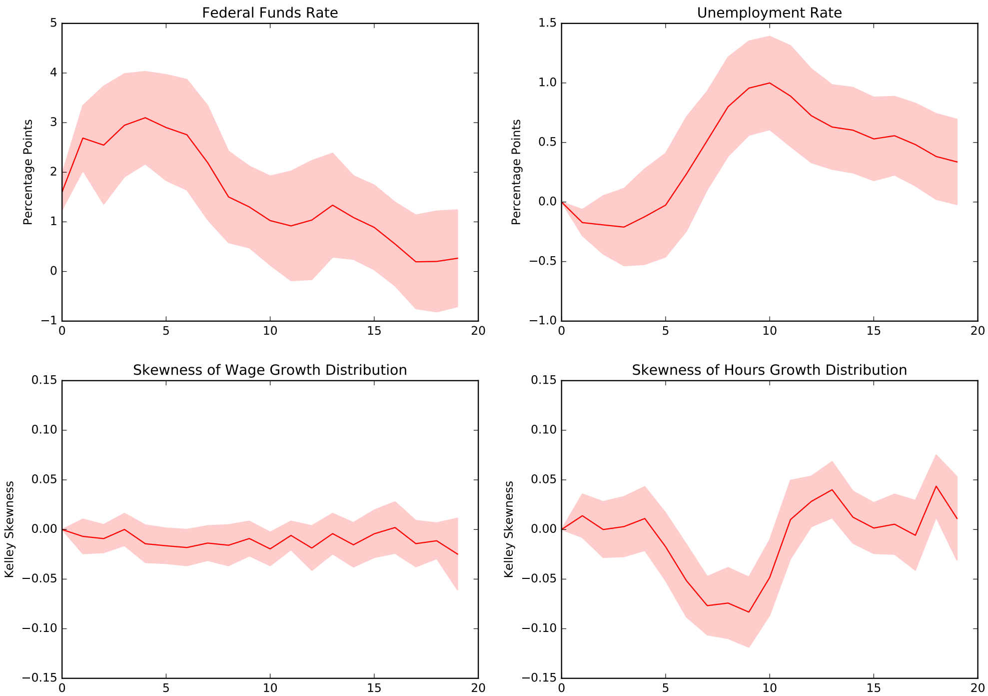
Notes: Skewness measured using Pearson's second skewness coefficient (median skewness).

Figure 16: Quarterly Measures of Skewness

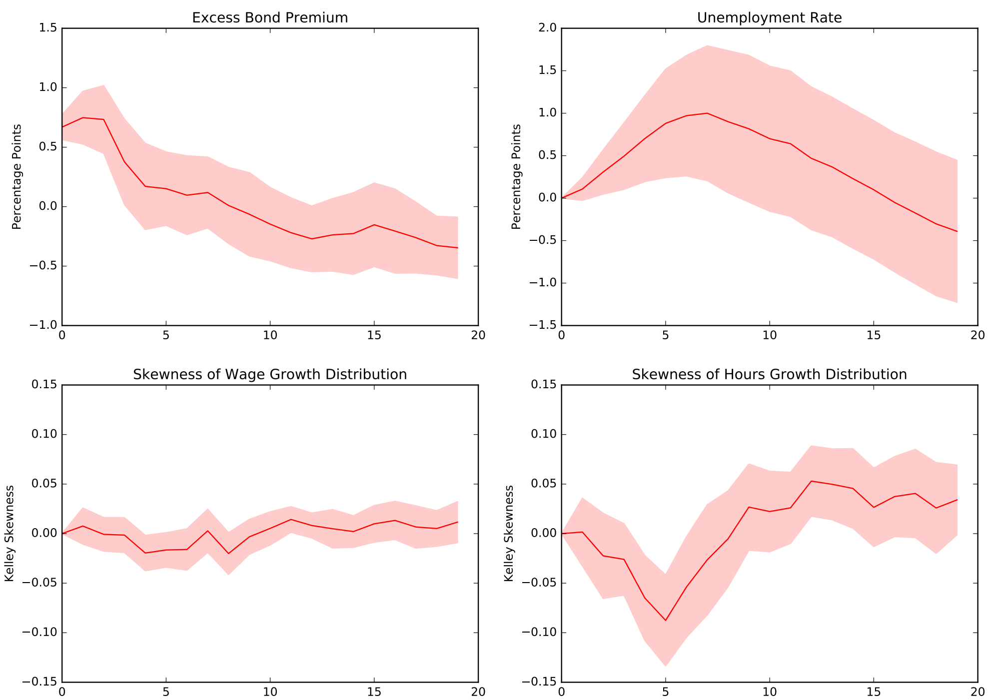


Notes: Skewness measured using Kelley's measure of skewness.

Figure 17: Response to Identified Macroeconomic Shocks



(a) Monetary Policy Shock



(b) Excess Bond Premium Shock

Notes: Shaded area shows a 95% confidence interval construct using robust standard errors. Skewness measured using Kelley's measure of skewness.

shocks, identified as in Christina D Romer and David H Romer (2004),[31] and excess bond premium (EBP) shocks, identified using by Simon Gilchrist and Egon Zakrajšek (2012). Figure 16 plots the quarterly estimates of the skewness of hours and wage growth. Due to the small sample size, I use the Kelley skewness measure.[32]

In both cases, I use a local projection approach[33] to estimate the effect of the shocks on the skewness of the wage and hours growth distributions at different horizons:

$$Y_{t+h} = \alpha_h + \psi_h(L)X_{t-1} + \beta_h \epsilon_t + \zeta_{t+h} \tag{G.3}$$

where ϵ_t is the identified shock at time t, X_{t-1} is a vector of control variables and Y_{t+h} is the variable of interest at period $t+h$.

Figure 17a shows the estimated response of the federal funds rate, the unemployment rate, and the skewness of the wage growth and hours growth distributions to a monetary policy shock, and Figure 17b shows the estimated responses to an excess bond premium shock. In both cases, the skewness of the wage growth distribution is unaffected by the shock, while the skewness of the hours growth distribution moves pro-cyclically. This provides further evidence that the income growth distribution is endogenous to macroeconomic shocks, and that this endogeneity is driven by unemployment risk.

H Amplification in the One-Asset Model

In this section I consider alternative calibrations of the one-asset model to understand the difference between the results in this paper and the results in Ravn and Sterk (2017).

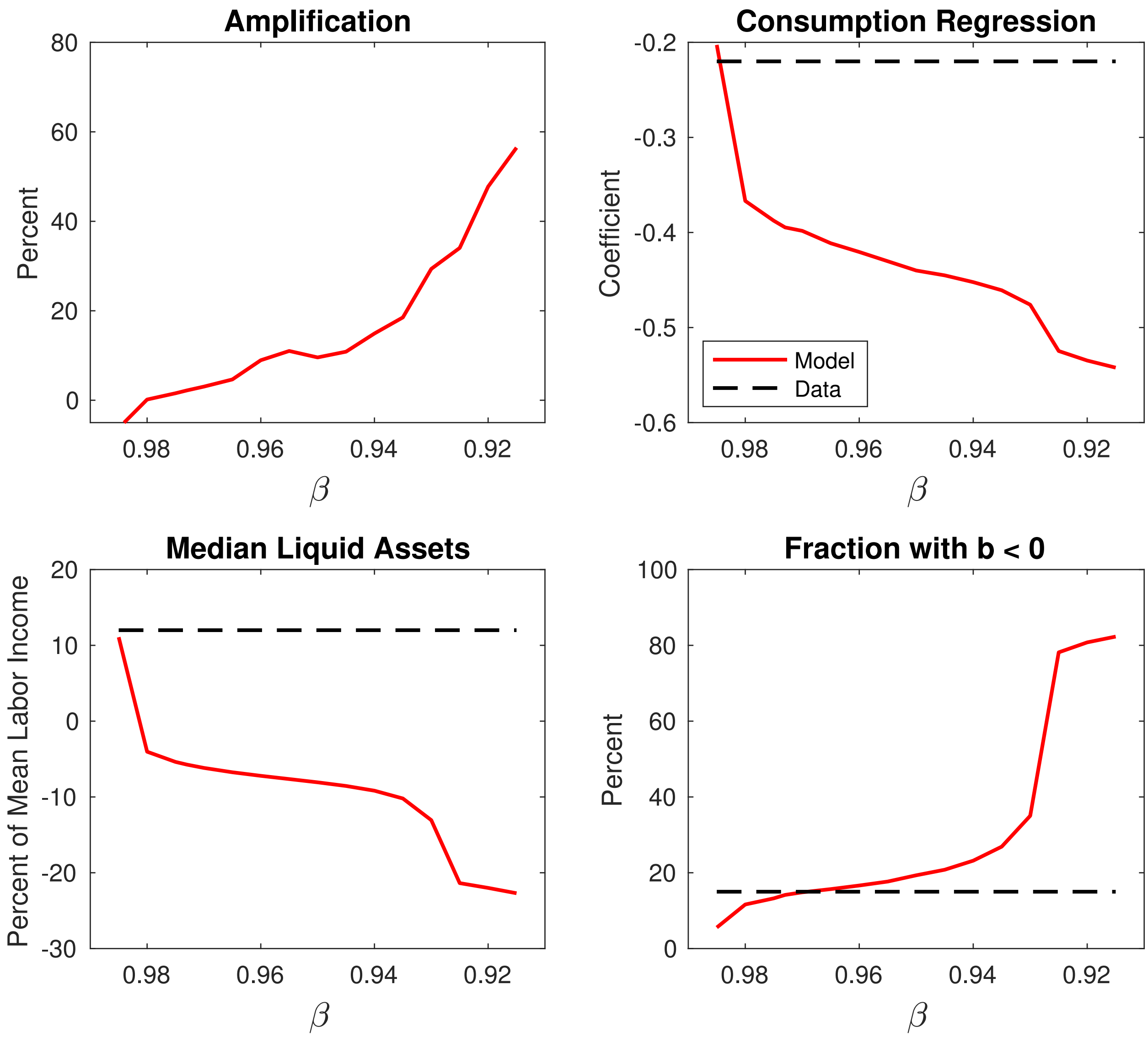
Their paper assesses the role of unemployment risk in a one-asset HANK model and finds large amplification. The key difference is the assumption that they make about the liquid asset distribution. In particular, they assume that agents hold no assets in equilibrium. The path of the real interest rate is determined by employed households, whose Euler equation holds with equality, while unemployed households are borrowing constrained. These assump-

[31] Extended to 2008 by Olivier Coibion, Yuriy Gorodnichenko, Lorenz Kueng and John Silvia (2017).

[32] Kelley Skewness is equal to ((P90 - P50) - (P50 - P10))/(P90 - P10) where P90/P50/P10 are the 90th/50th/10th percentiles of the distribution. This measure of skewness that is robust to outliers and is bounded by -1 and 1.

[33] As in Òscar Jordà (2005).

Figure 18: Varying β in the One-Asset Model



Notes: Amplification measured as the maximum change in unemployment in the version of the model with no unemployment insurance relative to the maximum change in the version of the model with no unemployment risk.

tions imply that the only force affecting the path of the real interest rate in their economy is the consumption smoothing motive of the employed households, as unemployed households are unable to borrow.

In Figure 18, I show the effect of varying β in the on-e asset model between 0.985 and 0.905. When β is close to 0.905, the model does display significant amplification, as in Ravn and Sterk (2017). However, in such a calibration almost all households are borrowing constrained:

median liquid asset holdings are far too low, too many households have negative liquid asset holdings, and the consumption decline during unemployment is much larger than in the data.

I Solving the Two-Asset Model

I.1 Solving the Household Problem

Solving equation 4.1 numerically involves a significantly higher computational burden than the corresponding problem when the household does not adjust their illiquid asset holdings, as the household has a two-dimensional maximization problem (rather than a one-dimensional problem that can easily be solved using the golden-section search method).

A robust but slow method for solving equation 4.1 is a nested golden-section search algorithm, in which the maximization over one asset is done in an outer loop, and the maximization over the other asset is done in an inner loop. However, this method is too slow for calculating the response of the economy to aggregate shocks, which requires solving a modified version of equation 4.1 for a large number of periods, multiple times.

A faster method is to break equation 4.1 down into two simpler problems. Specifically, I first solve the problem for households that choose not to adjust their illiquid asset holdings, shown in equation 4.4.

It is then possible to solve the full problem in equation 4.1 by solving the following one-dimensional maximization:

$$V_t^A(b,k,z,e) = \max_{k'} V_t^{NA}(b^*,k',z,e) \tag{I.1}$$
$$\text{subject to}$$
$$b^* = \frac{R_t^b(b)b + R_t^k(k-k') - \tau_k \mathbb{1}\{k'<k\}(k-k')}{R_t^b(b^*)}$$

To see why this works, consider the budget constraint of the problem given by $V_t^{NA}(b^*,k',z,e)$:

$$k' + b' + c = \mathbb{1}\{e=1\}w_t z(1-\tau_l) + \mathbb{1}\{e=0\}w_t\phi(z)(1-\tau_l) + T_t + R_t^b(b)b^* + R_t^k k' \tag{I.2}$$

Now, substitute in the value of b^* given in equation I.1:

$$\begin{aligned}
k' + b' + c &= \mathbb{1}\{e = 1\}w_t z(1-\tau_l) + \mathbb{1}\{e = 0\}w_t \phi(z)(1-\tau_l) + T_t + R_t^b(b^*)b^* + R_t^k k' \\
&= \mathbb{1}\{e = 1\}w_t z(1-\tau_l) + \mathbb{1}\{e = 0\}w_t \phi(z)(1-\tau_l) + T_t + R_t^b(b)b + R_t^k(k-k') - \tau_k \mathbb{1}\{k' < k\}(k-k') + R_t^k k' \\
&= \mathbb{1}\{e = 1\}w_t z(1-\tau_l) + \mathbb{1}\{e = 0\}w_t \phi(z)(1-\tau_l) + T_t + R_t^b(b)b + R_t^k k - \tau_k \mathbb{1}\{k' < k\}(k-k')
\end{aligned}$$

Thus, the problem in equation I.1 satisfies the household's budget constraint, regardless of the choice of k'. The adjustment to liquid asset holdings in b^* takes into account all effects of the capital adjustment on the household's budget constraint. As equation 4.4 and equation I.1 are relatively simple one-dimensional maximization problems, this significantly increase the speed of solving the full problem in equation 4.1.

I.2 Solving for the Steady-State of the Model

Since I assume that the equilibrium real interest rate is 1% on an annual basis, and that the steady-state unemployment rate must be 6%, the algorithm for finding the steady-state is as follows:

1. Guess the equilibrium level of capital, K.
2. The equilibrium unemployment rate implies an equilibrium labor-market tightness, θ, and value of h. Find the steady-state wage that is consistent with this using the steady-state FOC for the labor agency:

$$\beta\left(h - \bar{w} + \frac{c}{q(\theta)}(1-s)\right) = \frac{c}{q(\theta)} \tag{I.3}$$

   (Taking into account the calibrated relationship between c and $\bar{w}$.)
3. Given this wage and the job-finding probability, solve the household's problem.
4. Use non-stochastic simulation to find the equilibrium distribution of households.
5. Update the guess of K and return to Step 2.

I.3 Solving the Response to an Aggregate Shock

In Section 4, I solve the response of the model to an unanticipated aggregate productivity shock. The algorithm for solving for the equilibrium path in response to this shock is described below:

1. Guess paths for the real interest rate and capital stock: $\{r_t^b\}_{t=1}^T$ and $\{K_t\}_{t=1}^T$ (where T is large enough that the economy has returned to the steady-state).
2. Use the Taylor rule and Fisher relation to find the implied path of inflation and the nominal interest rate.
3. Guess a path of employment
   (a) Given the path of employment, calculate the path output using the production function.
   (b) Using output and inflation, calculate the path of the mark-up using the New Keynesian Phillips curve.
   (c) Using the path of the mark-up, calculate the path of wages.
   (d) Using the path of wages, calculate the path of the job-finding rate from the labor agency's Euler equation. Update the guess of the path of employment and return to step 3(a).
4. Given the implied paths of the job-finding rate, wage, the real interest rate, and the return on capital, solve the household's problem backwards from $t = T - 1$ to 1.
5. Simulate the household distribution forwards from $t = 1$ to T.
6. Use the implied paths of liquid asset holdings, $\{B^h\}_{t=1}^T$, and capital holdings, $\{K_t^h\}_{t=1}^T$, to update the guessed path of the real interest rate and capital stock and return to step 2.

I.4 Consumption-Equivalent Size of Adjustment Costs

In this section, I calculate the consumption-equivalent size of the utility costs of illiquid asset adjustment cost in the steady-state of the model. A household that pays adjustment cost χ

and has consumption C would be willing to lower their consumption to C^* which satisfies the following equation in order to avoid the adjustment cost:

$$\frac{C^{*(1-\gamma)} - 1}{1-\gamma} = \frac{C^{1-\gamma} - 1}{1-\gamma} - \chi \tag{I.4}$$

Solving for C^*:

$$C^* = \left[C^{1-\gamma} - (1-\gamma)\chi\right]^{\frac{1}{1-\gamma}} \tag{I.5}$$

In the calibrated version of the model, $\gamma = 2$, so this simplifies to:

$$C^* = \frac{1}{C^{-1} + \chi} \tag{I.6}$$

As the adjustment costs are random, the average level of C^* for a household with consumption C whose maximum adjustment cost is χ^* is as follows:

$$\begin{aligned} C^* &= \frac{1}{\bar{\chi}} \int_0^{\chi^*} \frac{1}{C^{-1} + \chi} d\chi + \frac{1}{\bar{\chi}} \int_{\chi^*}^{\bar{\chi}} \frac{1}{C^{-1}} d\chi \\ &= \frac{1}{\bar{\chi}} \left[\log(C^{-1} + \chi^*) - \log(C^{-1})\right] + C \frac{\bar{\chi} - \chi^*}{\bar{\chi}} \end{aligned} \tag{I.7}$$

Integrating across households, the total size of adjustment costs in terms of consumption is $\int (C - C^*) d\mu$, which is equal to 1.2% of total consumption or 0.9% of total output.

There is also a second, easier to quantify, adjustment cost, which is the illiquid asset withdrawal tax. The steady-state value of illiquid asset withdrawal tax payments is 0.6% of total output.

J Robustness

In this section, I undertake a number of robustness exercises. I show that the main results of the paper are robust to a wide range of values of the wage elasticity ϵ_w, robust to different assumptions about the distribution of profits, and that amplification relies on price stickiness.

I also show that unemployment insurance is a somewhat less effective automatic stabilizer if the lump-sum transfer adjusts to balance the government's budget constraint (rather than government spending). Finally, I show that if the illiquid asset is housing, rather than physical capital, the model still displays significant amplification through the flight-to-liquidity mechanism.

J.1 Wage Elasticity

Due to the complexity of the household problem, it is not possible to use a bargaining solution to determine the equilibrium wage in the models used in this paper. Consequently, I use a wage rule whereby the wage that households receive responds with elasticity ϵ_w to the wage that the labor agency receives from the intermediate good producers.

For the calibration in the main paper, I set ϵ_w to 0.45 (based on the elasticity of real wages to labor productivity documented by Hagedorn and Manovskii (2008)). In this section, I show that the main result of the paper, that unemployment risk significantly amplifies aggregate shocks in the two-asset model, is robust to a wide range of values of ϵ_w.

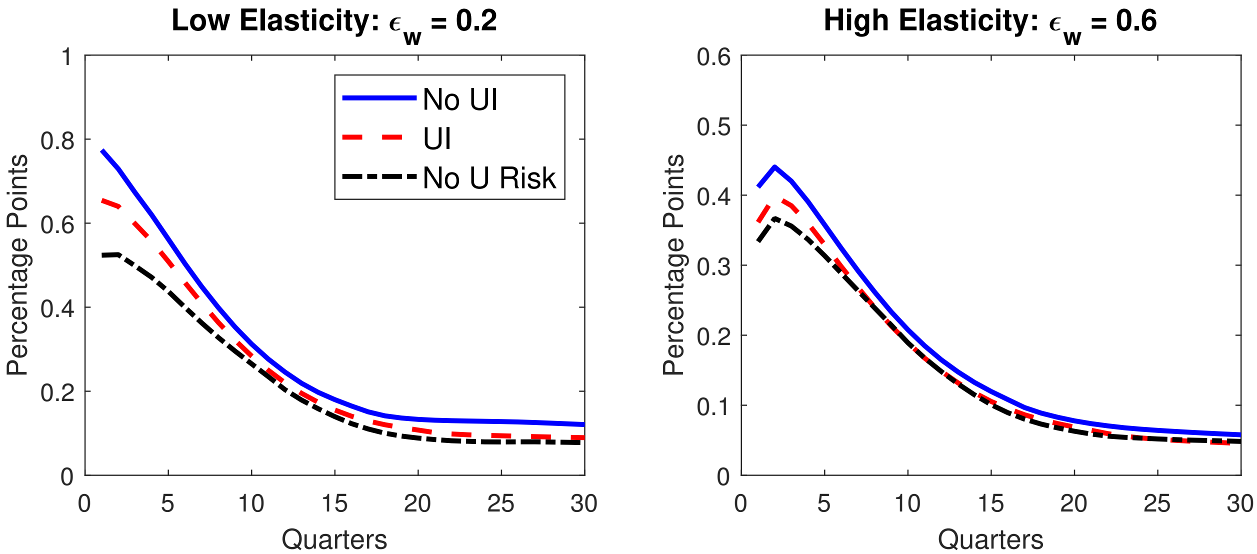
Figure 19 plots the response of unemployment to the aggregate productivity shock when ϵ_w is set to either 0.2 or 0.6. When the wage that households receive is more flexible, the overall effect of the shock is smaller, as the labor agency are able to pass through more of the decline in wages to households, and consequently the decline in vacancy posting is lessened. However, the amplification that comes from unemployment risk remains: in both cases, the response of unemployment is significantly larger in the model without unemployment insurance when compared to the model with unemployment insurance.

J.2 Response of Wages to Unemployment

In the model and in the above subsection I use a wage rule in which the wage that households receive responds with elasticity ϵ_w to the wage that the labor agency receives from the intermediate good producers.

In this section, I propose a different wage rule, assuming that the wage responds instead to

Figure 19: Robustness to different values of ϵ_w



Notes: Percentage point deviation of the unemployment rate from its steady-state value.

the level of employment (or unemployment):

$$w_t = \bar{w} \left(\frac{N_t}{\bar{N}} \right)^{\epsilon_U} \tag{J.1}$$

This alternative wage rule ties wages more closely to the unemployment risk that households face. I set $\epsilon_U = 0.1$, such that the response of wages to the aggregate productivity shock is of a similar magnitude to that in the baseline calibration.

Figure 20 shows the response of each of the three versions of the model to the aggregate productivity shock with this alternate wage rule. The amplification implied by the model is similar to that seen with the baseline wage rule.

J.3 Distribution of Profits

In the baseline version of the model I assume that profits are consumed by risk-neutral entrepreneurs. In this section I consider an alternative assumption where profits are distributed evenly to the households in the model. I assume that the government issues a lump-sum tax such that the steady-state of the model is unchanged.

Figure 21 shows the response of each of the three versions of the model to the aggregate productivity shock in this case. The amplification implied by the model is increased under this assumption on the distribution of profits.

J.4 Heterogeneous Job Separation Rates

In this section I assume that an individual's job separation rate varies exogenously with their labor productivity. I assume that:

$$s(z) = s_0 + s_1 \log(z) \tag{J.2}$$

I leave s_0 at the original calibration of 0.1, and I set s_2 to -0.02. This implies that the least productive individuals have a job separation rate that is three and a half times higher than the most productive.

In this version of the model the average productivity of unemployed households will now vary over time, complicating the problem of the representative labor agency. Consequently, I replace it with an unlimited mass of potential entrepreneurs that are able to post vacancies in the labor market. The free-entry condition for such entrepreneurs is:

$$\mathbb{E}_z[J_t(z)] = \frac{c}{q(\theta_t)} \tag{J.3}$$

where $J_t(z)$ solves the following recursion:

$$J_t(z) = (h_t - w_t) + \beta(1 - (s_0 + s_1 \log(z)))\mathbb{E}_{z'}[J_{t+1}(z')] \tag{J.4}$$

Note, the expectation in the free-entry condition is over the productivity of a unemployed worker, which potentially varies over time. The remainder of the model is unchanged.

Figure 22 shows the response to the productivity shock in the three versions of the model. The introduction of heterogeneous job separation rates leaves the amplification of the model unchanged.

Figure 20: Robustness: Wage Depends on Unemployment Rate

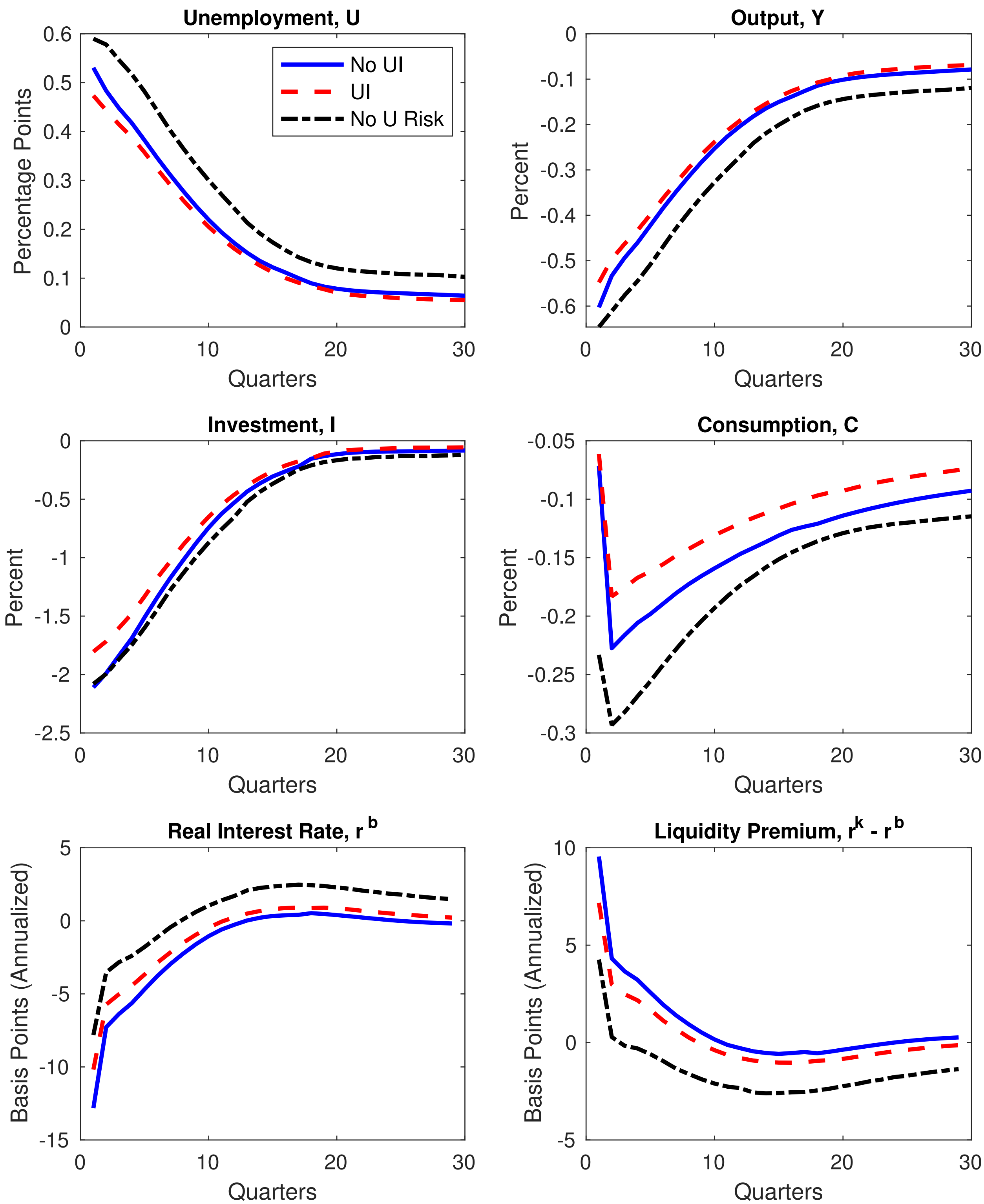


Figure 21: Robustness: Distributed Profits

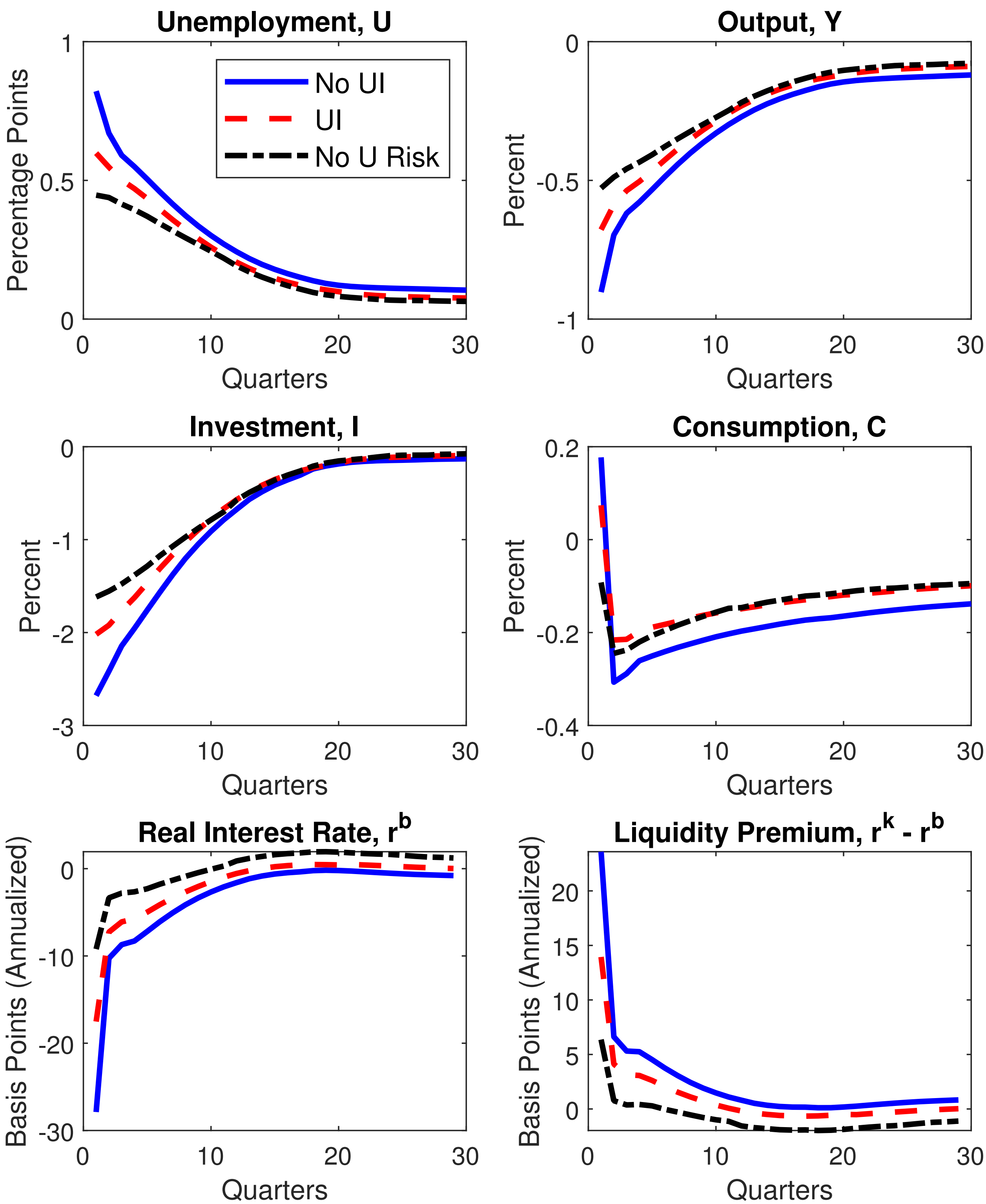
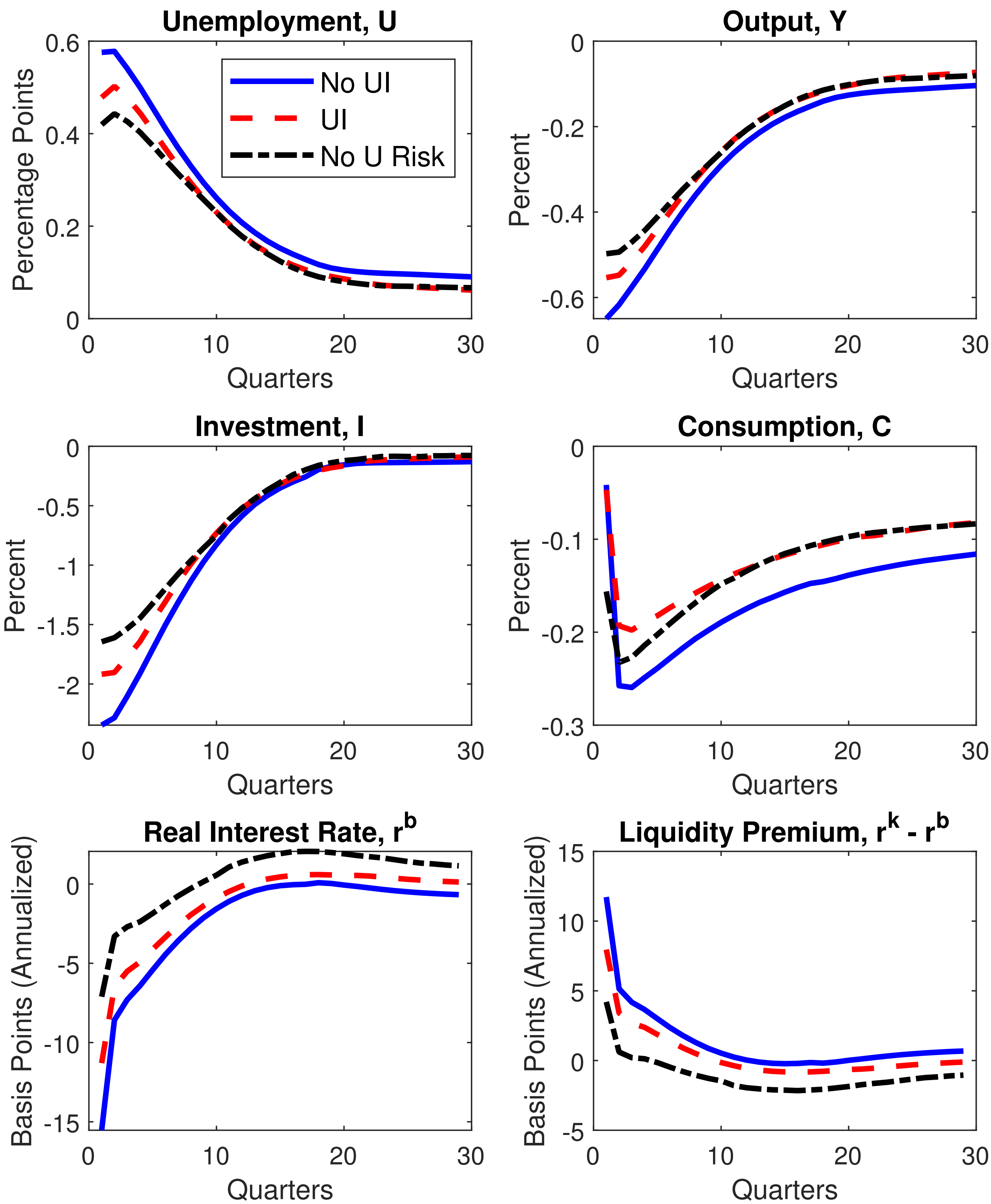


Figure 22: Robustness: Heterogeneous Separation Rates



J.5 Flexible Prices

Figure 23 plots the response of the three versions of the model in an economy with flexible prices. If prices are flexible, the effect of the decline in aggregate demand initiated by the rise in unemployment risk is accommodated entirely in prices rather than quantities, and the feedback loop between unemployment risk and aggregate demand is neutralized. Consequently, price rigidity is required for idiosyncratic unemployment risk to lead to business cycle amplification in this model.

J.6 Adjusting T_t Not G_t

In the experiments considered in Section 6, I assume that government spending adjusts to balance the governments budget constraint each period. In this section, I assume instead that government spending is held constant at its steady-state level, and that the lump-sum transfer adjusts. Figure 24 plots the response of the three versions of the model to the aggregate productivity shock under this assumption. By comparing the versions of the model with no unemployment insurance and no unemployment risk, it is clear that the overall degree of amplification is broadly unchanged under this assumption. However, unemployment insurance is now slightly less effective at reducing the amplification caused by the flight-to-liquidity mechanism. This occurs as the extra spending on unemployment insurance in response to a rise in unemployment risk is now financed by reducing the lump-sum transfer, rather than by reducing government spending. Consequently, unemployment insurance only redistributes total household income, and no longer supports the level of total household income.

J.7 Housing As the Illiquid Asset

In this section, I show that the main results of the paper are robust to interpreting the illiquid asset as housing rather than physical capital. The removal of physical capital changes the intermediate good producer problem, as in Section 7. I assume that households receive utility from consumption of the final good and from housing services according to the following utility function:

$$U(c,h) = \frac{(c^{\eta}h^{1-\eta})^{1-\gamma} - 1}{1-\gamma} \tag{J.5}$$

Figure 23: Aggregate Productivity Shock with Flexible Prices

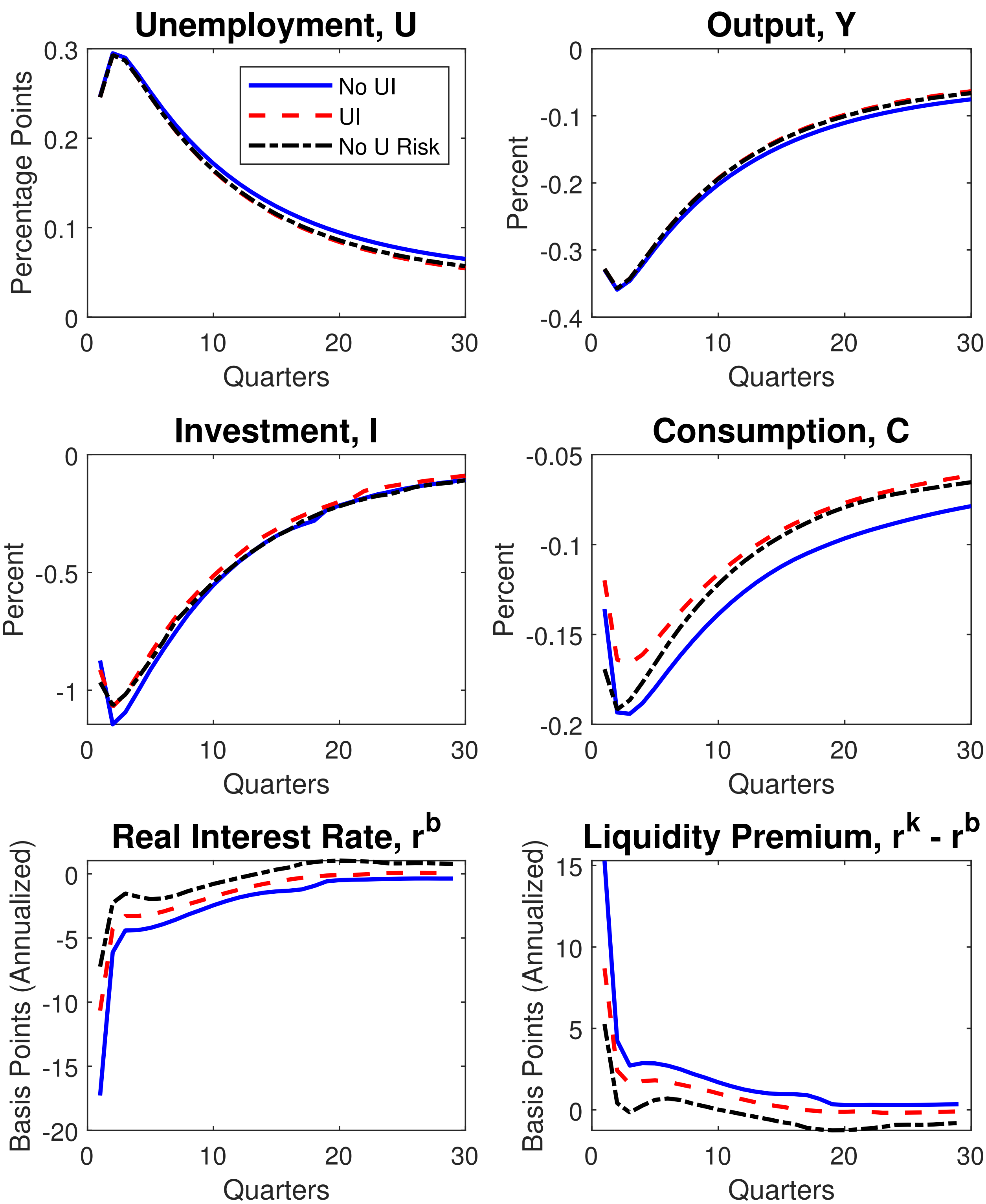
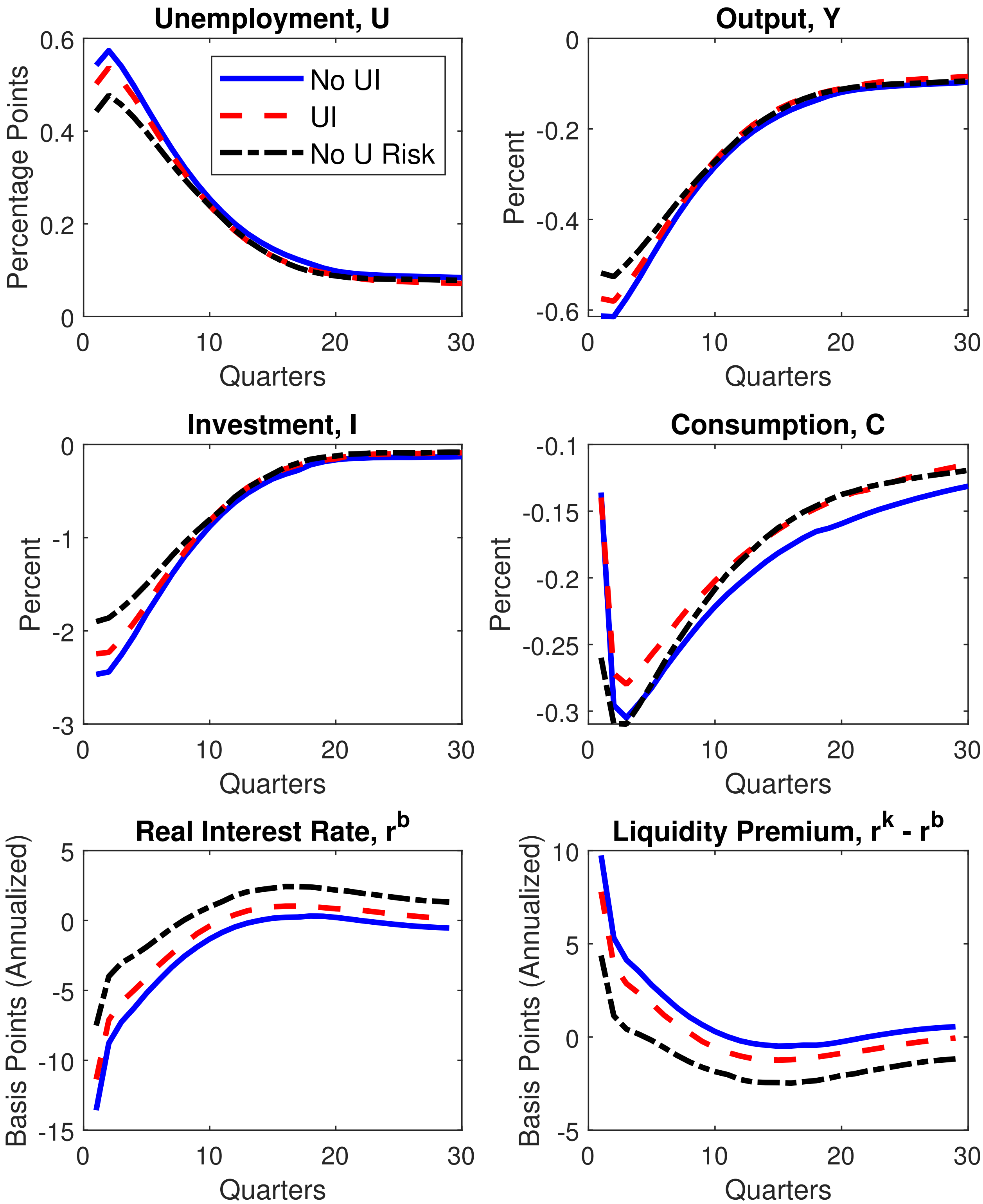


Figure 24: Aggregate Productivity Shock when T_t Adjusts



Owner-occupied housing provides a flow of housing services, net of depreciation, equal to $\tilde{r}^h = r^h - \delta$. Households are also able to purchase rental housing, c^h. Consequently, consumption of housing services is equal to $h = \tilde{r}^h k + c^h$. I remove the illiquid asset withdrawal tax but retain the random adjustment costs denoted in units of utility. The problem for a household that chooses to adjust their illiquid asset holdings is now:

$$
\begin{aligned}
V_t^A(b,k,z,e) &= \max_{c,h,b',k'} \frac{(c^\eta h^{1-\eta})^{1-\gamma}}{1-\gamma} + \beta \mathbb{E}_{e',z'} V_{t+1}(b',k',z',e') \qquad \text{(J.6)}\\
&\text{subject to}\\
k' + b' + c + c^h &= \mathbb{1}\{e=1\} w_t z (1-\tau_l) + \mathbb{1}\{e=0\} w_t \phi(z)(1-\tau_l) + R_t^b(b) b + k + T_t\\
h &= \tilde{r}^h k + c^h\\
b' &\geqslant -\underline{\mathrm{b}}\\
k' &\geqslant 0\\
z' &= \Gamma(z)
\end{aligned}
$$

The goods market clearing condition is:

$$
Y_t = C_t + C_t^h + I_t + G_t + \Theta_t + \kappa \int \max\{-b,0\}\, d\mu_t + cV_t
$$

where C_t^h is the aggregate consumption of rental housing and I_t is now residential investment. When solving the model, there is one fewer market clearing condition, as there is no longer a market for physical capital. Consequently, the algorithm to solve the model is similar to that used for the one-asset model.[34]

I recalibrate the model as in Section 7. I assume that $\tilde{r}^k$ is equal to the steady-state level of r^k in the two-asset model in Section 4. I lower β to 0.97 and $\bar{\chi}$ to 1.5 in order to target the total levels of liquid and illiquid assets relative to GDP. I assume a depreciation rate on housing of 1.5% per year, as in Greg Kaplan, Kurt Mitman and Giovanni L Violante (2017). Figure 25 shows the response of the economy to the same shock considered in Section 6. The main results are unchanged if the illiquid asset is housing rather than physical capital: a rise in unemployment risk leads to a flight to liquidity and a decline in investment. The only change is that the decline in investment is in housing rather than in physical capital. The amplification that this mechanism provides is roughly unchanged.

[34]The treatment of housing in this version of the model is the same as in the NBER working paper version of Kaplan, Moll and Violante (2018).

Figure 25: Aggregate Productivity Shock with Illiquid Housing