Online Appendix for Does Unemployment Risk Affect Business Cycle Dynamics?

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February 23, 2024

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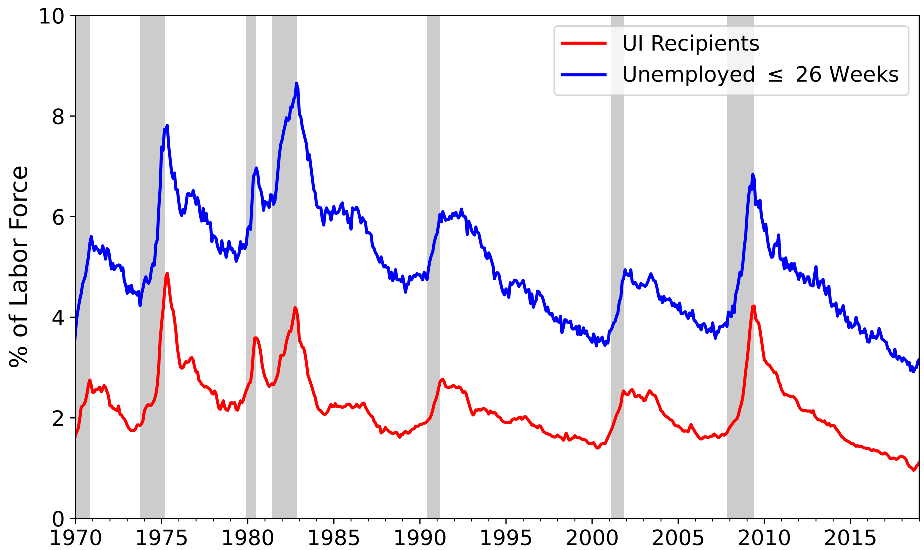
Appendices

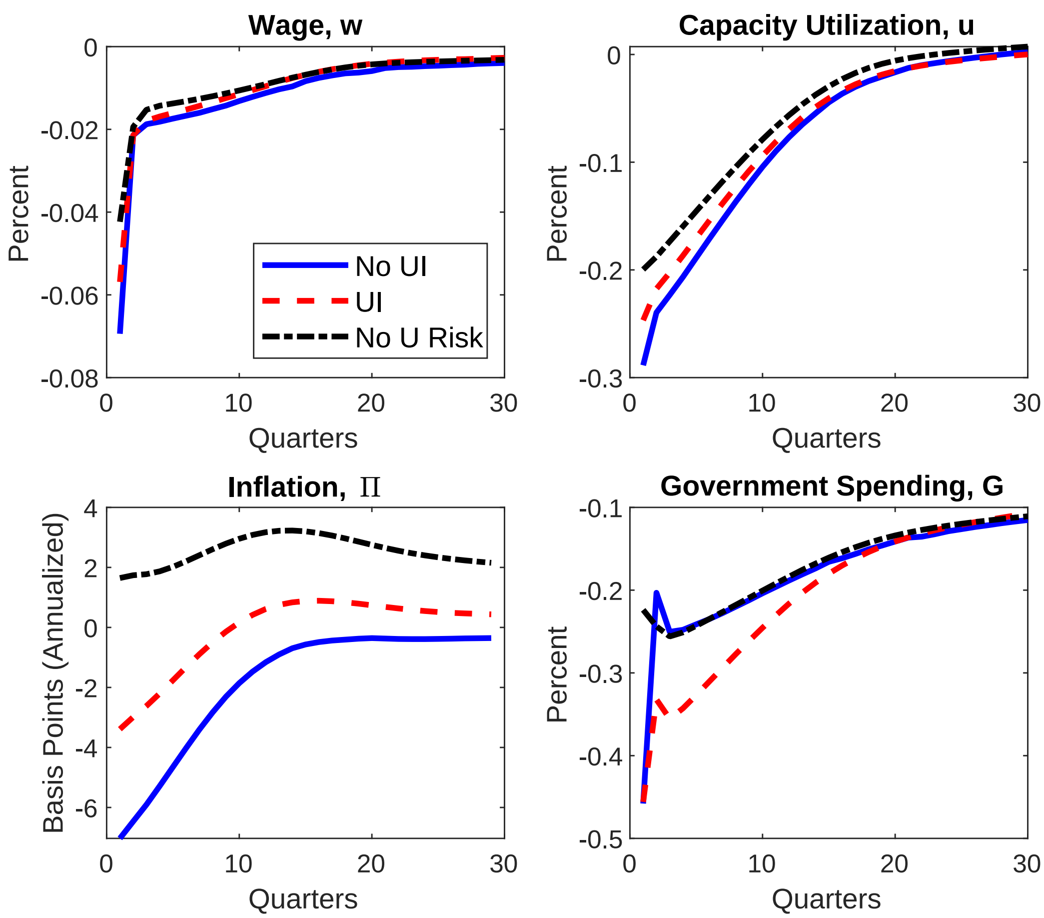
A Additional Figures

Figure A.1: Low Recipiency of Unemployment Insurance



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

Figure A.2: Response to an Aggregate Productivity Shock



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

B Data Sources

B.1 Consumer Expenditure Survey (CEX)

I construct the CEX sample using the microdata 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

Table A.1: Wealth Distributions in Alternative Models

Moment	Data	Baseline Model	No UI Model	No U Risk Model
Liquid Assets to Output	0.26	0.30	0.31	0.27
Illiquid Assets to Output	2.86	2.88	2.88	2.88
% Poor Hand-to-Mouth	0.10	0.05	0.05	0.04
% Wealthy Hand-to-Mouth	0.20	0.20	0.14	0.42
% Negative Liquid Assets	0.15	0.14	0.12	0.16
Gini Coefficient (Total Wealth)	0.81	0.82	0.81	0.83
Top 1% share (Liquid)	47	34	33	41
Top 1%-10% share (Liquid)	39	52	51	51
Top 10%-50% share (Liquid)	18	15	16	11
Bottom 50% share (Liquid)	-4	-2	0	-3
Top 1% share (Illiquid)	33	19	19	19
Top 1%-10% share (Illiquid)	37	55	55	55
Top 10%-50% share (Illiquid)	27	24	24	24
Bottom 50% share (Illiquid)	3	2	2	2

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.

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. Thus, I am able to measure liquid asset holdings immediately before the year in which the households report their employment status and consumption. 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). Table A.2 reports some descriptive statistics about the CEX sample and compares it to households from the SCF, where liquid and illiquid asset holdings are measured more accurately.

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 A.2 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.

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.

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. As the PSID occurs every other year, for the purposes of estimating equation 2.2 I group

Table A.2: 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	0.50	0.50	0.30	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	0.72	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 (000s)	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.

households based on their asset holdings in year $t-2$. Finally, the measure of consumption is food, clothing, recreation and vacation expenditures.

B.3 Survey of Consumer Finances (SCF)

I use microdata 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 Survey of Consumer Expenditures (SCE)

I use SCE data from 2014 to 2019. As in the SCF, I restrict the sample to households whose head is at most 55 years of age. This is important when considering contributions to retirement accounts, for the same reason as in the SCF.

Given the focus on idiosyncratic job loss risk, I drop self-employed respondents. I also restrict the sample to household heads that have been continuously employed for more than one year. I do this by using the response to two questions in the survey. The first (Q37) is asked only to new respondents, and asks respondents to identify their job tenure using five bins. The second (DSAME) asks repeat respondents whether they are still employed at the same job.

B.5 Current Population Survey (CPS)

In Section 7 and Appendix G, I document the central role of unemployment risk in explaining cyclical changes in the income growth distribution. This is based on microdata 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 mea-

Table A.3: Consumption Response to Unemployment Spells

	Data (CEX)		K Model (High β)		K Model (Low β)		B Model	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$U_{i,t}$	-0.22	-0.31	-0.13		-0.20		-0.19	
	(0.015)	(0.017)						
$U_{i,t}\mathbb{1}\{\text{N-HTM}\}$				-0.05		-0.07		-0.07
$U_{i,t}\mathbb{1}\{\text{HTM}\}$				-0.20		-0.32		-0.28
Fixed effects	✓	✓						
Control variables	✓							

Notes: Robust standard errors in parentheses. Regressions weighted using CEX sampling weights, with 31638 observations from 1996 to 2017. K Model refers to the one-asset model with capital, described in Appendix H.1. B Model refers to the one-asset model with bonds, described in Appendix H.2. In both the model and the data households are defined as hand-to-mouth if their liquid asset holdings are below the median.

sures 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.

C Consumption Response to Unemployment Spells

In this section, I provide further evidence on the consumption response to unemployment spells. Column (1) of Table A.3 repeats the average response shown in Table 1. The second 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) to (8) repeat the basic regressions in the various one-asset models studied in Section H.

D 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 A.4 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 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 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.

E 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 A.5 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, homeownership, 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 A.6 shows that there is no significant effect of education or homeownership on either of the dependent variables. The

Table A.4: 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)				
$\mathbb{1}\{U_{i,t} \leq 12 \text{ weeks}\}$			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.

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.

F Precautionary Saving: Robustness

Table A.7 replicates Table 3 using alternative lag lengths for calculating the change in idiosyncratic unemployment risk. For clarity, I do not include the percentage change in consumption as a dependent variable.

It is clear in Table A.7 that moving from the 9th to the 10th lag shrinks the sample by around a third, while moving from the 10th to the 11th lag

Table A.5: 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)
$U_{i,t}\mathbb{1}\{\text{HTM}\}$		-0.75			-0.84	
		(0.038)			(0.053)	
$U_{i,t}\mathbb{1}\{\text{W-HTM}\}$			-0.75			-0.84
			(0.051)			(0.091)
$U_{i,t}\mathbb{1}\{\text{P-HTM}\}$			-0.75			-0.83
			(0.055)			(0.064)
$H0 : \gamma_N = \gamma_H$		0.92			0.74	
$H0 : \gamma_N = \gamma_W = \gamma_P$			1.00			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.

shrinks the sample by half. This occurs because the Household Finance supplement and the Household Spending supplement are fielded infrequently. For example, as the Household Finance supplement was only fielded in one month each year, using the 9th lag allows us to include individuals who were in their 10th, 11th or 12th interview at the time of the supplement. If we use the 11th lag, we are only able to include individuals who were in their 12th interview at the time of the supplement.

Estimates are broadly similar using the 10th lag, although slightly attenuated and with larger standard errors. This pattern is exacerbated using the 11th lag, for which the available sample shrinks considerably.

Table A.6: Effect of Job Displacement in the CPS

	Δ log Weekly Earnings	Weeks Unemployed
Intercept	0.23	3.61
	(0.04)	(1.19)
$\mathbb{1}\{$High School$\}$	-0.004	-1.25
	(0.02)	(0.78)
$\mathbb{1}\{$Some College$\}$	-0.010	-0.77
	(0.02)	(0.79)
$\mathbb{1}\{$College$\}$	0.017	-0.33
	(0.02)	(0.80)
$\mathbb{1}\{$Homeowner$\}$	-0.004	-0.49
	(0.01)	(0.45)
Age	-0.008	0.25
	(0.001)	(0.03)

Notes: Robust standard errors in parentheses. The sample is restricted to men between the ages of 25 and 55. Regressions use sampling weights, with 7094 observations from 1990 to 2018.

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 7.

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:

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

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:

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

Table A.7: Robustness of Precautionary Response to Unemployment Risk

	$\mathbb{1}\{c^i_t \geq c^i_{t-12}\}$			$\mathbb{1}\{\mathbb{E}_{i,t}[P^i_{t,t+12} > P^i_{t-12,t}]\}$		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta_9\mathbb{E}_{i,t}[s^i_{t,t+12}]$	-.28			-.32		
	(.073)			(.13)		
$\Delta_{10}\mathbb{E}_{i,t}[s^i_{t,t+12}]$		-.24			-.25	
		(.097)			(.18)	
$\Delta_{11}\mathbb{E}_{i,t}[s^i_{t,t+12}]$			-.17			-.081
			(.12)			(.38)
Observations	946	633	313	260	184	92

Notes: Estimates from estimating equation 4.1. Dependent variable shown in the first row. Robust standard errors in parentheses. Regressions weighted using sampling weights. c^i_t denotes household consumption of individual i in month t. $\mathbb{E}_{i,t}\mathbb{1}\{(P^i_{t,t+12} > P^i_{t-12,t})\}$ is an indicator denoting that individual i expects to increase the proportion of earnings contributed to their Defined Contribution pension over the next year. $\Delta_x\mathbb{E}_{i,t}[s^i_{t,t+12}]$ denotes the change in the perceived annual job loss probability of individual i from month $t-x$ to t. Data from the Survey of Consumer Expectations from 2014 to 2019.

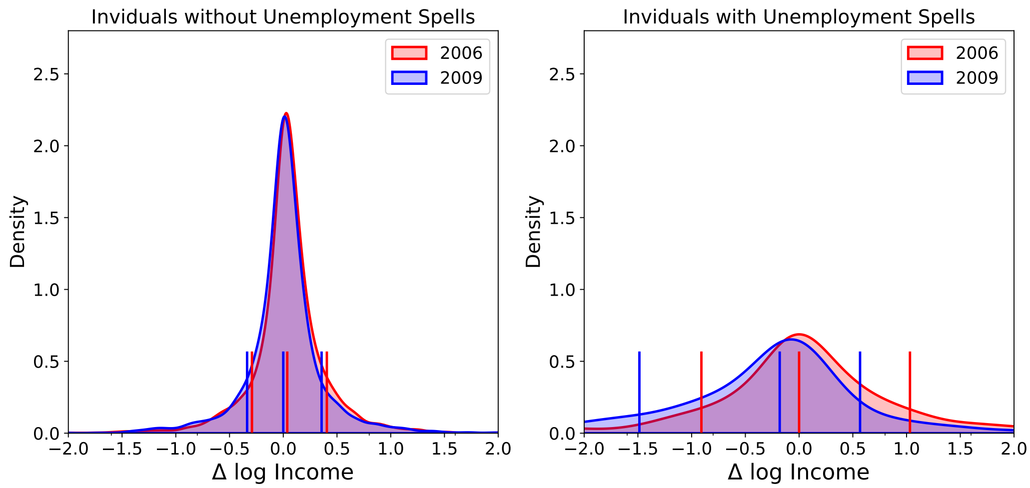
Figure 7 shows a measure of the skewness of the income growth, wage growth, and hours growth distributions over time.[1] It is clear that the skewness of hours growth drives that of income growth, while the skewness of wage growth changes little over the business cycle. Income growth becomes negatively 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.[2]

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 A.3 plots the income growth distribution in 2006 and 2009 for two

[1]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.

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

Figure A.3: Income Growth Densities and Unemployment Spells

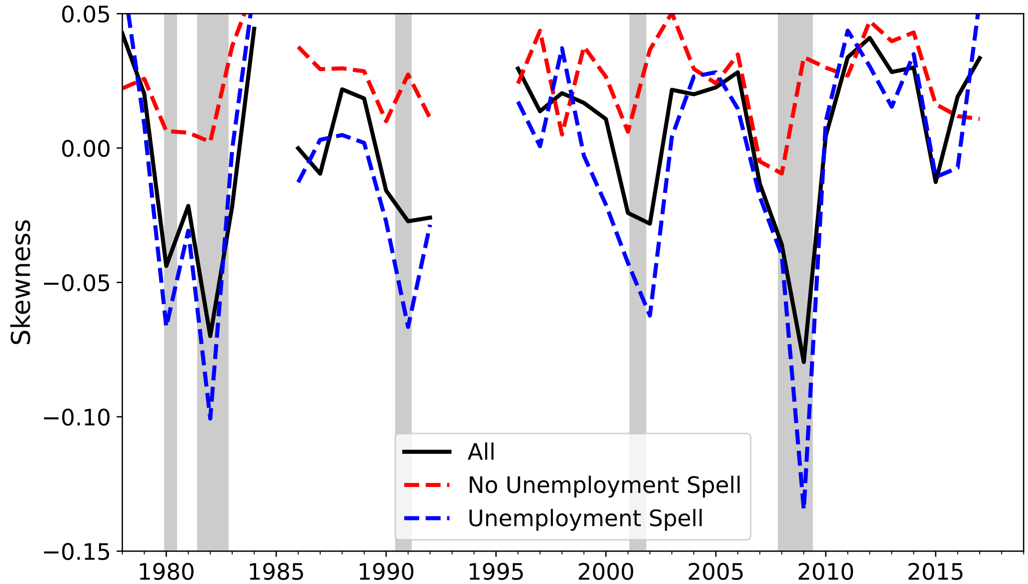


Notes: The vertical lines denote the 10th, 50th, and 90th percentiles of the distribution.

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 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.

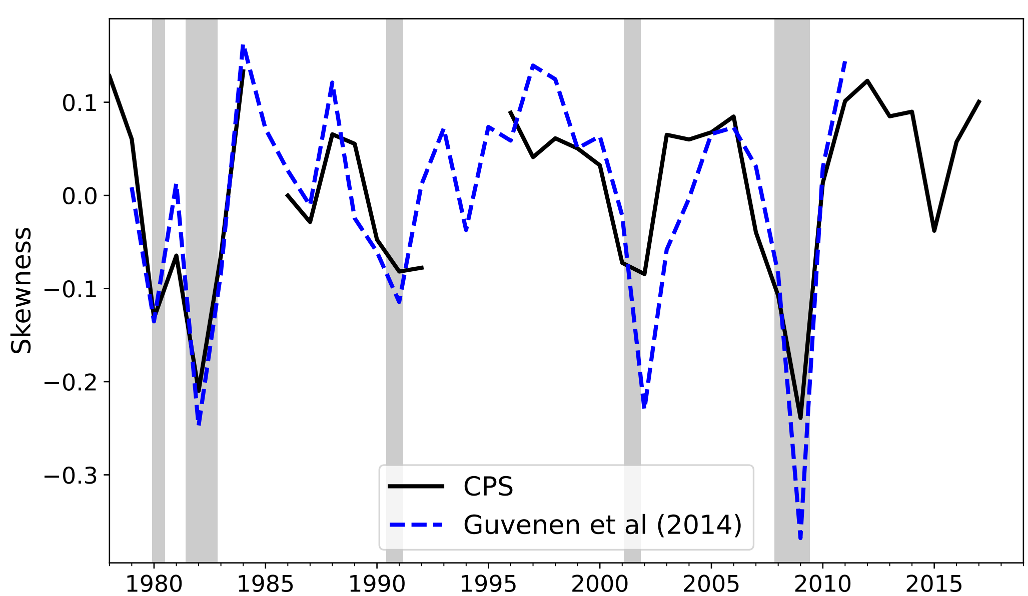
Figure A.4 plots the skewness of income growth for the entire sample of individuals, as well as the sub-samples of individuals that either did or did not experience an unemployment spell. This confirms that the group of individuals with unemployment spells drives the cyclicality of the skewness of the income growth distribution. Finally, Figure A.5 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.

Figure A.4: Unemployment Drives Skewness of Income Growth



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

Figure A.5: Income Skewness: CPS vs. Social Security Data



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

H Three Different One-Asset Models

In this section, I consider three different one-asset models. In the first, I remove bonds from the model and assume that households trade capital with no adjustment costs. Aside from these changes, I keep the parameterization as described in Section 5. In the second, I keep the liquid capital framework but lower the calibrated discount factor, β, in order to match the estimated consumption decline during unemployment. In the third, I remove capital and assume that households only trade liquid bonds.

H.1 A One-Asset Model with Liquid Capital

In the model with liquid capital and without bonds, the household's problem simplifies to:

$$\begin{aligned} V_t(k, z, e) = \max_{c,k'} \frac{c^{1-\gamma}}{1-\gamma} + \beta(1-\zeta)\mathbb{E}_{e',z'} V_{t+1}(k', z', e') \qquad \text{(A.3)} \\ \text{subject to} \\ k' + c = \mathbb{1}\{e = E\} w_t z (1-\tau_l) + \mathbb{1}\{e = U\} w_t \phi(z)(1-\tau_l) + R_t^k k + T_t \\ k' \geq 0 \\ z' = \Gamma(z) \end{aligned}$$

As in Gornemann, Kuester and Nakajima (2016), I use a cashless limit assumption, implying that the expected return on nominal bonds must be equal to that on capital.

In the first calibration of this one asset model with capital, I keep the parameterization as described in Section 5. In such a model, households are well insured against unemployment risk, and consequently the decline in consumption during unemployment is smaller than documented in Section 2. This is shown in Table A.3, which reports the consumption declines during unemployment for each of the one-asset models in this section. Figure A.6 shows the response of the economy to the aggregate productivity shock in this model: I find no amplification from unemployment risk. As in Gornemann, Kuester and Nakajima (2016), I find that unemployment risk raises the volatility of consumption but lowers the volatility of investment. Overall, it has almost no effect on the response of unemployment or output.

In the second calibration of this one-asset model with capital, I lower the calibrated discount factor, β, from 0.982 to 0.96, in order to match the estimated consumption decline during unemployment. Figure A.7 shows the response of the economy to the aggregate productivity shock in this model: I find that unemployment risk actually *dampens* business cycle fluctuations slightly. A rise in unemployment risk leads to an increase in precautionary saving in capital. This dampens the decline in investment sufficiently such that output and employment actually fall less with unemployment risk than without. In the language of Challe et al. (2017), the stabilizing "aggregate supply" channel of unemployment risk dominates in this setting. In Section J.2 I show that these results also hold in response to a shock to the marginal efficiency of investment.

H.2 A One-Asset Model with Liquid Bonds

In the model in which households trade bonds and there is no capital, the production function for the intermediate good producers is:

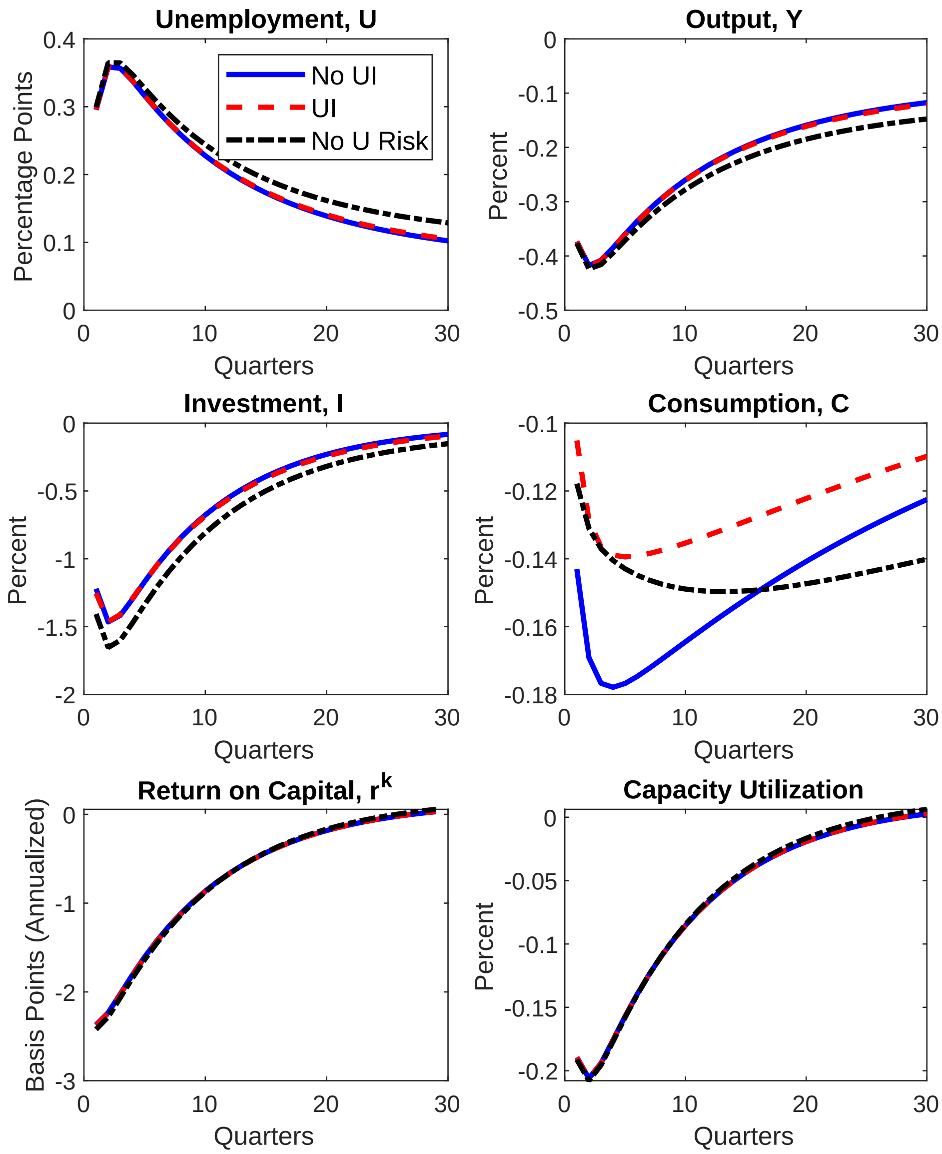
$$y_{j,t} = A_t n_{j,t} \tag{A.4}$$

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:

$$\begin{aligned} V_t(b,z,e) = \max_{c,b'} \frac{c^{1-\gamma}}{1-\gamma} + \beta(1-\zeta)\mathbb{E}_{e',z'} V_{t+1}(b',z',e') \qquad \text{(A.5)} \\ \text{subject to} \\ b' + c = \mathbb{1}\{e=E\} w_t z(1-\tau_l) + \mathbb{1}\{e=U\} w_t \phi(z)(1-\tau_l) + R_t^b(b) b + T_t \\ b' \geq \underline{\mathrm{b}} \\ z' = \Gamma(z) \end{aligned}$$

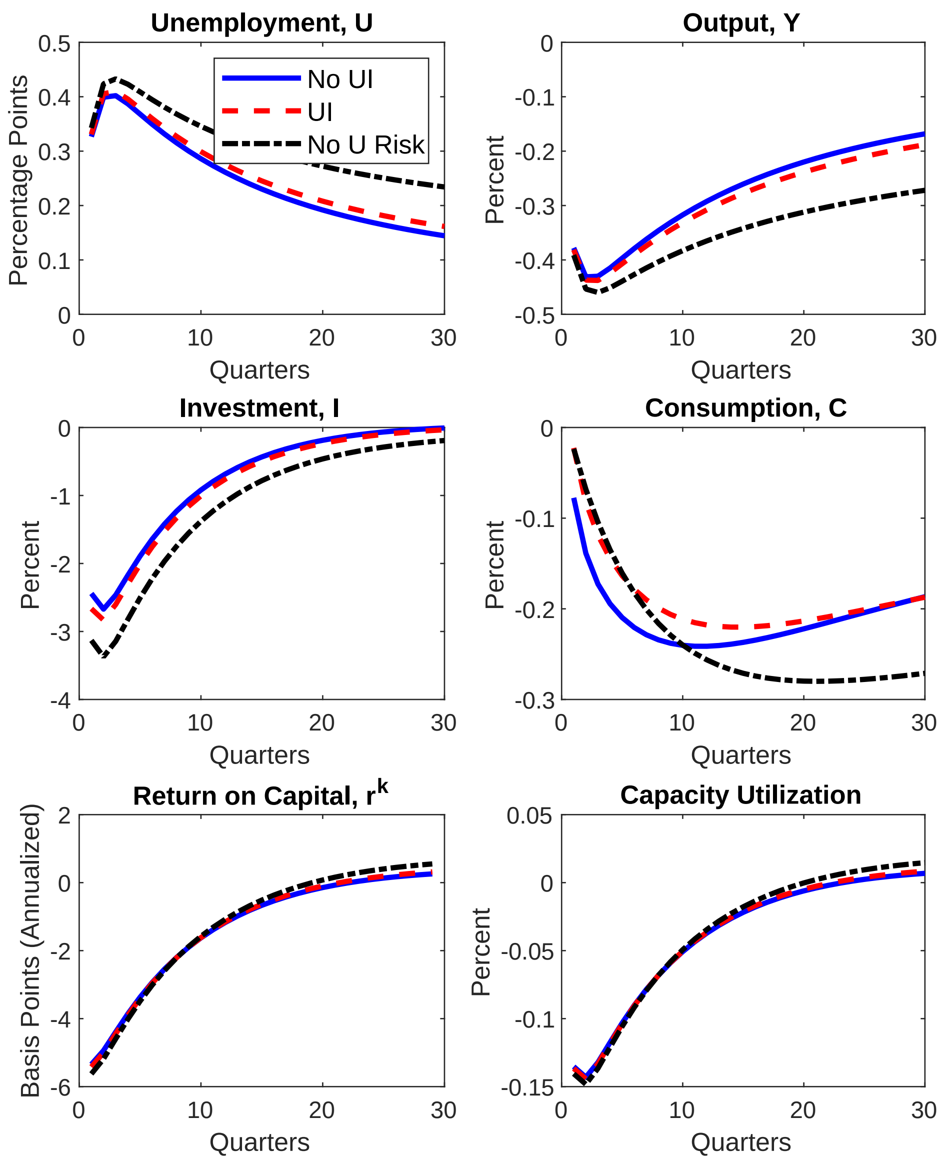
The rest of the model: the labor agency's problem and fiscal and monetary policy rules are exactly as in the two-asset model. I leave the calibration as close to the two-asset model as possible. I lower the discount factor, β, to 0.98, to match the estimated consumption decline during unemployment. I leave all other 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 $\underline{\mathrm{b}}$ such that they remain the same relative to $\bar{w}$ or output.

Figure A.6: Aggregate Shock (One-Asset Model: Capital, High β)



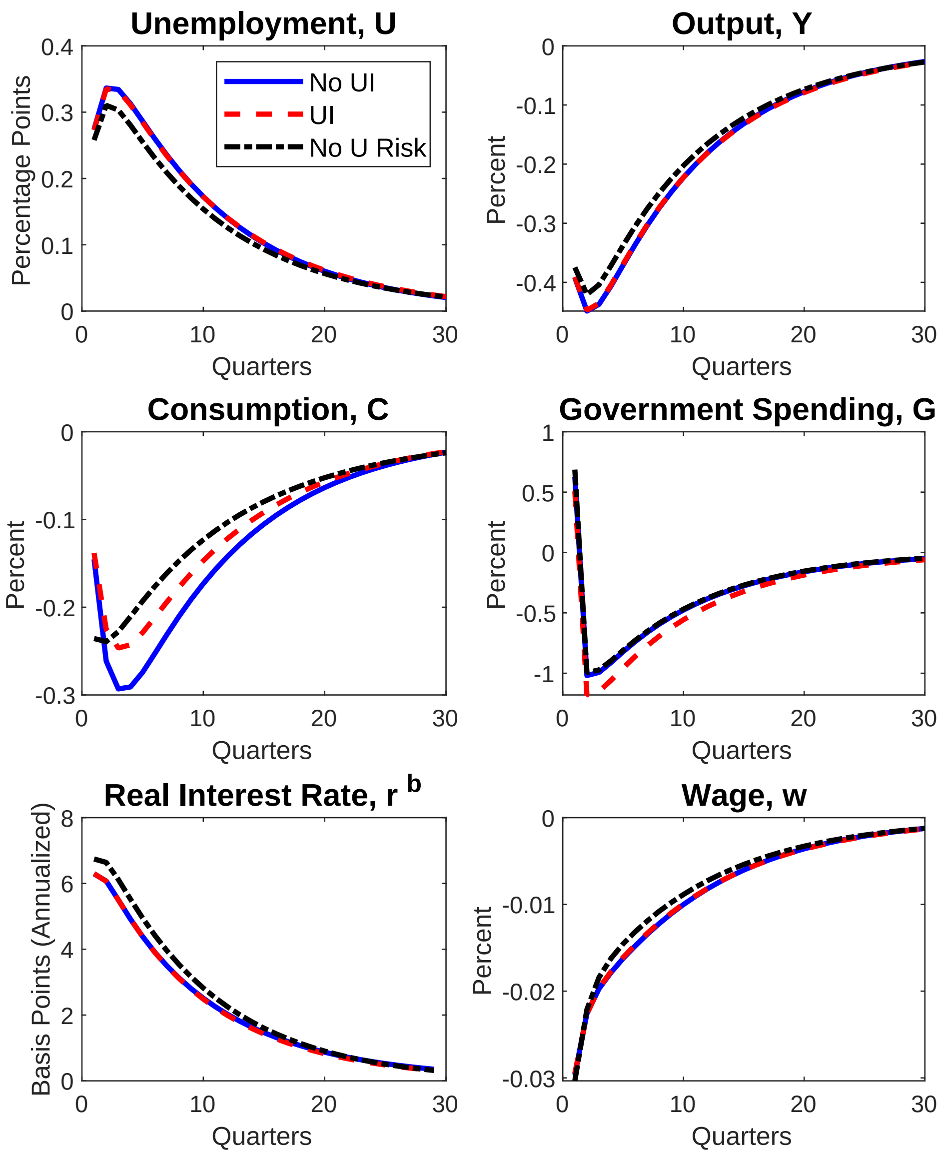
Notes: This figure shows the response of the economy to a negative productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.7: Aggregate Shock (One-Asset Model: Capital, Low β)



Notes: This figure shows the response of the economy to a negative productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.8: Aggregate Shock (One-Asset Model: Bonds)



Notes: This figure shows the response of the economy to a negative productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.8 plots the response of key variables to the aggregate productivity shock in all three versions of the one-asset model with liquid bonds. The main result is that there is little amplification of the shock due to unemployment risk in this framework. Despite the fact that this is a calibration in which consumption responds strongly to unemployment, idiosyncratic unemployment risk has little effect on business cycle dynamics in this model, and unemployment insurance plays no role as an automatic stabilizer.

H.2.1 Amplification in the One-Asset Model with Liquid Bonds

In this section, I consider alternative calibrations of the one-asset model in which households trade bonds to understand the difference between the results above and those 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 assumptions 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.

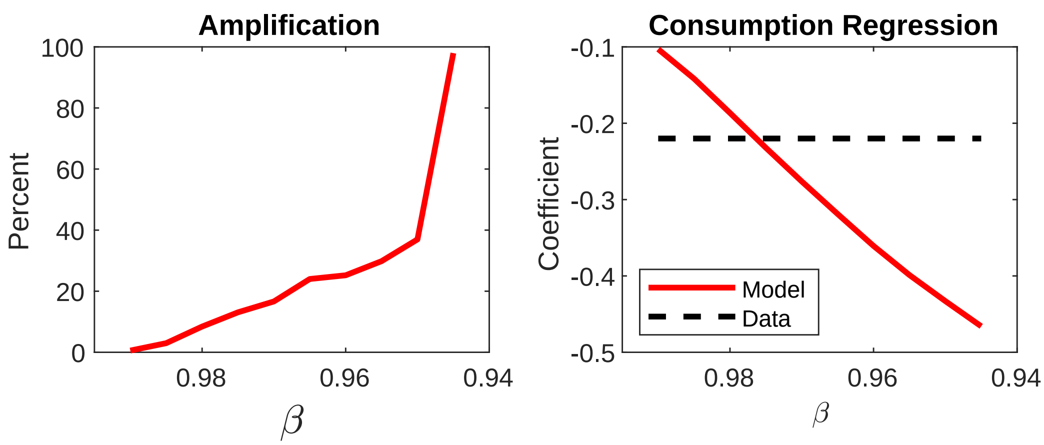
In Figure A.9, I show the effect of varying β in the one asset model between 0.99 and 0.945. When β is close to 0.945, the model does display significant amplification, as in Ravn and Sterk (2017). However, in such a calibration, the consumption decline during unemployment is much larger than in the data.

I Solving the Two-Asset Model

I.1 Solving the Household Problem

Solving equation 5.1 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).

Figure A.9: 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.

A robust but slow method for solving equation 5.1 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 5.1 for a large number of periods, multiple times.

A faster method is to break equation 5.1 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 5.4.

It is then possible to solve the full problem in equation 5.1 by solving the following one-dimensional maximization:

$$V_t^A(b,k,z,e) = \max_{k'} V_t^{NA}(b^*, k', z, e) \tag{A.6}$$
$$\text{subject to}$$
$$b^* = \frac{R_t^b(b)b + R_t^k(k-k') - \tau_k \mathbb{1}\{k' < k\}(k-k')}{R_t^b(b^*)}$$

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

$$k'+b'+c = \mathbb{1}\{e=E\}w_t z(1-\tau_l)+\mathbb{1}\{e=U\}w_t\phi(z)(1-\tau_l)+T_t+R_t^b(b^*)b^*+R_t^k k' \tag{A.7}$$

Now, substitute in the value of b^* given in equation A.6:

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

Thus, the problem in equation A.6 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 5.4 and equation A.6 are relatively simple one-dimensional maximization problems, this significantly increase the speed of solving the full problem in equation 5.1.

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:

   $$\beta\left(h-\bar{w}+\frac{c}{q(\theta)}(1-s)\right)=\frac{c}{q(\theta)} \tag{A.8}$$

   (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 5, 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:

$$\frac{C^{*(1-\gamma)}-1}{1-\gamma}=\frac{C^{1-\gamma}-1}{1-\gamma}-\chi \tag{A.9}$$

Solving for C^*:

$$C^*=\left[C^{1-\gamma}-(1-\gamma)\chi\right]^{\frac{1}{1-\gamma}} \tag{A.10}$$

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

$$C^*=\frac{1}{C^{-1}+\chi} \tag{A.11}$$

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:

$$\begin{aligned} C^* &= \frac{1}{\bar{\chi}}\int_0^{\chi^*}\frac{1}{C^{-1}+\chi}d\chi+\frac{1}{\bar{\chi}}\int_{\chi^*}^{\bar{\chi}}\frac{1}{C^{-1}}d\chi \\ &= \frac{1}{\bar{\chi}}\left[\log(C^{-1}+\chi^*)-\log(C^{-1})\right]+C\frac{\bar{\chi}-\chi^*}{\bar{\chi}} \end{aligned} \tag{A.12}$$

Integrating across households, the total size of adjustment costs in terms of consumption is $\int(C-C^*)d\mu$, which is equal to 0.6% of total consumption or 0.4% 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 0.3% 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 different aggregate shocks (specifically a shock to the marginal efficiency of investment), a Taylor rule featuring interest rate smoothing, 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).

J.1 A Shock to the Marginal Efficiency of Investment

In this section, I show that the amplification in the two-asset model due to unemployment risk is also present in response to other aggregate shocks.

Specifically, I study the response to a shock to the "marginal efficiency of investment". This is one of the "demand shocks" that explain most of the variance in output in the short-run in Smets and Wouters (2007), a finding that is corroborated by Justiniano, Primiceri and Tambalotti (2010). Bayer, Born and Luetticke (2020) show that such shocks remain important in estimated HANK models.

This shock varies the efficiency with which the final good can be transformed into physical capital. I assume that the marginal efficiency of investment declines by 0.3% unexpectedly and then returns to its steady-state value (of 1) following an AR(1) process with a quarterly persistence of 0.85.[3] I denote the path of its inverse by ν_t. This shock affects the household's budget constraint, which is now:

$$\begin{aligned}\nu_t k' + b' + c + \tau_k \mathbb{1}\{k' < k\}(k - k') = {} & \mathbb{1}\{e = E\} w_t z (1 - \tau_l) \\ & + \mathbb{1}\{e = U\} w_t \phi(z)(1 - \tau_l) + R^b_t(b) b + R^k_t k + T_t\end{aligned} \tag{A.13}$$

where

$$R^k_t = r^k_t u_t + (1 - \delta_0 u_t^{\delta_1})\nu_t \tag{A.14}$$

This shock raises ν_t and thus discourages households from investing in illiquid capital. Figure A.11 shows the response to this shock in the three versions of the model. The amplification that occurs due to unemployment risk, and the dampening that occurs due to the introduction of unemployment insurance, are both similar to that seen in Section 7.

[3] This magnitude generates a similar rise in unemployment in the baseline model to the productivity shock in Section 7.

J.2 A Shock to the Marginal Efficiency of Investment in the One Asset Model

In this section, I show that the *lack of* amplification in the one-asset model is also present in response to a shock to the marginal efficiency of investment.

I study the same shock as in the previous subsection in the two calibrations of the one-asset model with capital from Section H.1. Figures A.12 and A.13 show the response to this shock in the two one-asset models. In each case, there is a slight dampening of the aggregate shock due to unemployment risk. As in Bayer, Born and Luetticke (2020), the effect of a shock to the marginal efficiency of investment is both significantly smaller and significantly more persistent in one-asset models relative to a two-asset model.[4]

J.3 A Taylor Rule with Smoothing

In the main paper, I study the response to aggregate shocks with a very simple Taylor rule. I now consider whether amplification is affected by this assumption, by considering a Taylor rule with interest-rate smoothing:

$$i_{t+1} = \rho_i i_t + (1 - \rho_i)(\bar{r}^b + \psi(\Pi_t - 1)) \tag{A.15}$$

I set $\rho_i = 0.7$, in line with recent estimates such as Carvalho, Nechio and Tristao (2021) and leave ψ (and all other parameters) unchanged.

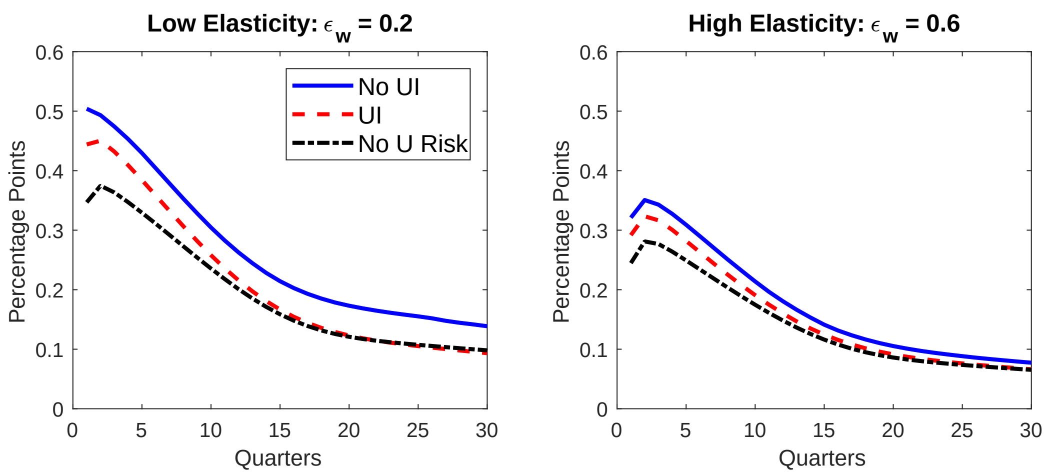
Figure A.14 shows the response to the aggregate productivity shock with this alternative monetary policy rule. I find that the amplification due to unemployment risk is significantly increased with this more sluggish response of monetary policy.

J.4 Stickier or More Flexible Wages

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.

[4] In their case, the one-asset model is a RANK model.

Figure A.10: Robustness to different values of ϵ_w



Notes: This figure shows the response of unemployment to a negative aggregate productivity shock under alternative calibrations of the wage rule.

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 A.10 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 is 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.5 Wages Responding 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 the level of employment (or unemployment):

$$w_t = \bar{w} \left(\frac{N_t}{\bar{N}} \right)^{\epsilon_U} \tag{A.16}$$

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 A.15 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.6 Profits Distributed to Households

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 A.16 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.7 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:

$$s(z) = s_0 + s_1 \log(z) \tag{A.17}$$

I leave s_0 at the original calibration of 0.1, and I set s_2 to -0.01. This implies that the least productive individuals have a job separation rate that is around two 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:

$$\mathbb{E}_z[J_t(z)] = \frac{c}{q(\theta_t)} \tag{A.18}$$

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

$$J_t(z) = (h_t - w_t) + \beta(1 - (s_0 + s_1 \log(z)))\mathbb{E}_{z'}[J_{t+1}(z')] \tag{A.19}$$

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

Figure A.17 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.

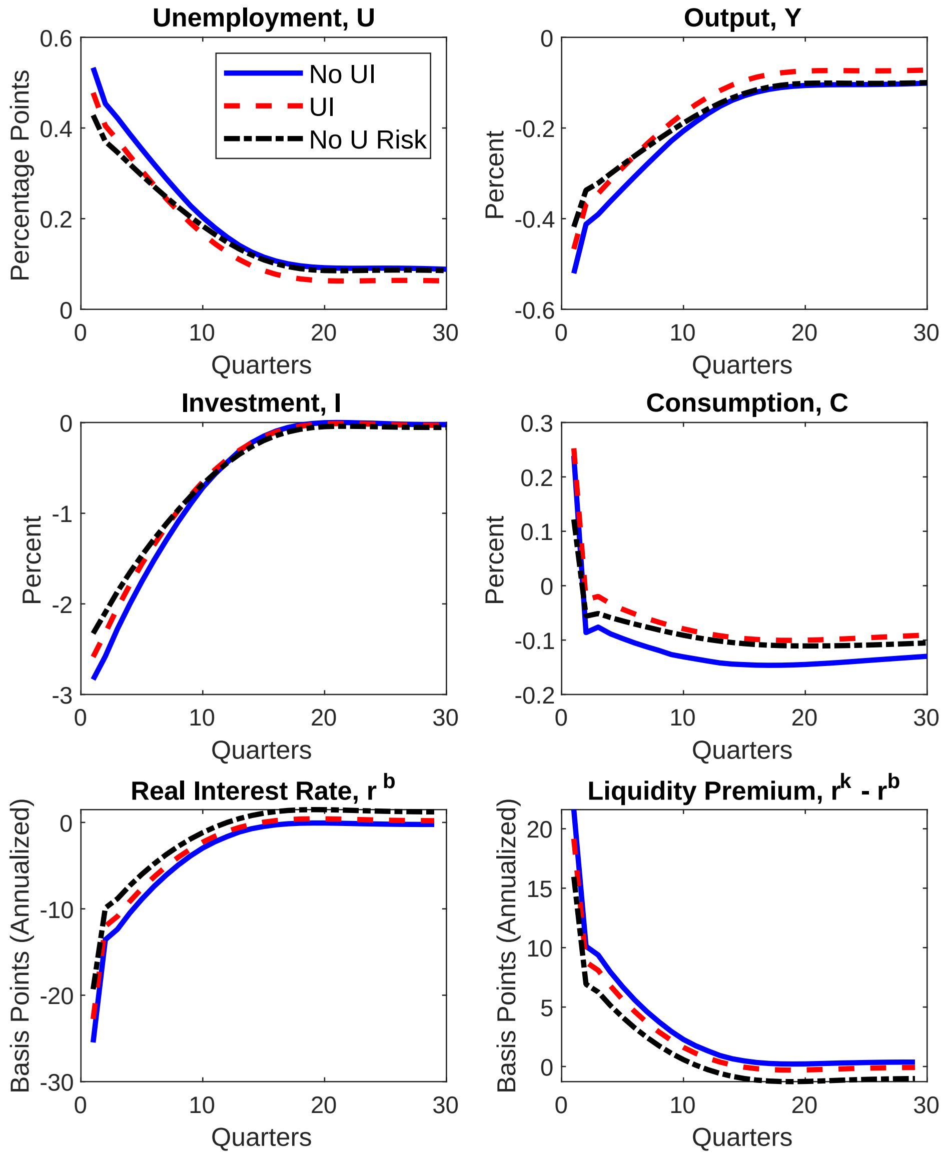
J.8 Flexible Prices

Figure A.18 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.9 Alternative Fiscal Policy Rules: Adjusting T_t Not G_t

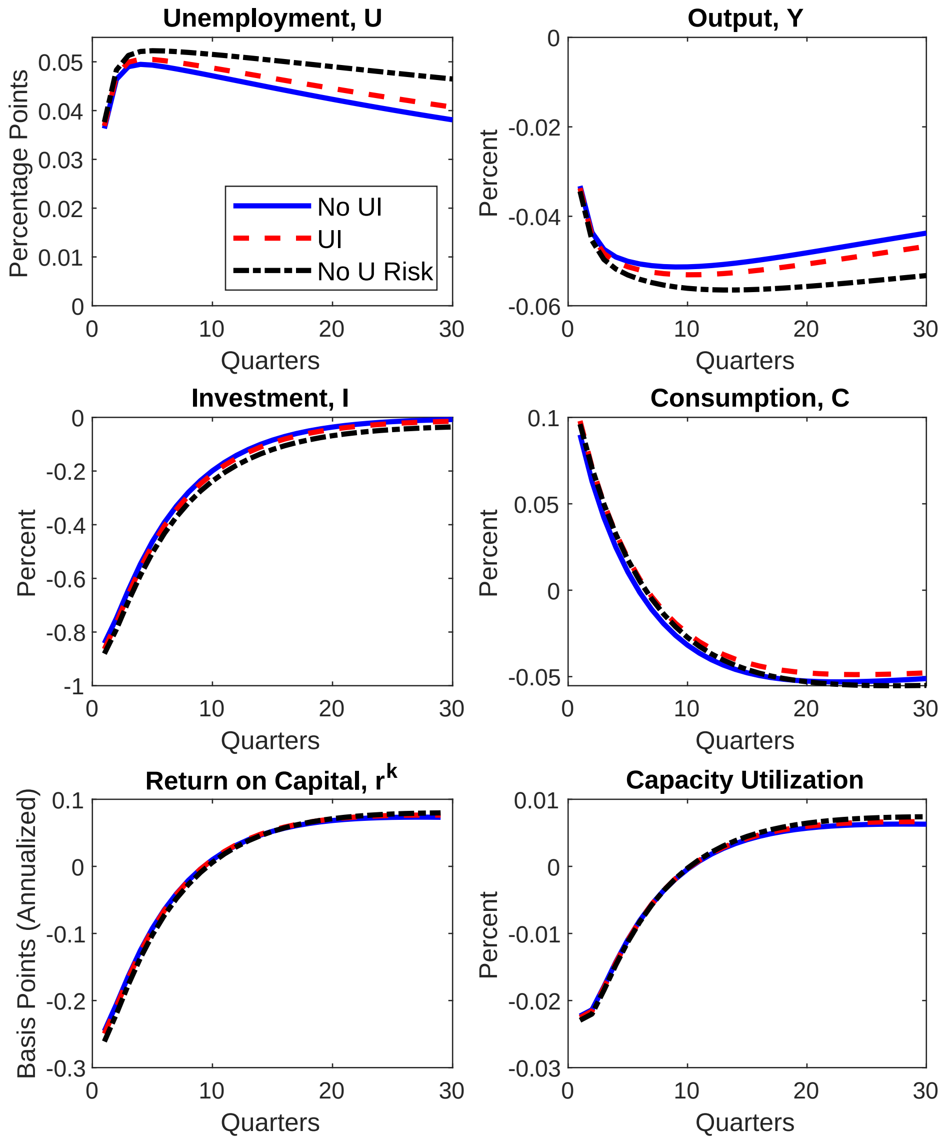
In the experiments considered in Section 7, I assume that government spending adjusts to balance the government's budget constraint each period. In this section, I assume instead that government spending is held constant at its steady-state level, and that the lump-sum transfer adjusts. Figure A.19 plots 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.

Figure A.11: Shock to Marginal Efficiency of Investment



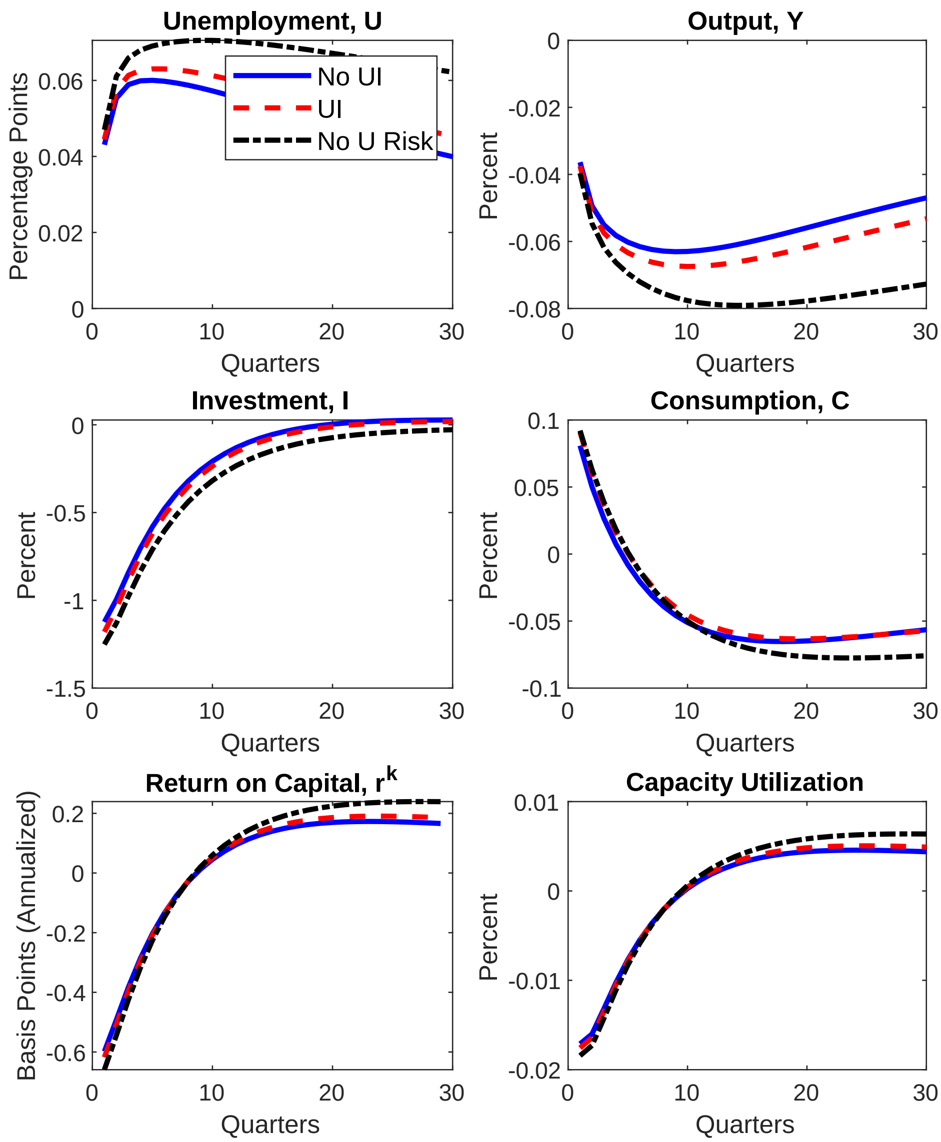
Notes: This figure shows the response of the economy to a shock to the marginal efficiency of investment. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.12: Shock to MEI in One-Asset Model (High β)



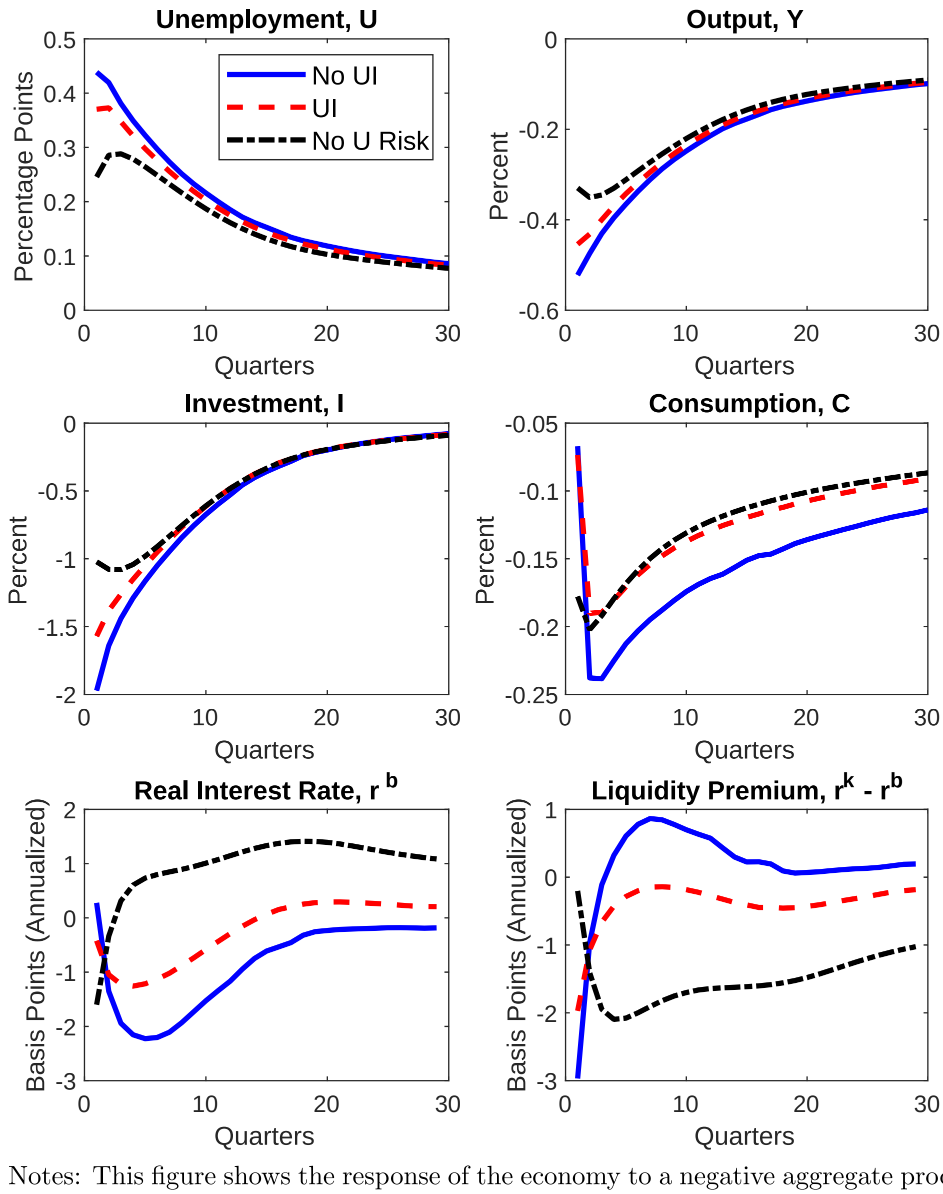
Notes: This figure shows the response of the economy to a shock to the marginal efficiency of investment. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.13: Shock to MEI in One-Asset Model (Low β)



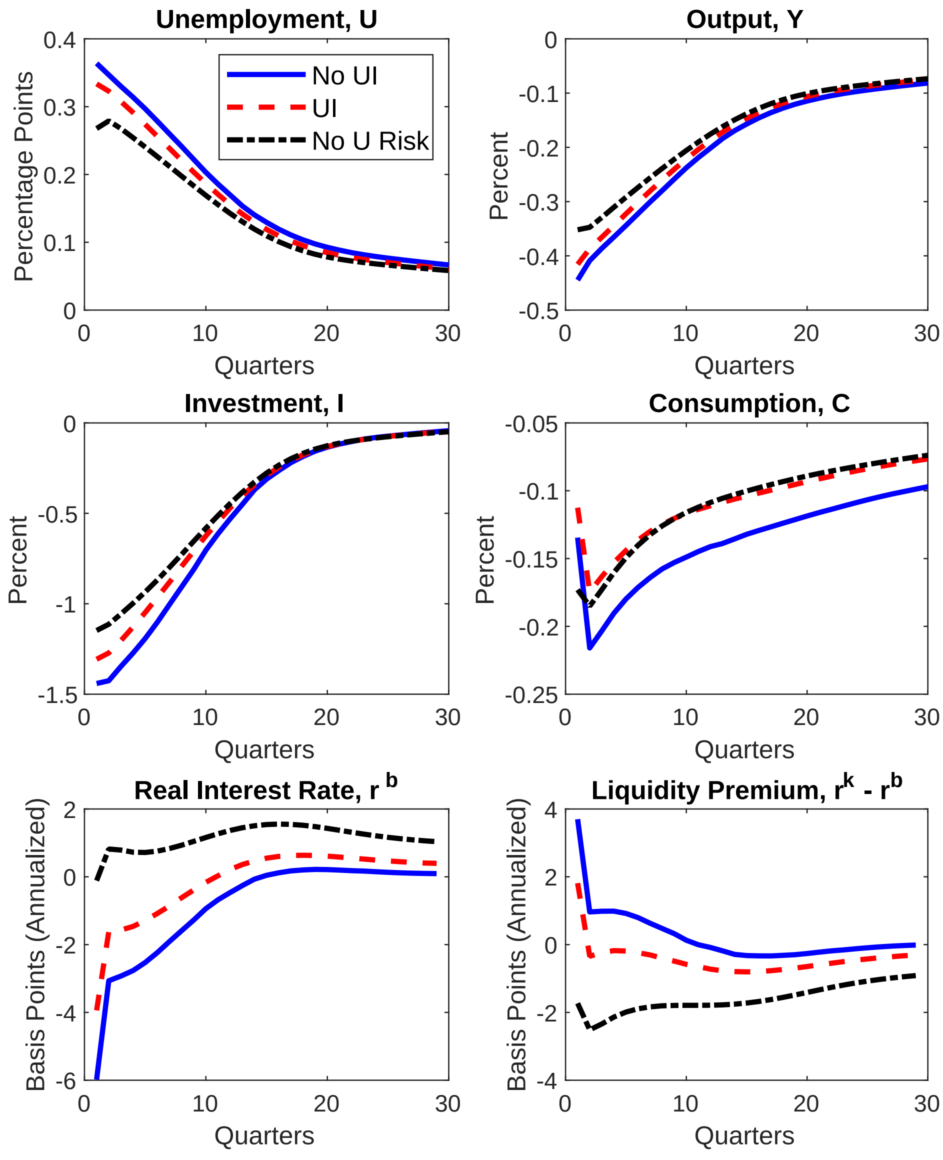
Notes: This figure shows the response of the economy to a shock to the marginal efficiency of investment. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.14: Robustness: Taylor Rule with Interest Rate Smoothing



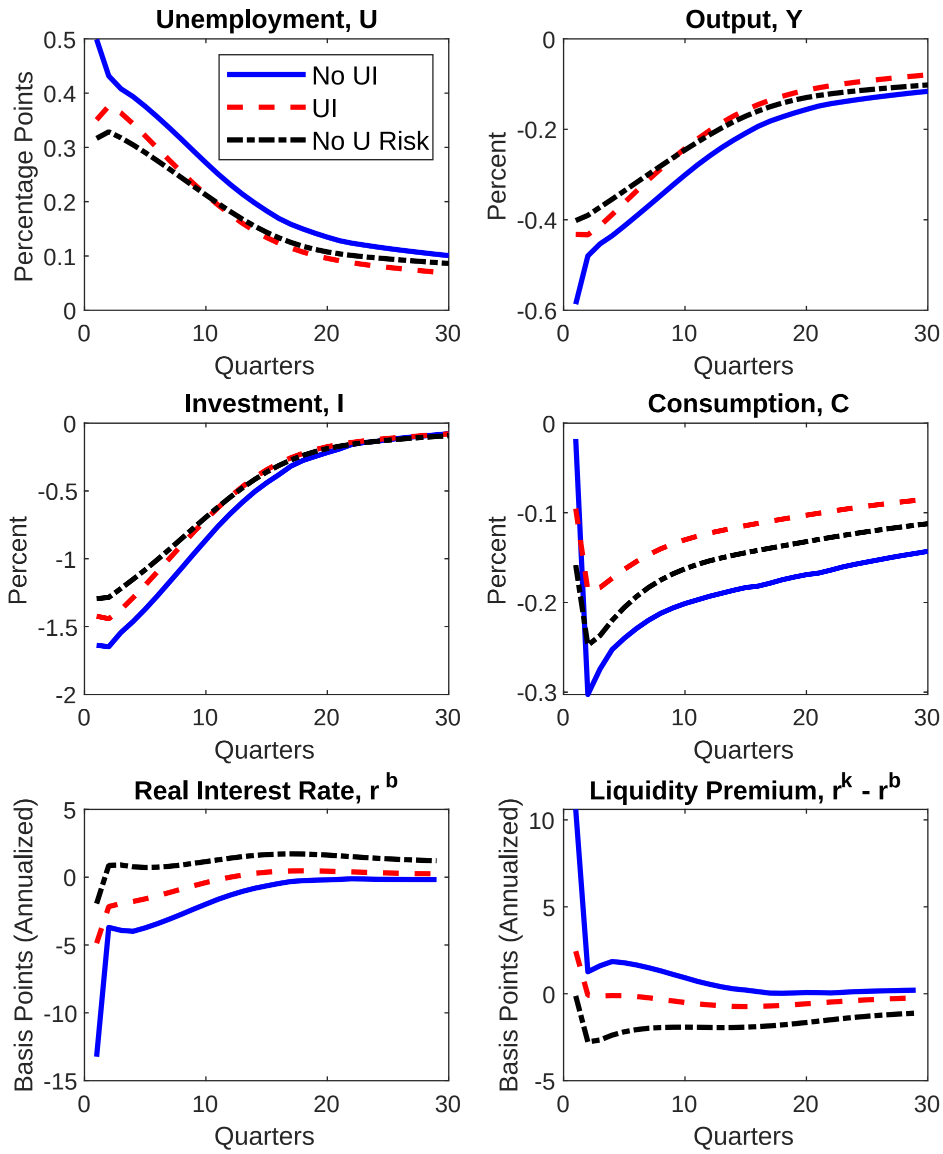
Notes: This figure shows the response of the economy to a negative aggregate productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.15: Robustness: Wage Depends on Unemployment Rate



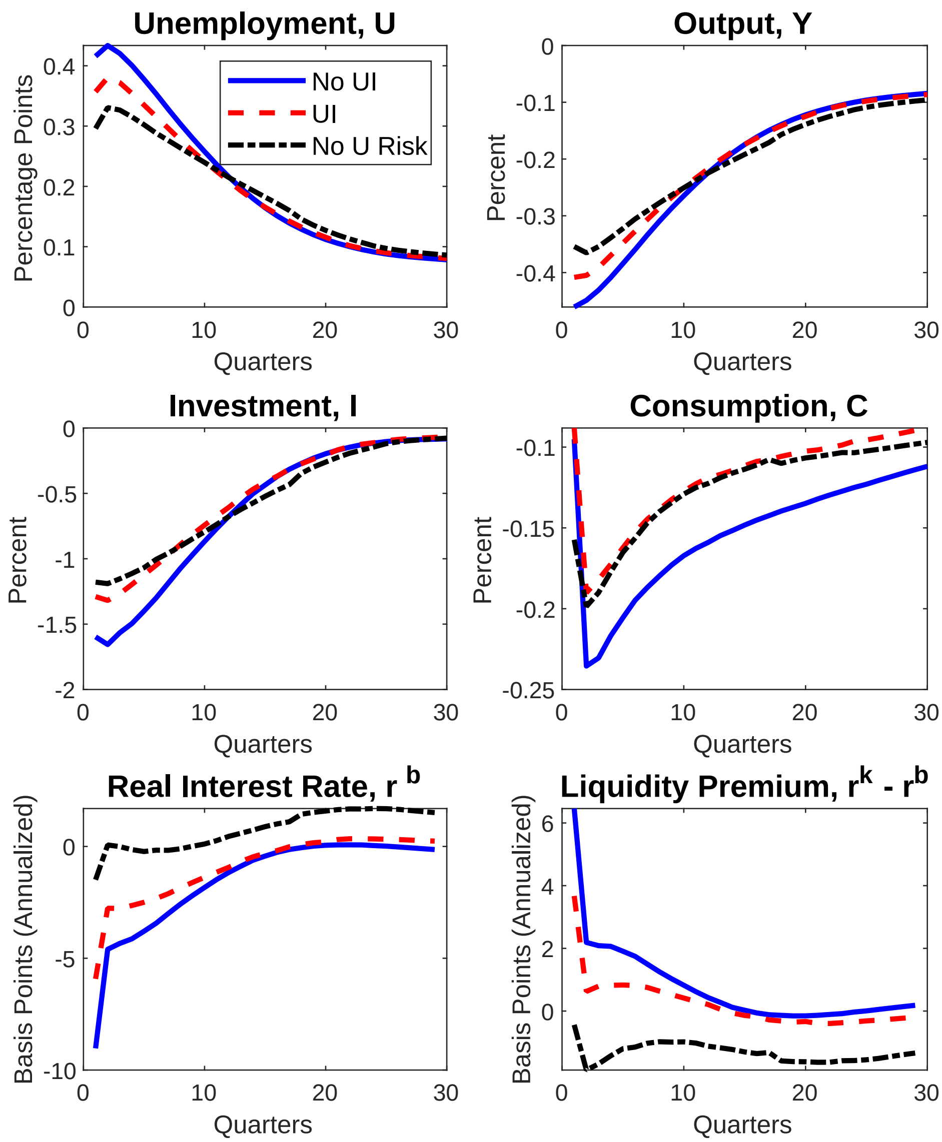
Notes: This figure shows the response of the economy to a negative aggregate productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.16: Robustness: Profits Distributed to Households



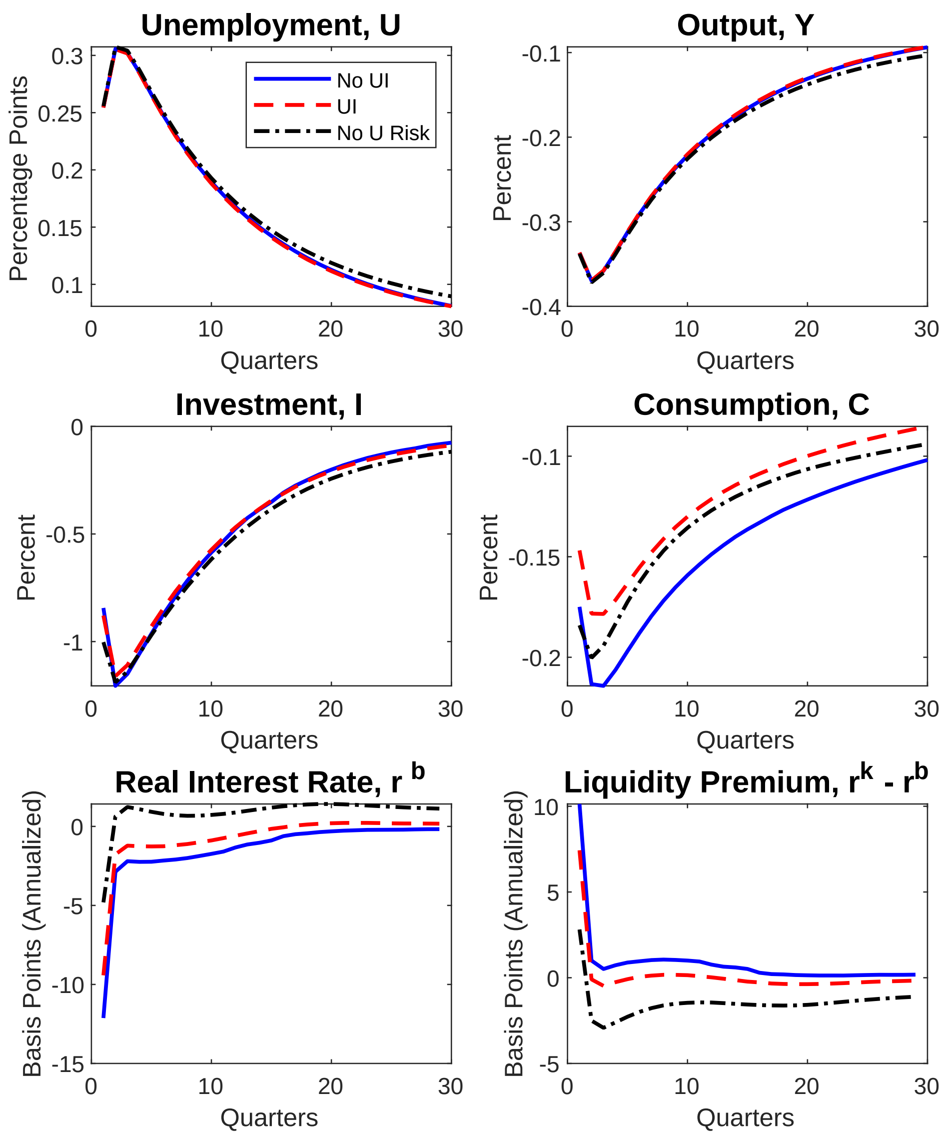
Notes: This figure shows the response of the economy to a negative aggregate productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.17: Robustness: Heterogeneous Separation Rates



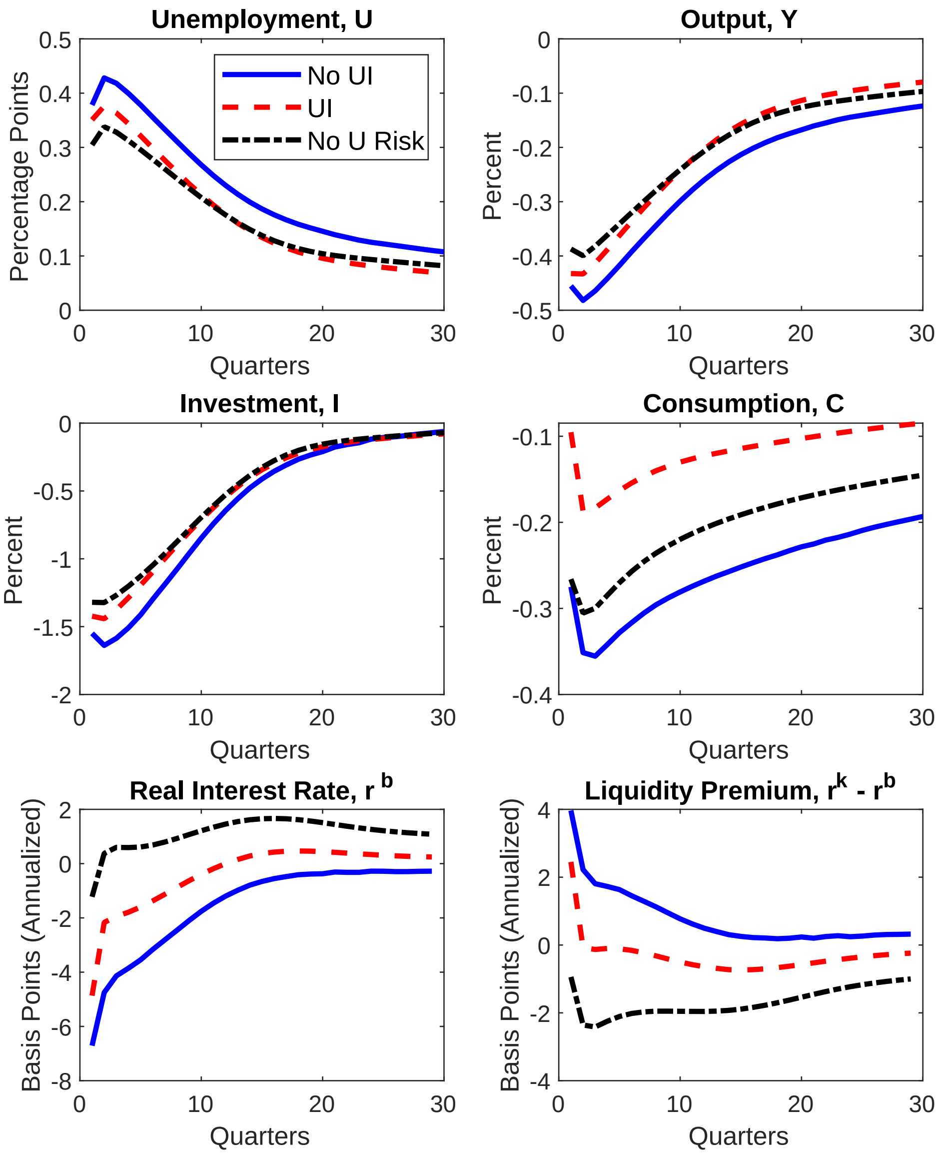
Notes: This figure shows the response of the economy to a negative aggregate productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.18: Robustness: Flexible Prices



Notes: This figure shows the response of the economy to a negative aggregate productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

Figure A.19: Robustness: Alternate Fiscal Policy: T_t Adjusts



Notes: This figure shows the response of the economy to a negative aggregate productivity shock. "No UI" refers to the model without unemployment insurance. "UI" refers to the baseline model with unemployment insurance. "No U Risk" refers to the model in which households pool unemployment risk. See the text for full details.

References

Bayer, Christian, Benjamin Born, and Ralph Luetticke. 2020. "Shocks, frictions, and inequality in US business cycles."

Carvalho, Carlos, Fernanda Nechio, and Tiago Tristao. 2021. "Taylor rule estimation by OLS." *Journal of Monetary Economics*, 124: 140–154.

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

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

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

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.

Justiniano, Alejandro, Giorgio E Primiceri, and Andrea Tambalotti. 2010. "Investment shocks and business cycles." *Journal of Monetary Economics*, 57(2): 132–145.

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

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

Smets, Frank, and Rafael Wouters. 2007. "Shocks and frictions in US business cycles: A Bayesian DSGE approach." *American economic review*, 97(3): 586–606.