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Abstract

Households' income heterogeneity is important to explain consumption dynamics in response to aggregate macro uncertainty: an increase in uncertainty generates a consumption drop that is stronger for income poorer households. At the same time, labor markets are strongly responsive to macro uncertainty as the unemployment rate and the job separation rate rise, while the job finding rate falls. A heterogeneous agent New Keynesian model with search and matching frictions in the labor market can account for these empirical findings. The mechanism at play is a feedback loop between income poorer households who, being subject to higher unemployment risk, contract consumption more in response to heightened uncertainty, and firms that post fewer vacancies following a drop in demand.

Keywords: Households' income heterogeneity, Precautionary savings, HANK and SaM

JEL Classification: E12, E31, E32, J64

Non-technical Summary

The Great Recession and, more recently, the Covid-19 pandemic and the war in Ukraine, have sparked a wide debate on the impact of macroeconomic uncertainty on the macroeconomy. In particular, close attention has been devoted to study the consequences of uncertainty shocks over the business cycle. While macro uncertainty has been shown to have contractionary effects on aggregate output and its subcomponents, less is known regarding its heterogeneous effects. For instance, heightened uncertainty might have a heterogeneous impact on households, who respond differentially to it.

This paper sheds light on the heterogeneous effects of macro uncertainty on households' consumption dynamics and proposes a mechanism underlying this heterogeneity. Using U.S. survey data, we uncover two main empirical facts. First, we show that households' consumption responds differentially along the income distribution. Namely, only income poorer households contract their consumption in a significant way in response to heightened macro uncertainty. Second, we find a strong reaction of aggregate labor market variables to an increase in uncertainty. The unemployment rate and the separation rate rise, while the job finding rate drops. We argue that the reason why poorer households are more responsive to heightened uncertainty is that they are less equipped to face unemployment risk. When uncertainty increases and unemployment risk goes up, poorer households are disproportionately affected. We show that a model with some degree of households' heterogeneity in insurance against the risk of becoming unemployed when uncertainty increases can account for our empirical findings.

To measure the impact of uncertainty along the income distribution, we use consumption and income household-level data from the Consumer Expenditure Surveys. We then study how the consumption of households located in different quintiles of the income distribution responds to macroeconomic uncertainty. We show that only the consumption of households in the bottom three quintiles contracts in a significant way in response to increased uncertainty. We next argue that the differential response of households is driven by their different exposure to unemployment risk. We provide evidence at aggregate level that a rise in macro uncertainty generates a strong response of labor market variables. In particular, we show that higher uncertainty generates a drop in the job finding rate as well as an increase in the unemployment rate and the separation rate. In

addition, we use data from the Survey of Income and Program Participation to understand how the job finding and separation rate vary across the households' income distribution. While both rates show heterogeneity, the biggest cross-sectional variation appears in the job separation rate, which is five times lower and four times less volatile for households in the top income quintile than for households in the bottom income quintile.

To rationalize our empirical findings, we build and estimate a New Keynesian model with heterogeneous households and search and matching frictions in the labor market. Households are heterogeneous in that they are differentially exposed to unemployment risk, but some of them can only partially insure against it as they are borrowing constrained. Within this framework, we study how a positive uncertainty shock propagates throughout the economy.

The main channel through which our heterogeneous-agent framework amplifies the propagation of uncertainty shocks is precautionary saving and works as follows. The initial drop in aggregate demand caused by higher uncertainty induces firms to lower vacancy posting. This reduces households' job finding rate and increases their separation rate, leading to higher unemployment risk. Since some households are borrowing constrained and can only partially insure against unemployment risk, a rise in such risk pushes them to further strengthen their precautionary saving behavior. This feedback effect amplifies the responses of output, consumption, unemployment rate, job finding rate, and separation rate in a way which is consistent with our empirical evidence. Moreover, when interpreting the imperfectly insured households as the theoretical counterpart to the income poorer households in our empirical analysis, our model replicates the empirical finding that income poor households contract consumption more in response to heightened uncertainty.

In sum, we argue that households' income heterogeneity combined with uninsured unemployment risk is an important feature to explain the consumption dynamics in response to higher macro uncertainty that we document in the US data.

1 Introduction

The Great Recession and, more recently, the Covid-19 pandemic and the war in Ukraine, have sparked a wide debate on the impact of uncertainty on the macroeconomy. After the seminal paper of [Bloom \(2009\)](#), close attention has been devoted to study the consequences of uncertainty shocks over the business cycle.¹ While uncertainty has been shown to have contractionary effects on aggregate output and its subcomponents, less is known regarding its heterogeneous effects. For instance, heightened uncertainty might have a heterogeneous impact on households, who respond differentially to it.

This paper sheds light on the heterogeneous effects of uncertainty on households' consumption dynamics and proposes a mechanism underling this heterogeneity. We uncover two main empirical facts. First, we show that households' consumption responds differentially along the income distribution. Namely, only income poorer households contract their consumption in a significant way in response to heightened macro uncertainty. Second, we find a strong reaction of aggregate labor market variables to an increase in uncertainty. The unemployment rate and the separation rate rise, while the job finding rate drops. We argue that the reason why poorer households are more responsive to heightened uncertainty is that they are less equipped to face unemployment risk. When uncertainty increases and unemployment risk goes up, poorer households are disproportionately affected. We show that a model with some degree of households' heterogeneity in insurance against the risk of becoming unemployed when uncertainty increases can account for our empirical findings.

To measure the impact of uncertainty along the income distribution, we use consumption and income household-level data from the Consumer Expenditure Surveys (CEX). We run a Bayesian vector autoregression (BVAR) with a recursive identification to study how the consumption of households located in different quintiles of the income distribution responds to macro uncertainty as measured by [Jurado et al. \(2015\)](#)'s index. We show that only the consumption of households in the bottom three quintiles contracts in a significant way in response to increased uncertainty. We then argue that the differential response of households is driven by their different exposure

¹Following the macro literature, we use the word 'uncertainty' to refer to 'objective uncertainty' or 'risk', in which the probabilities are well understood by all agents. There could be an alternative source of uncertainty, that is ambiguity, in which the probabilities are not well understood.

to unemployment risk. We provide evidence at aggregate level that a rise in macro uncertainty generates a strong response of labor market variables. In particular, we show that higher uncertainty generates a drop in the job finding rate as well as an increase in the unemployment rate and the separation rate. In addition, we use data from the Survey of Income and Program Participation (SIPP) to understand how the job finding and separation rate vary across the households' income distribution. While both rates show heterogeneity, the biggest cross-sectional variation appears in the job separation rate, which is five times lower and four times less volatile for households in the top income quintile than for households in the bottom income quintile.

To rationalize our empirical findings, we build and estimate a heterogeneous-agent New Keynesian (HANK) model with search and matching (SaM) frictions in the labor market. Within this framework, we study how a positive uncertainty shock, modeled as a second moment shock to technology, propagates throughout the economy. The model is estimated by using impulse response function matching.

In representative-agent New Keynesian models (RANK), uncertainty shocks affect aggregate demand through the precautionary saving behavior of risk-averse households. Due to the convexity of the marginal rate of substitution between present and future consumption, higher uncertainty induces households to increase their savings. Enhancing this framework with some degree of households' heterogeneity adds an indirect channel of precautionary savings, which strongly amplifies the propagation of uncertainty shocks. This channel works as follows. The drop in aggregate demand induces firms to lower vacancy posting. This reduces households' job finding rate and increases their separation rate, leading to higher unemployment risk. Since some households are borrowing constrained and can only partially insure against unemployment risk, a rise in such a risk pushes them to further strengthen their precautionary saving behavior. This feedback effect amplifies the responses of output, consumption, unemployment rate, job finding rate, and separation rate in a way which is consistent with our empirical evidence. Moreover, when interpreting the imperfectly insured households as the theoretical counterpart to the income poorer households in our BVAR analysis, our model replicates the empirical finding that income poor households contract consumption more in response to heightened uncertainty.

In our HANK model the differential consumption response across households is the result of two distinct forces: a heterogeneous marginal propensity to consume (MPC) and a heterogeneous

exposure to income risk, which generates a motive for precautionary saving. To isolate the effect of these two forces, we write down a model with only two agents (TANK): a hand-to-mouth, who cannot save and thus has a higher MPC, and a fully Ricardian household, who can smooth his consumption via savings. In the TANK model, the aggregate consumption response is mostly determined by the strength of the MPC of the two types, while there is no effect coming from precautionary saving. Thus, comparing the RANK to the TANK and the HANK allows us to distinguish which of the two channels, the MPC heterogeneity or the differential exposure to income risk, is the main driver of the aggregate consumption response. We show that the main driver of amplification is the differential exposure to income risk rather than to the heterogeneity in MPCs.

In sum, we argue that households' income heterogeneity combined with uninsured unemployment risk is an important feature to explain the consumption dynamics in response to higher macro uncertainty that we document in the data.

Related Literature First, our paper contributes to the literature on uncertainty (see e.g., [Born and Pfeifer, 2014](#), [Fernández-Villaverde et al., 2015](#), [Mumtaz and Theodoridis, 2015](#), [Leduc and Liu, 2016](#), and [Basu and Bundick, 2017](#)). It focuses specifically on macro uncertainty as estimated by [Jurado et al. \(2015\)](#). Other papers have highlighted how theoretically challenging it is to obtain quantitatively relevant responses of macro variables to uncertainty shocks (e.g., [Born and Pfeifer, 2014](#), [Cesa-Bianchi and Fernandez-Corugedo, 2018](#), [de Groot et al., 2018](#), and [Oh, 2020](#)). [Freund et al. \(2023\)](#) point out how including households' risk aversion and sticky prices in a model with SaM frictions in the labor market activates a risk-premium channel that helps generating an economic contraction in response to heightened uncertainty. We show that households' heterogeneity is an alternative channel that strengthens precautionary saving motives. This is crucial to qualitatively and quantitatively account for our empirical evidence on heterogeneous consumption response to macro uncertainty.

Second, our paper contributes to the literature on the distributional effects of business cycle shocks. This literature has mainly focused on monetary policy ([Coibion et al., 2017](#), [Amberg et al., 2021](#), [Andersen et al., 2021](#), and [Holm et al., 2021](#)). More recently, [Fernández-Villaverde et al. \(2024\)](#) show how households' heterogeneity shapes monetary policy transmission and, in particular, how it affects the frequency of hitting the zero-lower bound, with all the challenges

arising from that. Our paper instead focuses on how households' income heterogeneity affects the transmission of macroeconomic uncertainty. A recent and related paper to ours is [Coibion et al. \(2021\)](#) who use survey data at euro area level to show how different segments of the population in terms of the probability of losing their job in a recession, exposure to portfolio risk, and region of residence are differentially affected by uncertainty in their consumption behavior.

Our paper is also related to the fast growing literature of HANK models, such as those developed by [McKay and Reis \(2016\)](#), [Kaplan et al. \(2018\)](#), [Bayer et al. \(2019\)](#), and [Bilbiie \(2021\)](#). More in detail, our paper is part of a novel literature of HANK models with SaM frictions, which studies how labor market frictions interact with households' precautionary saving behavior (see e.g., [Ravn and Sterk, 2017, 2021](#), [Gornemann et al., 2021](#), [Dolado et al., 2021](#), [McKay and Reis, 2021](#), [Graves, 2022](#), and [Cho, 2023](#)). Our paper is related to a specific stream of the HANK literature, which introduces households' heterogeneity in a simplified, but effective framework. This setup allows us to gain tractability, which is essential to study the propagation of uncertainty shocks, while at the same time retaining the main feature of introducing households' heterogeneity, which is the precautionary saving motive.² This framework is presented by [Challe et al. \(2017\)](#), who construct and estimate a tractable HANK model with SaM frictions, where the cross-sectional heterogeneity of households remains finite dimensional. A similar framework where households' heterogeneity is kept to the minimum to retain model tractability is the one of [Challe \(2020\)](#), who studies optimal monetary policy in the presence of uninsured unemployment risk and nominal rigidities. Our paper instead studies aggregate uncertainty shocks in the context of a HANK model with SaM frictions and highlights how these features are crucial to explain the propagation of uncertainty throughout the economy.

The remainder of the paper is structured as follows. Using aggregate and CEX micro data, [Section 2](#) shows empirical evidence on the responses of macroeconomic variables to an increase in macro uncertainty. Taking stock of the empirically relevant features, [Section 3](#) builds a New Keynesian model with uninsured unemployment risk and aggregate uncertainty. [Section 4](#) displays our main quantitative results on the model dynamics in response to an increase in uncertainty. [Section 5](#) concludes.

²Studying uncertainty shocks requires to solve the model to a third-order approximation or a fully global solution method. This gets extremely complicated in fully fledged heterogeneous models.

Table 1: Descriptive Statistics

	All Households		Bottom 60%		Top 40%	
	Mean	SD	Mean	SD	Mean	SD
Male	0.51	0.50	0.44	0.50	0.60	0.49
Age	50.27	18.26	52.79	20.46	46.46	13.47
Family size	2.33	1.40	1.98	1.30	2.85	1.39
Less than High School	0.20	0.40	0.26	0.44	0.11	0.31
High school	0.24	0.43	0.28	0.45	0.17	0.37
Post-secondary	0.56	0.50	0.45	0.50	0.73	0.45
White	0.83	0.37	0.81	0.40	0.87	0.34
Black	0.11	0.31	0.14	0.35	0.07	0.25
Native American	0.01	0.08	0.01	0.09	0.00	0.07
Other	0.05	0.22	0.05	0.21	0.06	0.24
Income	188,149.69	200,106.30	79,247.33	46,784.13	352,138.58	228,676.63
Earnings	155,359.52	200,972.25	48,299.68	55,487.59	316,573.91	23,0920.80
Hours worked per week	24.04	21.51	16.38	19.71	35.59	18.76
Nondurable consumption	14,721.45	12,922.20	10,244.86	7,862.55	21,462.44	15,802.70
Durable consumption	3,910.23	15,202.27	2,252.48	10,428.65	6,406.53	20,124.19

Note: Income, earnings, nondurable consumption, and durable consumption are in U.S. dollars, 2000 prices. They are annual averages. ‘All Households’ refers to Mean and SD computed over the all sample. ‘Bottom 60%’ and ‘Top 40%’ refers to Mean and SD computed within respectively the Bottom 60% and the Top 40% of the households’ pre-tax income distribution. Sample period: 1994Q1-2019Q4.

2 Empirical Evidence

Our empirical investigation shows two main facts. First, the consumption response to heightened macroeconomic uncertainty is heterogeneous across households along the income distribution and is stronger for households in the bottom 60%. Second, aggregate labor markets are highly responsive to fluctuations in uncertainty.

2.1 Descriptive Statistics of Households from the CEX

Throughout our analysis, we use households' income and consumption data from the CEX, a detailed survey of consumption expenditure done at household-level in the U.S. — see Appendix [A.1](#) for a more thorough description of the survey. Table [1](#) reports some descriptive statistics of households along some characteristics. The columns “All Households” report means and standard deviations for the full sample, while “Bottom 60%” and “Top 40%” report the same moments for the bottom 60% and the top 40% of households along the pre-tax income distribution. While the full sample is quite balanced in terms of gender (51% of the sample is male), with an average age of 50 years and a family size of 2.33, the bottom 60% in the income distribution has fewer males (44%), older households (almost 53 years on average) and with smaller families (1.98). In the top 40% there are 60% males, with an average age of 46 and an average family size of 2.85. When looking at education, households have on average a lower education level in the bottom 60% than in the top 40%. Compared to the total sample of households, in the bottom 60% there are less white and more black, while in the top 40% there are more white and less black. Focusing now on income, while the average income in the bottom 60% is around \$ 80,000, it jumps to roughly \$352,000 for the top 40%. A similar gap is also reflected in earnings. While households in the bottom 60% work an average of 16 hours, households in the top 40% work an average of 35 hours, suggesting that they tend to have full time jobs. Finally, a big disparity between the two groups is also reflected in consumption: the bottom 60% consumes on average about \$10,200 in nondurable goods and \$2,200 in durable goods, whereas the top 40% consumes on average roughly \$21,400 in nondurables and \$6,400 in durables. More granular descriptive statistics by income quintile are reported by Table [B.1](#) in Appendix [B.1](#).

2.2 Consumption Response to Macro Uncertainty is Heterogeneous

We estimate a BVAR to investigate whether macro uncertainty has heterogeneous effects on households' consumption behavior.

To measure macroeconomic uncertainty we rely on the macro uncertainty index of [Jurado et al. \(2015\)](#). We identify uncertainty shocks through a Cholesky decomposition where macro uncertainty

is ordered last. We use U.S. quarterly data over the sample period 1994Q1-2019Q4.³ The variables included in our BVAR are: log of per capita real GDP, the job finding rate, the separation rate, the unemployment rate, log of per capita real consumption (including nondurable goods and services), logged consumer price index, the policy rate, and macroeconomic uncertainty. We use a Normal Wishart prior and add two lags. We run 2000 iterations, of which the first 1000 are used as burn-in.

We estimate four different BVARs where all variables are kept the same except for consumption. In the first BVAR, we include aggregate consumption from the CEX. In the second BVAR, we put the ratio between the consumption of the bottom 60% and the top 40% of the income distribution. In the third and last BVAR, we insert consumption of respectively the bottom 60% and the top 40% of the income distribution. We use the CEX data on consumption and income. The definitions of our series are detailed in Appendix A.1.

Figure 1 exhibits the consumption responses to macro uncertainty shocks in the four estimated BVARs. In response to a one-standard deviation positive uncertainty shock, aggregate consumption contracts and reaches its trough of about -0.2 percent after six quarters, remaining persistently low for at least 20 quarters. The response of aggregate consumption masks some heterogeneity across households. The consumption response of the bottom 60% of the income distribution is strong, significant, and persistent. Instead, the response of the top 40% is much milder and never significantly different from zero. The responses of these two groups are statistically different from each other as the response of their ratio shows. Section 3 will introduce a HANK model with search-and-matching, which is well able reproduce these patterns. This can be seen from the model-implied impulse responses that are plotted in Figure 1 along with the empirical responses from the BVAR.

Our choice to cut the data into the bottom 60% and the top 40% is driven by the responses of consumption across different quintiles. Figure B.1 in Appendix B.1 shows that the bottom three quintiles contract consumption significantly in response to an identified uncertainty shock, while the top two quintiles do not. Appendix B reports additional robustness checks to our empirical analysis. Appendix B.2 shows that our baseline results are robust to controlling for households' characteristics when measuring consumption. Appendix B.3 focuses on durable consumption. Appendix B.4 discusses potential concerns regarding the accuracy of the CEX. Finally, Appendix B.5 conducts

³The length of our sample is dictated by the CEX consumption data. As noted in Heathcote et al. (2023), while the CEX has continuous data available since 1980Q1, the definitions for some consumption components are not consistent prior to 1994. For consistency, we thus start our analysis from 1994Q1.

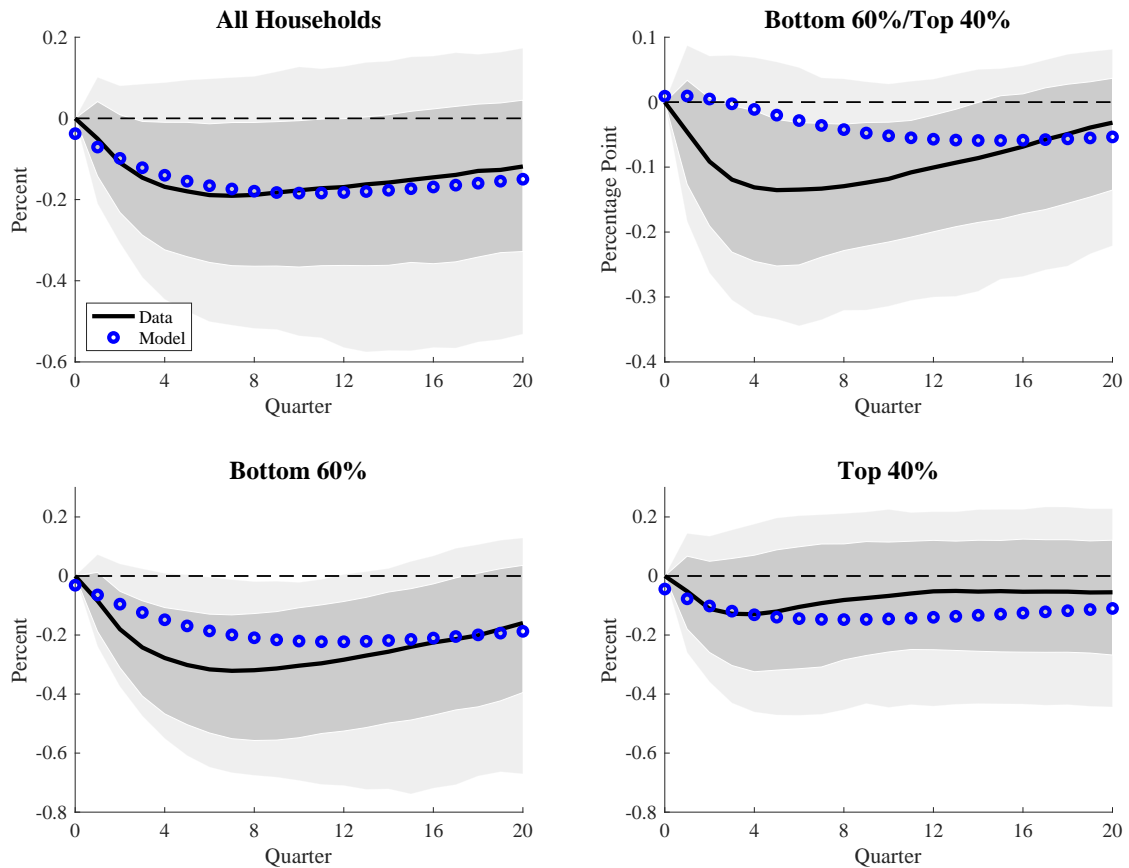


Figure 1: Empirical and Model-implied Impulse Responses of Consumption across the Income Distribution to One-Standard Deviation Macro Uncertainty Shocks

Note: “Bottom 60%” and “Top 40%” denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Dark and light grey areas indicate respectively 68 and 90 percent confidence bands.

various robustness checks to our VAR specification.

2.3 Labor Markets Are Highly Responsive to Macro Uncertainty

Figure 2 shows the impulse responses of aggregate macro variables to a one standard deviation shock in the macro uncertainty index. GDP and the job finding rate drop significantly and persistently for at least fifteen quarters, while the separation rate rises significantly for eight quarters. The response of the unemployment rate is positive and persistent and reaches a 0.22 percentage point increase at its peak.⁴ Aggregate consumption reaches its trough after about eight quarters when it

⁴The responses of the job finding and separation rates are novel results, while the response of the unemployment rate is in line with the linear specification results of Caggiano et al. (2014), who examine the impact of uncertainty on unemployment dynamics.

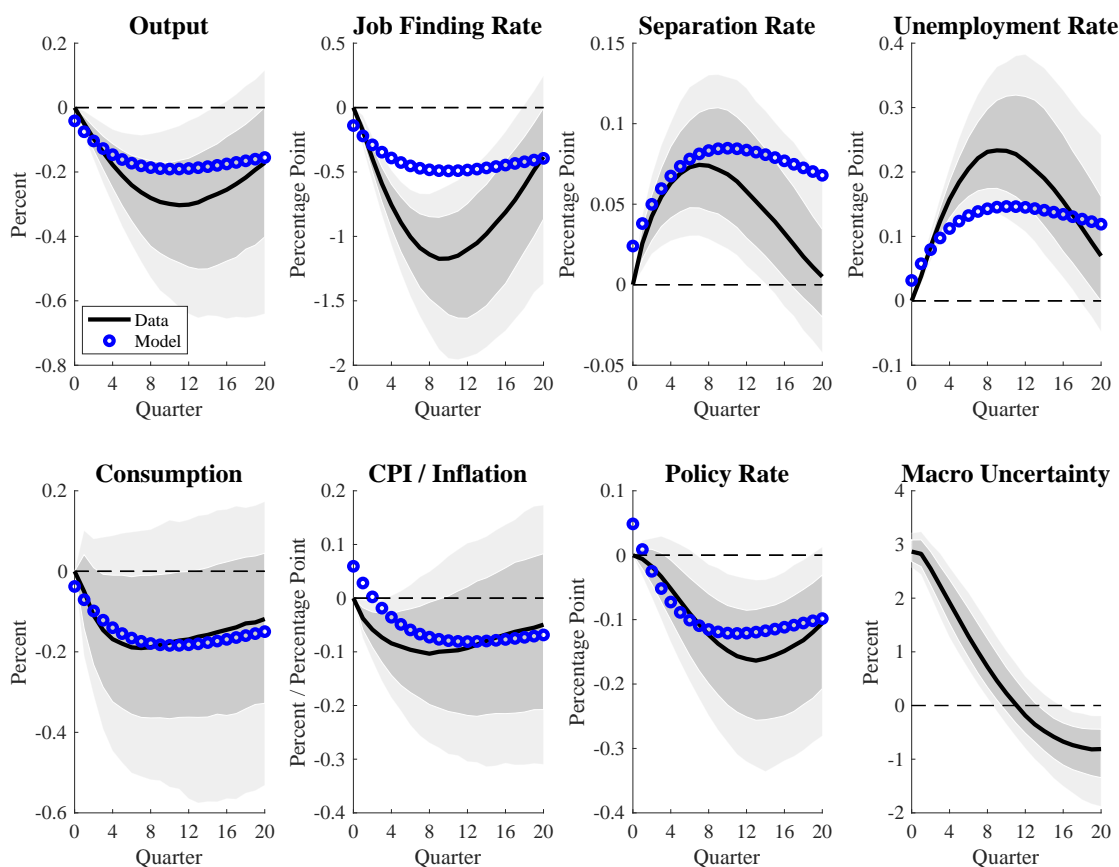


Figure 2: Empirical and Model-implied Impulse Responses to One-Standard Deviation Macro Uncertainty Shocks

Note: Dark and light grey areas indicate respectively 68 and 90 percent confidence bands.

declines by 0.20 percent. CPI contracts and the policy rate drops.

Next, as we are interested in looking at how the job finding and separation rate vary across the income distribution, we use data from the Survey of Income and Program Participation (SIPP). This allows us to compute the job finding and separation rate by income quintile from 1996 to 2019 as in [Birinci and See \(2023\)](#).⁵ Figure 3 exhibits moments (mean and standard deviation) of the job finding rate and separation rate by income quintile. The heterogeneity of the finding rate across income quintiles is much lower than the heterogeneity in the separation rate. In particular, high income households have an average job separation rate that is five times lower than low income households and four times less volatile. As the time series have missing values, though, we only show average job finding and separation rates by income quintile, while we refrain from estimating

⁵More information on SIPP panels can be found at the following link: <https://www.census.gov/programs-surveys/sipp/methodology/organizing-principles.html>.

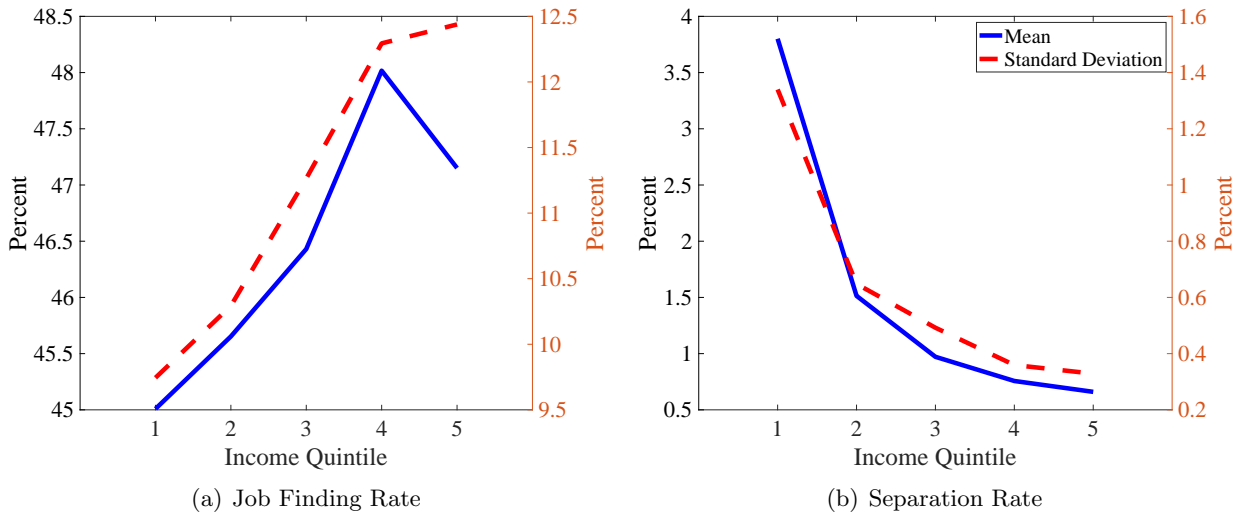


Figure 3: Moments of Job Finding Rate and Job Separation Rate by Income Quintile

Note: Data is from the SIPP over the period 1996-2019. Job finding rate and separation rate by income quintile are computed following [Birinci and See \(2023\)](#).

a VAR by income quintile.

In summary, using micro data from the CEX we have shown that households respond differentially to uncertainty along the income distribution. We argue that an important part of this heterogeneous response comes from the different ability of households to insure themselves against unemployment risk. In the next section we build a tractable model with heterogeneous agents subject to uninsurable unemployment risk and study how this dimension of heterogeneity helps us explain the transmission of uncertainty shocks that we observe in the data.

3 The Model

To rationalize our empirical findings, we build a tractable New Keynesian model with some degree of households' heterogeneity, as some households can only partially insure themselves against unemployment risk. In this setup, we introduce a technology process with stochastic volatility. We argue that households' heterogeneity is crucial to generate the dynamics that we see in the aggregates in response to heightened uncertainty. In particular, we simulate a temporary increase in the stochastic volatility of technology and study how the economy reacts.⁶

⁶The empirical analysis conducted in Section 2 studies the impact of macro uncertainty. This is a comprehensive measure, which aims to capture 'uncertainty that may be observed in many economic indicators at the same time,

Following [Challe et al. \(2017\)](#), the model features *imperfect* insurance against idiosyncratic unemployment risk in a New Keynesian framework with labor market frictions à la [Mortensen and Pissarides \(1994\)](#). There are two types of households, a perfectly and an imperfectly insured one. Only perfectly insured households can own firms. Both perfectly and imperfectly insured households participate in the labor and bond market and are subject to idiosyncratic unemployment risk. However, while perfectly insured households fully share risk among each other, imperfectly insured households cannot fully insure themselves against unemployment risk and face a borrowing constraint. The two latter features generate precautionary saving motives for employed households who are not perfectly insured.

To simplify the introduction of both labor market frictions and nominal rigidities, the production side is made of four types of firms as in [Gertler et al. \(2008\)](#). First, labor market intermediaries hire labor from both perfectly and imperfectly insured households, subject to search and matching frictions, and transform it into labor services. Second, wholesale goods firms buy labor services in a competitive market to produce wholesale goods used by intermediate goods firms. Third, intermediate goods firms buy wholesale goods, differentiate it, and sell it monopolistically while facing price stickiness à la [Rotemberg \(1982\)](#). Fourth, a competitive final good sector aggregates the intermediate good into a final good used for consumption and vacancy posting costs. The nominal interest rate is set by a central bank which follows a standard Taylor rule.

To specify the timing of events within a period, every period can be divided into three sub-periods: a labor market transition stage, a production stage and a consumption-saving stage. In the first stage, the exogenous state is revealed, workers are separated from firms, firms open vacancies and new matches are created. In the second stage, production takes place and the income components are paid out to the agents in the economy as wages, unemployment benefits, and profits. In the third stage, asset holding choices are made and the family heads redistribute assets across household members.

[Challe et al. \(2017\)](#)'s assumptions on imperfect risk sharing and a tight borrowing constraint faced by imperfectly insured households allow us to reduce the state space to a finite dimensional object. If we also assume that the borrowing constraint becomes binding after one period of

across firms, sectors, markets, and geographic regions', [Jurado et al. \(2015\)](#). In our baseline theoretical analysis we study macro uncertainty by focusing on a technology uncertainty shock. In the robustness checks we study the sensitivity of our main results to other sources of uncertainty shocks such as interest rate uncertainty.

unemployment spell, we can further reduce the heterogeneity of imperfectly insured households to three types. Section 3.1 - 3.6 describe the model in detail by focusing on the specific case in which imperfectly insured households are reduced to three types. For notation purposes, aggregate variables are in bold characters. In addition, variables corresponding to the beginning of the labor transition stage are denoted with a tilde. We leave the derivations of the model to Appendix C.1.

3.1 Households

There is a unit mass of households in the economy. Each household is endowed with one unit of labor. If at the beginning of the production stage the household is employed, she supplies her unit of labor inelastically. All households are subject to idiosyncratic changes to their employment status. A share $f \in [0, 1]$ of the unemployed households at the beginning of the labor market transition stage finds a job by the beginning of the production stage, while a share $s \in [0, 1]$ loses her job over the same period. There are two types of households: a measure $\Omega \in [0, 1)$ of imperfectly insured ones and a measure $1 - \Omega$ of perfectly insured ones. They have different subjective discount factors. In particular, the discount factor β^P of perfectly insured households is higher than the discount factor β^I of imperfectly insured ones. They all share the same period utility function $u(c) = \frac{(c - h\mathbf{c})^{1-\sigma}}{1-\sigma}$, where c is consumption, \mathbf{c} is the level of consumption habits, and h is a constant habit parameter. Consumption habits are external. We define \mathbf{c}^P as the common consumption habits of the perfectly insured households in the current period. These habits are assumed to be the average of the perfectly insured households' consumption in the previous period. Consumption habits of the imperfectly insured, instead, depend on their unemployment spell $N \geq 0$. Namely, we assume that imperfectly insured households with unemployment spell N are going to have consumption habits $\mathbf{c}^I(N)$. These habits are equal to the average consumption of the imperfectly insured households with unemployment spell N in the previous period.

3.1.1 Imperfectly Insured Households

Imperfectly insured households face idiosyncratic shocks to their employment state and are subject to a borrowing limit that prevents them from borrowing beyond a given threshold \underline{a} .

Employed households earn a wage w that gets taxed by a rate τ to pay for the unemployment benefit b^u that unemployed households receive. Since the unemployment insurance scheme is

balanced every period, the following equation has to hold:

$$\tau w \mathbf{n}^I = b^u (1 - \mathbf{n}^I), \quad (1)$$

where \mathbf{n}^I is the imperfectly insured households' employment rate at the end of the labor market transition stage. Following the literature, we adopt the family structure according to which every imperfectly insured household belongs to a representative family, whose head makes consumption and saving decisions to maximize the family current and expected utility.

There are two crucial assumptions that Challe et al. (2017) make to keep the model tractable, while still preserving the heterogeneity across imperfectly insured households: *i*) the borrowing limit is tighter than the natural debt limit; *ii*) there is only partial risk sharing across members of the imperfectly insured households. In particular, only employed members can fully insure each other by transferring assets. Instead, no transfer is admitted between employed and unemployed members or across unemployed members.

Because of idiosyncratic shocks and imperfect risk sharing, there is heterogeneity across imperfectly insured households. This heterogeneity implies a distribution $\mu(a^I, N)$ of imperfectly insured households over assets a^I and unemployment spells $N \geq 0$. Thanks to the two aforementioned assumptions, for every N the cross-sectional distribution $\mu(a^I, N)$ of imperfectly insured households can be summarized by the unique mass point $a^I(N)$ and the associated number of imperfectly insured households $n^I(N)$.

Given X the vector of aggregate states,⁷ the head of a representative family of imperfectly insured households maximizes the family current and future utility with respect to assets $a^I(N)$ and consumption $c(N)$:

$$V^I(a^I(N), n^I(N), X) = \max_{\{a^{I'}(N), c^I(N)\}_{N \in \mathbb{Z}_+}} \left\{ \sum_{N \geq 0} n^I(N) u(c^I(N) - h c^I(N)) + \beta^I \mathbb{E}_{\mu, X} [V^I(a^{I'}(N), n^{I'}(N), X')] \right\}, \quad (2)$$

⁷See Section 3.6 for the aggregate state definition.

subject to:

$$a^{I'}(N) \geq \underline{a}, \quad (3)$$

$$a^{I'}(0) + c^I(0) = (1 - \tau)w + (1 + r)A, \quad N = 0, \quad (4)$$

$$a^{I'}(N) + c^I(N) = b^u + (1 + r)a, \quad N \geq 1. \quad (5)$$

Equation (3) is the borrowing constraint, where \underline{a} is higher than the natural borrowing limit. Equation (4) is the budget constraint of an employed household (the unemployment spell N is zero). An employed household consumes $c^I(0)$ and buys assets $a^I(0)$, while receiving after tax income $(1 - \tau)w$ and return from previously held assets $(1 + r)A$. Equation (5) is the budget constraint of a household, who has been unemployed for N periods. This household consumes $c^I(N)$, buys assets $a^I(N)$, gets the unemployment benefit b^u and the return $(1 + r)a$ from previously held assets (of course, if these are negative assets, i.e. debt, r is the interest paid on debt).

If $N = 0$, the value of assets and the employed households' law of motion are given by:

$$A' = \frac{1}{n^{I'}(0)} \left((1 - s') a^{I'}(0) + f' \sum_{N \geq 1} a^{I'}(N) n^I(N) \right), \quad (6)$$

$$n^{I'}(0) = (1 - s') n^I(0) + f' (1 - n^I(0)). \quad (7)$$

Equation (6) says that the next period value of assets that each employed imperfectly insured household gets is the total of assets that next period employed imperfectly insured households bring divided by the total number of employed imperfectly insured households $n^{I'}(0)$, who belong to the family. The total of assets that next period employed imperfectly insured households bring is given by the fraction of assets that households who *remain* employed bring to the family $(1 - s') a^{I'}(0)$, plus the fraction of assets that households, who *become* employed bring to the family $f' \sum_{N \geq 1} a^{I'}(N) n^I(N)$. Equation (7) says that next period employed imperfectly insured households are given by the fraction of this period employed imperfectly insured households who *remain* employed $(1 - s') n^I(0)$, plus the fraction of this period unemployed imperfectly insured households who *become* employed $f' (1 - n^I(0))$.

If $N \geq 1$, the value of next period assets and next period unemployed households' law of

motion are given by:

$$a^I(N) = a^{I'}(N-1), \quad (8)$$

$$n^{I'}(1) = s'n^I(0) \text{ and } n^{I'}(N) = (1-f')n^I(N-1) \text{ if } N \geq 2. \quad (9)$$

Equation (8) says that the value of next period assets of an imperfectly insured household, who has been unemployed for $N-1$ periods is equal to the value of this period assets of an imperfectly insured household, who has been unemployed for N periods. Equation (9) says that next period unemployed people with one period unemployment spell are the fraction of this period employed households, who become unemployed, while next period unemployed with more than one period unemployment spell are the fraction of this period unemployed households, who stay unemployed.

Imperfectly insured households face a binding borrowing limit after \hat{N} consecutive periods of unemployment. This problem has a particularly easy solution for the case of $\hat{N} = 1$, which, following Challe et al. (2017), is supported by empirical evidence (liquid wealth is fully liquidated after one period). When $\hat{N} = 1$, in every period there are *three* types of imperfectly insured households: $N = 0$, $N = 1$, and $N \geq 2$. To these three types, there are the three following associated consumption levels $c^I(0)$, $c^I(1)$, and $c^I(2)$ for all $N \geq 2$, and the two following assets levels $a^I(0)$, and \underline{a} . $a^I(0)$ is the asset level of employed households, while \underline{a} is the asset level of unemployed households. Since all unemployed households face a binding borrowing constraint, their asset level is the same regardless of their unemployment spell. These three types of imperfectly insured households are in number $\Omega \mathbf{n}^I$, $\Omega s \tilde{\mathbf{n}}^I$, and $\Omega (1 - \mathbf{n}^I - s \tilde{\mathbf{n}}^I)$. In equilibrium, for any $N \geq 0$ the Euler condition for imperfectly insured households is:

$$\mathbb{E}_{\mu, X} [M^{I'}(N) (1 + r')] = 1 - \frac{\Gamma(N)}{u_c(c^I(N) - \mathbf{c}^I(N)) n(N)}, \quad (10)$$

where $M^I(N)$ is the intertemporal marginal rate of substitution (IMRS) and $\Gamma(N)$ is the Lagrange multiplier associated to the borrowing limit. When the household is employed ($N = 0$), the borrowing limit is not binding. Therefore, $\Gamma(N) = 0$ and the Euler condition holds with equality:

$$\mathbb{E}_{\mu, X} [M^{I'}(0) (1 + r')] = 1. \quad (11)$$

Instead, when the household is unemployed ($N \geq 1$), the borrowing limit is binding, $\Gamma(N) > 0$, and $\mathbb{E}_{\mu, X} [M^{I'}(N)(1+r')] < 1$. The IMRS is the ratio of the next-period and the current period marginal utility:

$$M^{I'}(0) = \beta^I \frac{(1-s')u_c^{I'}(0) + s'u_c^{I'}(1)}{u_c^I(0)}, \quad N = 0, \quad (12)$$

$$M^{I'}(N) = \beta^I \frac{(1-f')u_c^{I'}(N+1) + f'u_c^{I'}(0)}{u_c^I(N)}, \quad N \geq 1. \quad (13)$$

Equation (12) is the IMRS of an employed household. The denominator is the current period marginal utility. The numerator is the next period marginal utility, which is a weighted average of the household's marginal utility if she remains employed $u_c^{I'}(0)$ times the probability of remaining employed $1-s'$, and her marginal utility if she becomes unemployed $u_c^{I'}(1)$ times the probability of becoming unemployed s' . Similarly, Equation (13) is the IMRS of an unemployed household. In this case, the numerator is the weighted average of the household's marginal utility if she remains unemployed $u_c^{I'}(N+1)$ times the probability of remaining unemployed while already being unemployed $1-f'$, and her marginal utility if she becomes employed $u_c^{I'}(0)$ times the probability of becoming employed f' .

3.1.2 Perfectly Insured Households

The fraction of employed members within every family of perfectly insured households before and after the labor-market transitions stage are denoted by \tilde{n}^P and n^P , respectively. We thus have:

$$n^{P'} = (1-s')n^P + f'(1-n^P), \quad (14)$$

$$n^P = \tilde{n}^{P'}. \quad (15)$$

As before, these are family-level variables. The corresponding aggregate variables are denoted by $\tilde{\mathbf{n}}^P$ and \mathbf{n}^P . Employed perfectly insured households earn after tax wage $(1-\tau)w^P$, while unemployed perfectly insured households get unemployment benefit b^{uP} . Also the unemployment insurance scheme of perfectly insured households is balanced every period, thus the following equation holds:

$$\tau w^P \mathbf{n}^P = b^{uP} (1 - \mathbf{n}^P). \quad (16)$$

Besides having a higher discount factor, what differentiates perfectly insured households from imperfectly insured ones is that there is full risk sharing among their family members, regardless of their employment status. This implies that all family members are symmetric, consume c^P and save $a^{P'}$. The family head of perfectly insured households solves:

$$V^P(a^P, n^P, X) = \max_{a^{P'}, c^P} \{u(c^P - hc^P) + \beta^P \mathbb{E}_{n^P, X} [V^P(a^{P'}, n^{P'}, X')]\}, \quad (17)$$

subject to:

$$c^P + a^{P'} = w^P n^P + (1 + r) a^P + \Pi, \quad (18)$$

where w^P is the real wage that perfectly insured households get and Π is the profit from intermediate goods firms and labor intermediaries, which are owned by perfectly insured households.

Since all perfectly insured households are homogeneous, they have the same Euler equation:

$$\mathbb{E}_X [M^{P'} (1 + r')] = 1, \quad (19)$$

where the IMRS $M^{P'}$ is given by:

$$M^{P'} = \beta^P \frac{u_c^{P'}}{u_c^P}. \quad (20)$$

3.2 Firms

There are four types of firms in the economy. Labor intermediaries hire labor in a frictional labor market and sell labor services to wholesale goods firms. Wholesale goods firms buy labor to produce wholesale goods in a competitive market. Intermediate goods firms buy wholesale goods and sell them to the final goods firms while facing [Rotemberg \(1982\)](#) price rigidities. Final goods firms aggregate intermediate goods into a final good.

3.2.1 Final Goods Firms

A continuum of perfectly competitive final goods firms combine intermediate goods, which are uniformly distributed on the interval $[0, 1]$, according to the production function:

$$y = \left(\int_0^1 y_i^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (21)$$

where ε is the elasticity of substitution between two intermediate goods. Let p_i denote the real price of intermediate good variety i in terms of final good price. The final goods firm solves:

$$\max_y y - \int_0^1 p_i y_i di, \quad (22)$$

subject to Equation (21). The solution of the maximization gives the final firm's demand of intermediate good:

$$y_i(p_i) = p_i^{-\varepsilon} y, \quad (23)$$

while the zero-profit condition for final goods firms gives:

$$\left(\int_0^1 p_i^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} = 1. \quad (24)$$

3.2.2 Intermediate Goods Firms

Each intermediate goods firm i produces x_i with a linear technology $y_i = x_i - \Phi$, where Φ is the fixed cost measured in units of the wholesale good. Its profit is given by $\Xi = (p_i - p_m)y_i - p_m\Phi$, where p_m is the real price of intermediate goods in terms of final goods. It faces pricing frictions à la Rotemberg (1982) and chooses price p_i to maximize the present discounted value of future profits subject to the demand curve (23):

$$V(p_{i,-1}, X) = \max_{p_i} \left\{ \Xi - \frac{\eta}{2} \left(\frac{(1+\pi)p_i}{(1+\bar{\pi})p_{i,-1}} - 1 \right)^2 y + \mathbb{E}_X [M^{P'} V(p_i, X')] \right\}, \quad (25)$$

where $\frac{\eta}{2} \left(\frac{(1+\pi)p_i}{(1+\bar{\pi})p_{i,-1}} - 1 \right)^2 y$ is a quadratic price adjustment cost. Imposing a symmetric equilibrium across firms implies that $p_i = 1$ and $y_i = y$. The optimal price equilibrium condition then is:

$$\eta \left(\frac{1+\pi}{1+\bar{\pi}} - 1 \right) \frac{1+\pi}{1+\bar{\pi}} = \eta \mathbb{E}_X M^{P'} \left(\frac{1+\pi'}{1+\bar{\pi}} - 1 \right) \frac{1+\pi'}{1+\bar{\pi}} \frac{y'}{y} + 1 - \varepsilon + \varepsilon p_m. \quad (26)$$

3.2.3 Wholesale Goods Firms

The wholesale good y_m is produced by a continuum of perfectly competitive identical firms, which use a linear technology in labor $y_m = z\check{n}$, where \check{n} is labor demand and z is technology. These firms

solve:

$$\max_{\tilde{n}} \{p_m z \tilde{n} - Q \tilde{n}\}. \quad (27)$$

The real unit price Q of labor services n is given by the first order condition:

$$Q = p_m z. \quad (28)$$

3.2.4 Labor Intermediaries

Labor intermediaries hire labor from both perfectly and imperfectly insured households in a frictional labor market and sell labor services to wholesale goods firms. Every period there is exogenous separation rate ρ between employers and workers.⁸ At the same time, labor intermediaries post vacancies at the unit cost κ . There is a skill premium for perfectly insured households over imperfectly insured ones.⁹ In particular, while an employed imperfectly insured household provides one unit of labor services and earns a wage w , an employed perfectly insured household provides $\psi > 1$ units of labor services and earns $w^P = \psi w$. Hence, the values for a labor intermediary of a match with imperfectly and perfectly insured households are:

$$J^I = Q - w + \mathbb{E}_X [(1 - \rho) M^{I'} J^{I'}], \quad (29)$$

$$J^P = \psi Q - \psi w + \mathbb{E}_X [(1 - \rho) M^{P'} J^{P'}], \quad (30)$$

which implies that $J^I = \psi J^P$. Moreover, given the vacancy filling rate λ , the free entry condition of labor intermediaries implies that the value of opening a vacancy has to equalize its cost:

$$\lambda (\Omega J^I + (1 - \Omega) J^P) = \kappa. \quad (31)$$

⁸In line with most of the literature on HANK and SaM, we assume that the match destruction rate ρ is exogenous. This implies that the job separation rate inherits its cyclical properties from the job finding rate. Recently, [Broer et al. \(2021\)](#) have shown how endogenizing the match destruction rate helps generating stronger precautionary saving motives in recessions. As our focus is on the cross-sectional heterogeneity of households' exposure to unemployment risk, rather than on the cyclical properties of aggregate unemployment, we prefer to maintain comparability with most of the literature and assume that match destruction rate is exogenous. This assumption still not prevents our model from generating impulse responses that well match the VAR responses, as can be seen from [Figure 1](#) and [2](#).

⁹We follow [Challe et al. \(2017\)](#) in introducing a skill premium for the perfectly insured. As a matter of fact, consumption heterogeneity in the U.S. cannot be fully imputed to the heterogeneity in asset income. Some heterogeneity in labor income is needed to match the heterogeneity in consumption. We test the sensitivity of our results to the skill premium in [Section C.4](#).

The aggregate employment rate at the beginning and at the end of the labor market transition stage are given respectively by

$$\tilde{\mathbf{n}} = \Omega\tilde{\mathbf{n}}^I + (1 - \Omega)\psi\tilde{\mathbf{n}}^P, \quad (32)$$

$$\mathbf{n} = \Omega\mathbf{n}^I + (1 - \Omega)\psi\mathbf{n}^P, \quad (33)$$

which implies that $\tilde{\mathbf{n}}' = \mathbf{n}$.

The aggregate unemployment pool \mathbf{u} is given by the unemployed households $\mathbf{1} - \tilde{\mathbf{n}}$ at the beginning of the labor market transition stage plus the fraction ρ of employed households, who loose their job over the period:

$$\mathbf{u} = \mathbf{1} - \tilde{\mathbf{n}} + \rho\tilde{\mathbf{n}}. \quad (34)$$

Firm-worker matches are created through the following matching technology

$$m = \mu\mathbf{u}^\chi v^{1-\chi}, \quad (35)$$

where v are the posted vacancies, μ is the matching efficiency parameter, and χ is the elasticity of matches with respect to unemployed households. The aggregate job finding and job filling rates are given by:

$$f = \frac{m}{\mathbf{u}}, \quad (36)$$

$$\lambda = \frac{m}{v}. \quad (37)$$

Since the workers who loose their job at the beginning of the labor market transition period can be rematched within the same period, the period-to-period separation rate is:

$$s = \rho(1 - f). \quad (38)$$

Given the job finding rate f and the job separation rate s , the law of motion of aggregate labor is:

$$\mathbf{n} = f\tilde{\mathbf{n}} + (1 - s)\tilde{\mathbf{n}}. \quad (39)$$

We assume that wages are set according to the following wage rule:

$$w = \bar{w} \left(\frac{\mathbf{n}}{\bar{n}} \right)^{\phi_w}, \quad (40)$$

where ϕ_w indicates the elasticity of wages to deviations of employment from its steady-state value \bar{n} and \bar{w} is the steady state wage.

3.3 Monetary Authority

The monetary authority follows a standard Taylor rule, where the nominal interest rate R reacts to inflation and output growth. The rule is:

$$\frac{1 + R}{1 + \bar{R}} = \left(\frac{1 + \pi}{1 + \bar{\pi}} \right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}} \right)^{\phi_y}, \quad (41)$$

where \bar{R} is the steady-state nominal interest rate, and ϕ_π and ϕ_y are the reaction coefficients to inflation and output growth.

The real interest rate is determined as follows:

$$1 + r = \frac{1 + \mathbf{R}_{-1}}{1 + \pi}. \quad (42)$$

3.4 Exogenous Processes

The technology z used by wholesale goods firms is subject to first and second moment shocks according to the following stochastic processes:

$$\log z = \rho_z \log z_{-1} + \sigma^z \varepsilon^z, \quad (43)$$

$$\log \sigma^z = (1 - \rho_{\sigma^z}) \log \bar{\sigma}^z + \rho_{\sigma^z} \log \sigma_{-1}^z + \sigma^{\sigma^z} \varepsilon^{\sigma^z}. \quad (44)$$

In particular, $\varepsilon^z \sim N(0, 1)$ is a first-moment shock capturing innovations to the level of technology, while $\varepsilon^{\sigma^z} \sim N(0, 1)$ is a second moment shock capturing innovations to the standard deviation σ^z of technology. ρ_z and ρ_{σ^z} indicate the persistence of the two processes and σ^{σ^z} is the standard

deviation of σ^z . The second moment shock is how we introduce uncertainty into the model.¹⁰ We interpret a positive second moment shock as an increase in uncertainty in the economy.

3.5 Market Clearing

3.5.1 Labor Market

All households face the same job finding rate f and job separation rate s . Since we assume that employment is symmetric between perfectly and imperfectly insured households at the beginning of period zero, for the law of large numbers it remains symmetric at every point in time. Hence, the share of perfectly and imperfectly insured agents which is employed is the same, and family-level variables are equal to aggregate variables:

$$\tilde{n}^P = \tilde{n}^I = \tilde{\mathbf{n}}^P = \tilde{\mathbf{n}}^I \equiv \tilde{\mathbf{n}}, \quad (45)$$

$$n^P = n^I = \mathbf{n}^P = \mathbf{n}^I \equiv \mathbf{n}. \quad (46)$$

Moreover, the aggregate labor supply is:

$$\Omega \mathbf{n}^I + (1 - \Omega) \psi \mathbf{n}^P = (\Omega + (1 - \Omega) \psi) \mathbf{n}, \quad (47)$$

and the labor market clearing condition is:

$$(\Omega + (1 - \Omega) \psi) \mathbf{n} = \tilde{\mathbf{n}}. \quad (48)$$

3.5.2 Assets Market

All households participate in the assets market, which is in zero net supply:

$$\Omega (A + (1 - \mathbf{n}) \underline{a}) + (1 - \Omega) a^P = 0. \quad (49)$$

¹⁰Oh (2020) shows that responses of macro variables do not qualitatively depend on the source of uncertainty.

There are Ω imperfectly insured households and $1 - \Omega$ perfectly insured households. Imperfectly insured households own either A if their budget constraint is not binding or \underline{a} if it is binding.¹¹ Perfectly insured households own assets a^P .

3.5.3 Goods Market

The final good production y has to be equal to the final good aggregate consumption c plus the cost of posting vacancies and the price adjustment cost:

$$c + \kappa v + \frac{\eta}{2} \left(\frac{1 + \pi}{1 + \bar{\pi}} - 1 \right)^2 y = y. \quad (50)$$

Aggregate consumption is the share Ω of imperfectly insured households' consumption plus the share $1 - \Omega$ of perfectly insured households' consumption c^P . The former is made of the consumption of imperfectly insured households who are employed $n^I(0) c^I(0)$, who have been unemployed for one period $n^I(1) c^I(1)$, and who have been unemployed for at least two periods $n^I(2) c^I(2)$:

$$c \equiv \Omega (n^I(0) c^I(0) + n^I(1) c^I(1) + n^I(2) c^I(2)) + (1 - \Omega) c^P. \quad (51)$$

Intermediate goods market is in equilibrium when the intermediate goods demand y is equal to its supply $y_m - \Phi$:

$$y = y_m - \Phi. \quad (52)$$

Finally, the market clearing condition for the wholesale goods is:

$$\int_0^1 x_i di = y_m = z\tilde{n}. \quad (53)$$

¹¹Since we have assumed that the borrowing constraint of unemployed imperfectly insured households becomes binding after one period of unemployment spell, the assets that they own is equal to the borrowing limit \underline{a} regardless of the length of their unemployment spell N . This would not be the case if the borrowing limit became binding after more than one period of unemployment spell.

3.6 Aggregate State and Equilibrium

We focus on symmetric equilibrium, where variables at family-level are identical. The aggregate state X is then given by:

$$X = \{\tilde{\boldsymbol{\mu}}(\cdot), a^P, a^I(0), \mathbf{c}^P, \mathbf{c}^I(N)_{N \geq 0}, \mathbf{R}_{-1}, \mathbf{y}_{-1}, \boldsymbol{\Delta}_{-1}, \tilde{\mathbf{n}}, z, \sigma^z\}. \quad (54)$$

When $\hat{N} = 1$, i.e. when the borrowing constraint becomes binding after one period of unemployment spell, the heterogeneity of the imperfectly insured households can be reduced to three types: the employed type $N = 0$, the unemployed type for one period $N = 1$, and the unemployed type for more than one period $N \geq 2$. These types are in shares of respectively: $\Omega \mathbf{n}$, $\Omega s \tilde{\mathbf{n}}$, and $\Omega(1 - \mathbf{n} - s \tilde{\mathbf{n}})$. In this specific case, a symmetric equilibrium is given by the following conditions:

1. the Euler condition (19) and the IMRS (20) for the perfectly insured households hold, and the Euler condition (11) and the IMRS (12) for the imperfectly insured households hold;
2. the budget constraint for the perfectly insured households (18) and the budget constraints for the three types of imperfectly insured households (4) and (5) with assets determined by (6) and (7);
3. the price set by optimizing firms is determined by (26), and the real unit price of labor services by (28);
4. the aggregate employment and unemployment rates are given by (32), (33), and (34), the job finding rate, the job filling rate, the period-to-period separation rate, and the matching function technology by (36), (37), (38) and (35), the aggregate labor law of motion by (39), the value of a match and the value of opening a vacancy are given by (29) to (31);
5. wages are determined according to (40), social contributions to (1) and (16), and nominal and real interest rates to (41) and (42);
6. the market clearing conditions (45) to (53) hold;
7. consumption habits are as follows: $\mathbf{c}^{P'} = c^P$, $\mathbf{c}^{I'}(0) = c^I(0)$, $\mathbf{c}^{I'}(1) = c^I(1)$, and $\mathbf{c}^{I'}(2) = c^I(2)$.

3.7 Precautionary Savings

The model features precautionary savings induced by positive uncertainty shocks through two different channels, a direct and an indirect one. The direct channel works through households' risk aversion. Because of its convexity, the IMRS of all households under uncertainty is larger than under certainty. A higher IMRS induces households to substitute out of consumption towards savings in a precautionary manner.

The indirect channel is due to uninsured unemployment risk. While both perfectly and imperfectly insured households bear unemployment risk, perfectly insured households fully share this risk, while imperfectly insured households face partial risk sharing. Partial insurance further strengthens the precautionary saving behavior of imperfectly insured households. This indirect channel works as follows. Higher uncertainty triggers a drop in aggregate demand, which, in turn, generates a fall in production and a decrease in posted vacancies. Less vacancies lead to a drop in the finding rate f , which increases the separation rate $s = \rho(1 - f)$. A lower finding rate and a higher separation rate increase the imperfectly insured households' propensity to save. The last implication can be derived from the IMRS of imperfectly insured households. In particular, if imperfectly insured households are employed ($N = 0$), their IMRS is as follows:

$$M^{I'}(0) = \beta^I \frac{(1 - s') u_c^{I'}(0) + s' u_c^{I'}(1)}{u_c^I(0)}, \quad N = 0. \quad (55)$$

Their marginal utility of consumption when becoming unemployed $u_c^{I'}(1)$ is higher than their marginal utility of consumption when remaining employed $u_c^{I'}(0)$, as falling into unemployment generates a drop in consumption and marginal utility is decreasing in consumption. Therefore, whenever the separation rate s' rises, the IMRS increases, thus pushing imperfectly insured households to save more. A similar reasoning applies to the IMRS of imperfectly insured households who are unemployed ($N \geq 1$):

$$M^{I'}(N) = \beta^I \frac{(1 - f') u_c^{I'}(N + 1) + f' u_c^{I'}(0)}{u_c^I(N)}, \quad N \geq 1. \quad (56)$$

Whenever the finding rate f' drops, the IMRS increases as the marginal utility of consumption when remaining unemployed $u_c^{I'}(N + 1)$ is higher than the marginal utility of consumption when

becoming employed.

Notice that since throughout the paper we assume that the borrowing limit becomes binding after one period of unemployment spell, only the Euler condition for $N = 0$ will hold with equality, while the Euler condition for $N > 0$ will be slack. This implies that the precautionary saving motive will only concern *employed* imperfectly insured households, who are the only type of imperfectly insured households allowed to save. To the contrary, *unemployed* imperfectly insured households will be at their borrowing limit, so their asset position will simply be \underline{a} .

4 Quantitative Results

This section details how the parameters of the model are calibrated or estimated, then explains how the model is solved, and afterwards discusses our main quantitative results.

4.1 Calibration and Estimation of Parameters

We divide parameters into two groups: the first set of parameters is calibrated, while the second is estimated by means of impulse response matching. Table 2 reports all parameter values. We first discuss the calibrated parameters and then the estimated ones. To calibrate parameters, we use quarterly data for the the U.S. economy over the period 1994Q1-2019Q4. The share of imperfectly insured households Ω is calibrated to 0.60 to map the impatient households to the bottom 60% in our VAR analysis. Risk aversion σ is set to the standard value of 1.00 to have log utility. The discount factor of perfectly insured households β^P is set to match an annual interest rate of 3%, while the discount factor of imperfectly insured households β^I is set to target a 21% consumption drop when falling into unemployment. The unemployment benefits are calibrated to target a replacement rate of 33%. As for parameters related to firms, we set the elasticity of substitution between goods to get a 20% markup. The price stickiness η is calibrated to have a four-quarter stickiness. Moving to labor market parameters, the matching efficiency μ is set to target a job filling rate of 71%, which follows [Den Haan et al. \(2000\)](#). The job separation rate ρ targets a job loss rate of 5% and a job finding rate of 71%. The matching function elasticity χ is set according to [Petrongolo and Pissarides \(2001\)](#). The vacancy posting cost κ is calibrated to being 1% of output following [Challe et al. \(2017\)](#). The skill premium ψ is set to 1.42 so as to match the consumption share (51.6%) of

Table 2: Quarterly Calibration

Parameter	Description	Value	Target/Source
Households			
Ω	Share of imp. insured HHs	0.6	Bottom 60% in our VAR
\underline{a}	Borrowing limit	0	Challe et al. (2017)
σ	Risk aversion	1	Log utility
h	Habit persistence	0.85	Estimation
β^I	Discount factor of imp. insured HHs	0.967	21% consumption loss
β^P	Discount factor of perf. insured HHs	0.993	3% annual real interest rate
b^u	Unemployment benefits	0.27	33% replacement rate
Firms			
ε	Elasticity of substitution btw goods	6	20% markup
η	Price stickiness	58.70	4-quarter stickiness
Labor Market			
μ	Matching efficiency	0.71	71% job filling rate
χ	Matching function elasticity	0.5	Petrongolo and Pissarides (2001)
ρ	Job separation rate	0.17	71% job finding & 5% job loss rates
κ	Vacancy posting cost	0.04	1% of output
ψ	Skill premium	1.42	Bottom 60% consumption share (51.6%)
ϕ_w	Wage elasticity wrt employment	0.375	Estimation
Monetary Authority			
$\bar{\pi}$	Steady-state inflation	0.005	2% annual inflation rate
ϕ_π	Taylor rule coefficient for inflation	1.5	Standard
ϕ_y	Taylor rule coefficient for output	0.25	Standard
Exogenous Processes			
ρ_z	Persistence of technology shock	0.95	Standard
$\bar{\sigma}^z$	Volatility of technology shock	0.007	Standard
ρ_{σ^z}	Persistence of uncertainty shock	0.96	Estimation
σ^{σ^z}	Volatility of uncertainty shock	0.103	Estimation

the poorest 60% of the households. As far as monetary policy parameters are concerned, we set the steady-state inflation $\bar{\pi}$ to target a 2% annual inflation, the interest rate responsiveness to inflation ϕ_π to 1.50 and the interest rate responsiveness to output growth ϕ_y to 0.25. Moving to the shock processes, we set the persistence ρ_z and the steady-state volatility $\bar{\sigma}^z$ of the technology shock to the standard values of 0.95 and 0.007.

The parameters that appear in bold in Table 2 are estimated using impulse response function matching. The basic idea behind this methodology is to find a vector of parameter estimates $\hat{\lambda}$ that minimizes the distance between the impulse responses of our VAR (\hat{r}) and those implied by the model (r). More formally, the estimation procedure involves solving the following minimization problem:

$$\min_{\lambda} D = [\hat{r} - r(\lambda)]' W^{-1} [\hat{r} - r(\lambda)], \quad (57)$$

where W^{-1} is a matrix of weights for impulse response function matching. We use a matrix with the inverse of the variances of the impulse response functions on the diagonal. The impulse responses we target to match are those of output, job finding rate, separation rate, unemployment rate, consumption, and policy rate. The parameters that we estimate are the habit persistence, the wage elasticity with respect to employment, and the persistence and volatility of the uncertainty shock process. We estimate the habit persistence to be 0.85, the wage elasticity with respect to employment to be 0.375, and the persistence and volatility of the uncertainty shock process to be respectively 0.96 and 0.103. These estimates are in line with values calibrated or estimated in the literature.

4.2 Solution Method

To study the effects of uncertainty shocks, we solve the model using a third-order perturbation method, as suggested by [Fernández-Villaverde et al. \(2011\)](#). The third-order perturbation moves the ergodic means of the endogenous variables of the model away from their deterministic steady-state values. Hence, we compute the impulse responses in percent deviation from the stochastic steady state of each endogenous variable. For that, we use the Dynare software package developed by [Adjemian et al. \(2022\)](#) and the pruning algorithm designed by [Andreasen et al. \(2018\)](#).

4.3 Main Results

Figure 4 shows impulse responses of the variables of interest to a one standard deviation shock in technology uncertainty. The solid blue line shows the responses of the model with imperfectly insured unemployment risk as described in Section 3. We will refer to this model as HANK. The dashed red line shows the responses of the corresponding RANK model where unemployment risk

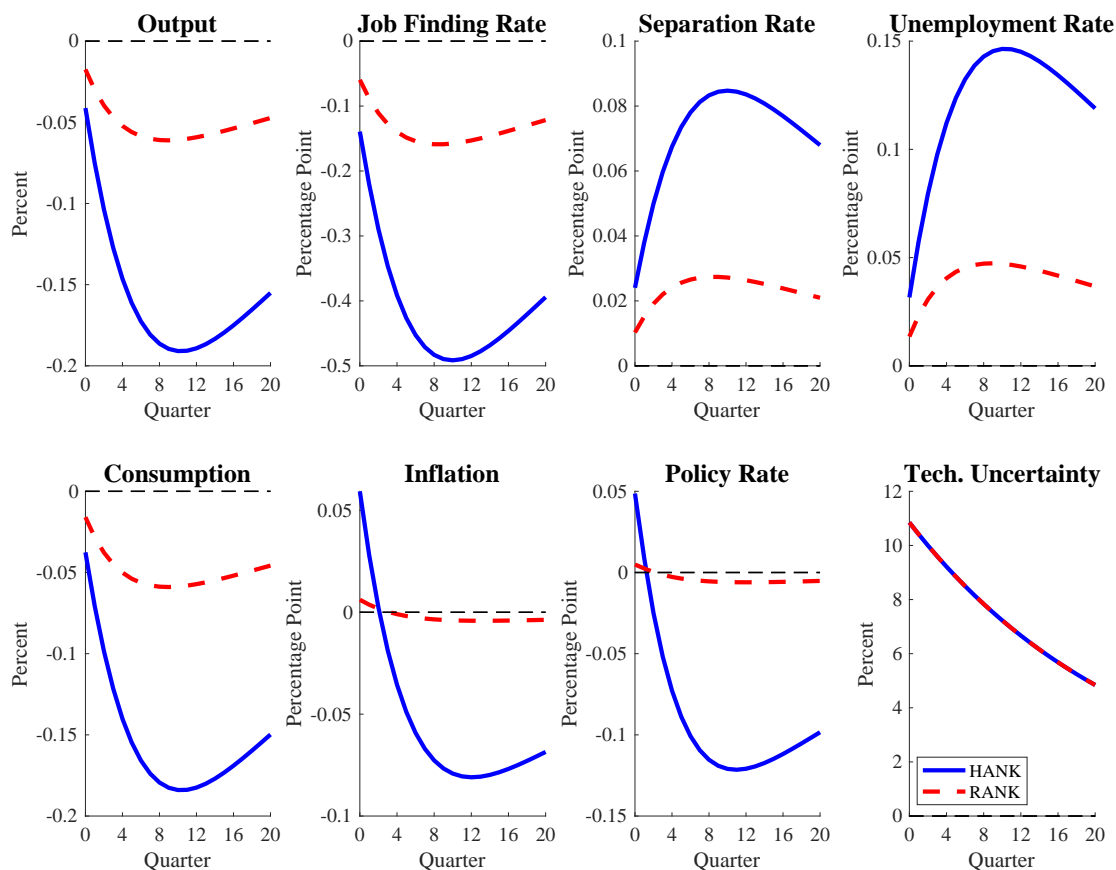


Figure 4: Impulse Responses to One-Standard Deviation Technology Uncertainty Shocks

Note: Impulse responses of output, consumption, and uncertainty are in percent deviation from their stochastic steady state, impulse responses of unemployment rate, job finding rate, and job separation rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

is fully insured. This model is identical to the former except that there are no imperfectly insured households, that is $\Omega = 0$. In this case, there is only one type of households, the perfectly insured ones, who fully share risk. As a benchmark, we first describe the responses of the model with perfect insurance (RANK), before illustrating the responses generated by the model with imperfect insurance (HANK).

In the RANK model, higher uncertainty induces a negative wealth effect on risk-averse households, who increase savings and decrease consumption (see [Fernández-Villaverde et al., 2015](#), [Leduc and Liu, 2016](#), [Basu and Bundick, 2017](#), and [Oh, 2020](#) for this precautionary saving channel). The drop in aggregate demand reduces the marginal cost that firms face and pushes them to lower prices to stimulate demand. The HANK model adds a new channel of transmission and amplification of

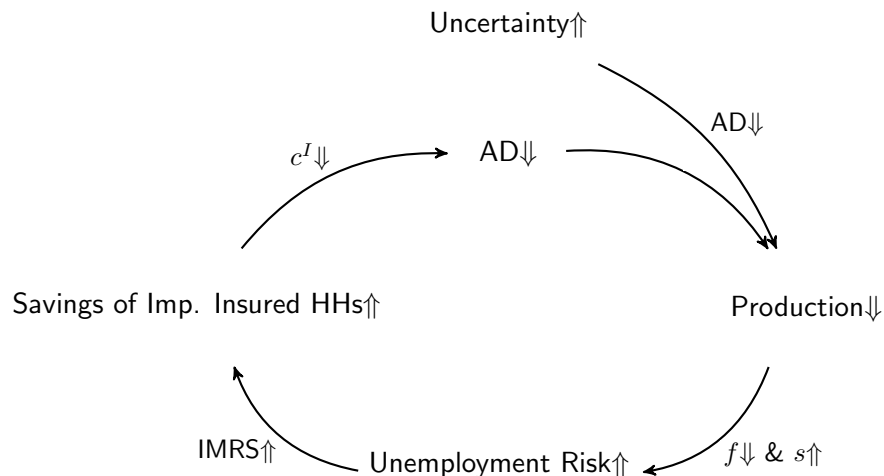


Figure 5: Propagation Mechanism of Positive Uncertainty Shocks

the uncertainty shock, which is graphically illustrated by Figure 5.

As explained for the RANK model, an uncertainty shock causes a drop in aggregate demand triggered by the precautionary saving behavior of households. The drop in demand induces firms to lower their vacancy posting, thus reducing the job finding rate and increasing the unemployment rate. At this stage the presence of imperfectly insured households becomes key to explain the dynamics of the model. As imperfectly insured households are subject to imperfect risk sharing, they cannot fully insure against unemployment. Thus, a higher unemployment risk induces them to further increase savings and decrease consumption. The precautionary saving behavior of the imperfectly insured households triggers a feedback loop, which reinforces the drop in aggregate demand. The solid blue line in Figure 4 shows impulse responses of the HANK model. The amplification generated by the precautionary behavior of the imperfectly insured households allows us to obtain responses that are quantitatively in line with the empirical responses in Figure 1.

Figure 6 illustrates the responses of consumption for both imperfectly (dashed line) and perfectly (dotted line) insured households. Because of the precautionary saving behavior that partial risk sharing induces, imperfectly insured households contract consumption much more. Consumption of the perfectly insured households also drops on impact due to risk aversion. Yet, as imperfectly insured households increase their savings and asset markets have to clear, perfectly insured households get to borrow from them. The rise in borrowing is strong enough to push perfectly

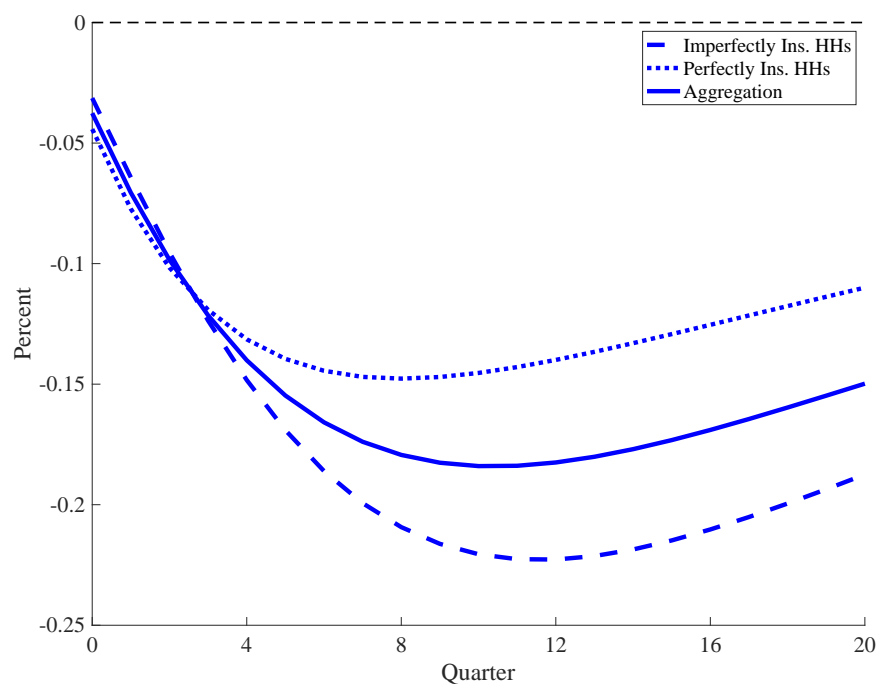


Figure 6: Consumption Heterogeneity

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state.

insured households to increase their consumption and revert the initial consumption contraction due to precautionary motives.

The differential response of the perfectly and imperfectly insured households in the model can guide the interpretation of our empirical responses in Figure 1, where we found that only the bottom 60% of households along the income distribution were contracting consumption significantly. We interpret this result as the consequence of households at the bottom of the distribution being more exposed to unemployment risk than households at the top of the distribution. Households who are perfectly insured against unemployment risk contract consumption only mildly in response to higher uncertainty. To the contrary, households who cannot fully insure against unemployment risk, are much more responsive to heightened uncertainty and contract consumption more. We interpret these households as the model counterpart to the poorer income households in the bottom three quintiles of our empirical analysis.

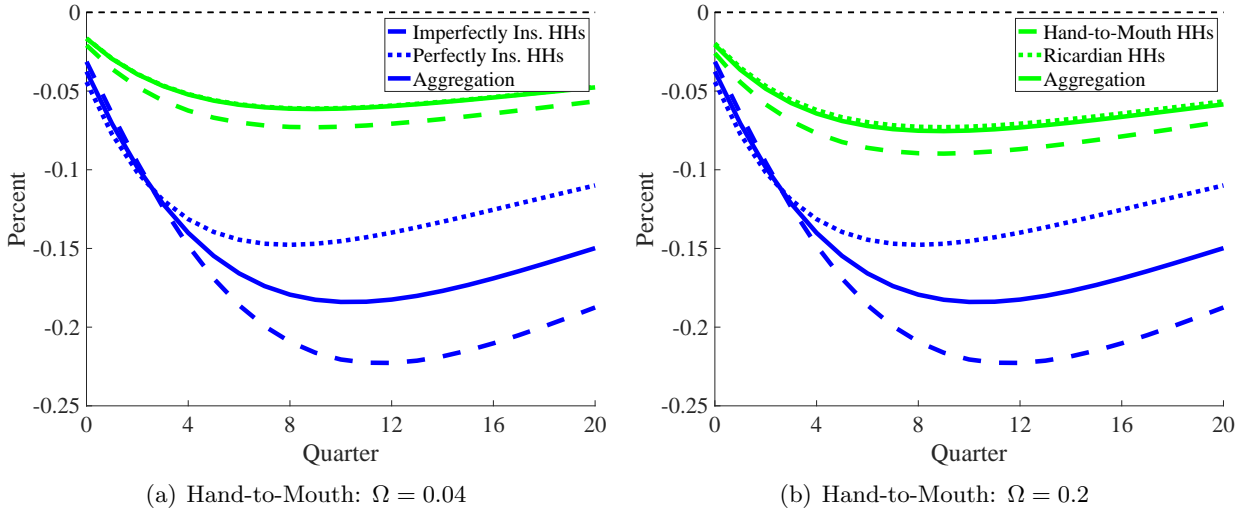


Figure 7: Consumption Heterogeneity in Response to Technology Uncertainty: Hand-to-Mouth Households

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state.

4.4 A Model with Hand-to-Mouth and Ricardian Households

To understand how powerful the precautionary saving motive is in amplifying the effects of uncertainty, we have compared our HANK model to the RANK. In the HANK, however, the differential consumption response across households is the result of two distinct forces: a heterogeneous marginal propensity to consume (MPC) and a heterogeneous exposure to income risk, which generates a motive for precautionary saving. To isolate the effect of these two forces, we write down a model with only two agents (TANK): a hand-to-mouth, who cannot save and thus has a higher MPC, and a fully Ricardian household, who can smooth his consumption via savings.¹² In the TANK model, the aggregate consumption response is mostly determined by the strength of the MPC of the two types, while there is no effect coming from precautionary saving. Thus, comparing the RANK to the TANK and the HANK allows us to distinguish which of the two channels, the MPC heterogeneity or the differential exposure to income risk, is the main driver of the aggregate consumption response.

For a fair comparison between the TANK and the HANK model, we implement two calibrations of the share Ω of hand-to-mouth households in the TANK. In one case, we calibrate $\Omega = 0.2$ to

¹²Appendix C.2 specifies which equilibrium conditions have to be changed to get a TANK version of our model.

have a quarterly average MPC of 0.2, in line with the literature. In a second case, we calibrate $\Omega = 0.04$ to match the average MPC from our HANK model.

Figure 7 compares impulse responses of consumption from the two versions of the calibrated TANK model with those from the HANK model. As expected, in the presence of a higher share of hand-to-mouth consumers (Figure 7(b)), aggregate consumption contracts more in response to heightened uncertainty. However, the comparison between the HANK response (blue solid line) and the TANK response (green solid line) shows that while some of the effect is driven by heterogeneity in MPC, the biggest amplification comes from the precautionary saving motive, which is only present in the HANK version of the model. While the aggregate response of consumption drops by around 0.05-0.07 percent in the TANK versions of the model, it contracts by almost 0.2 percent in the HANK, indicating that the biggest driver of the heterogeneous consumption response is the precautionary saving motive.

Figure 8 shows the responses of aggregate macro variables to the uncertainty shock. While the responses of the TANK versions of the model (green lines) are quite close to the responses of the RANK (red lines), the biggest amplification is present only in the HANK (blue lines). This again shows that the main driver of amplification is the differential exposure to income risk rather than to the heterogeneity in MPCs.

4.5 Robustness Checks

Different Source of Macro Uncertainty In line with the vast majority of the literature on uncertainty propagation, we have so far focused on TFP uncertainty. Yet, the macro uncertainty index by [Jurado et al. \(2015\)](#) that we have used in our empirical analysis captures a broader concept of uncertainty. Appendix C.3 extends our analysis to study how the economy reacts to higher uncertainty on the demand side of the economy. Even if the responses are quantitatively smaller than in the case of a TFP uncertainty shock, the HANK model generates more amplified responses than the RANK model.

Additional Sensitivity Analyses Some parameters of model are calibrated as explained in Section 4.1. Appendix C.4 discusses the sensitivity of our results to this calibration.

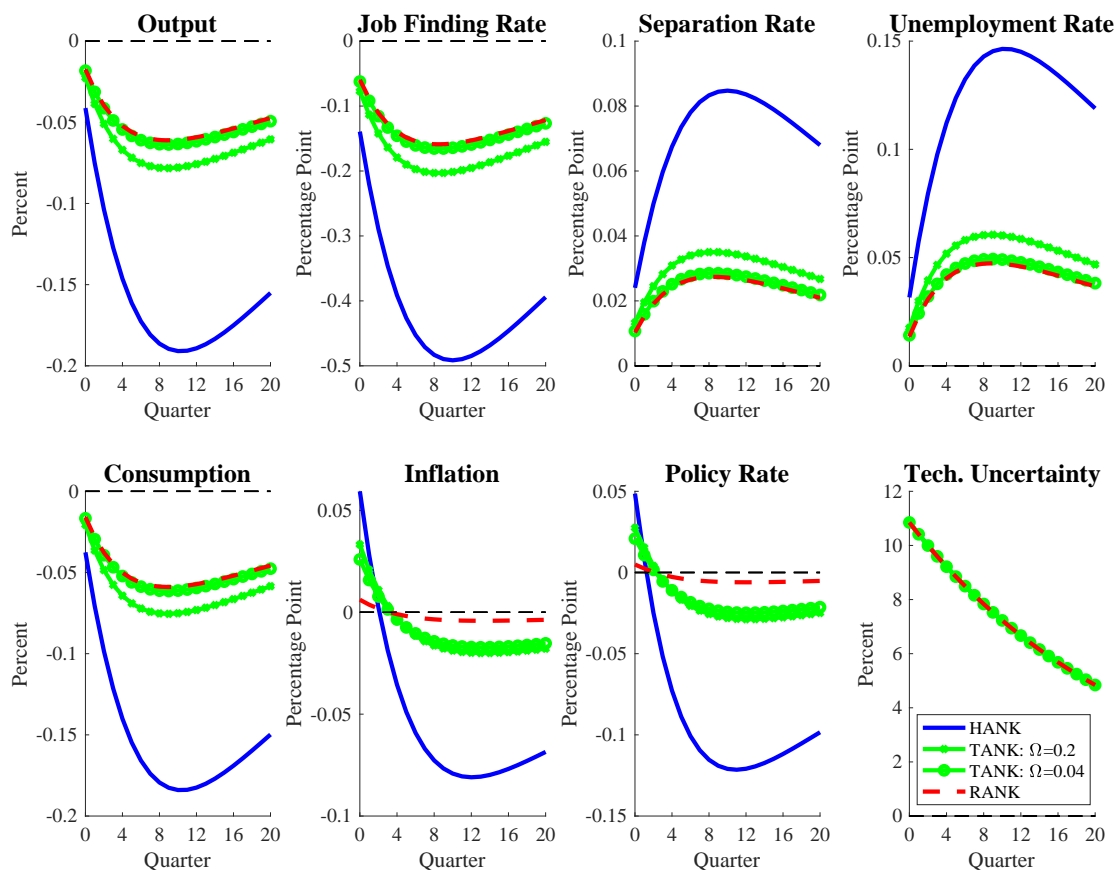


Figure 8: Impulse Responses to One-Standard Deviation Technology Uncertainty: Comparison between HANK, TANK, and RANK

Note: Impulse responses of output, consumption, and uncertainty are in percent deviation from their stochastic steady state, impulse responses of unemployment rate, job finding rate, and job separation rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

5 Conclusion

This paper has shown how households' heterogeneity is important to explain the propagation of uncertainty to the macroeconomy. By estimating a BVAR with data from the CEX survey we have shown that in response to heightened macro uncertainty households in the bottom three quintiles of the income distribution decrease consumption more than those in the top quintile. Moreover, using aggregate data we have provided evidence that an increase in macro uncertainty has significant effects on labor markets, generating a drop in the job finding rate, and a rise in the unemployment and the separation rate. To rationalize these empirical findings, we have built an NK model with imperfectly insured unemployment risk and SaM frictions. In response to a positive uncertainty

shock, the interaction between the precautionary saving behavior of partially insured households and the labor market SaM frictions is able to generate responses of output, consumption, unemployment rate, job finding rate, and separation rate that are in line with our empirical evidence. Moreover, we can replicate the empirical result that income poorer households –who correspond to imperfectly insured households in the model– contract consumption in response to higher uncertainty, while income rich households barely do. The goal of our model has been to study the propagation of uncertainty shocks in a model with unemployment risk and imperfect insurance. This has been possible thanks to the tractability of our framework. Our setup has allowed us to introduce minimal heterogeneity across households, while at the same time retaining the main precautionary saving motive implied by heterogeneity. There could be additional channels through which macro uncertainty affects households differentially. We plan to explore them further in our future research.

References

- ADJEMIAN, S., H. BASTANI, M. JUILLARD, F. KARAMÉ, F. MIHOUBI, W. MUTSCHLER, J. PFEIFER, M. RATTO, N. RION AND S. VILLEMOT, “Dynare: Reference Manual Version 5,” Dynare Working Papers 72, CEPREMAP, 2022.
- AGUIAR, M. AND M. BILS, “Has Consumption Inequality Mirrored Income Inequality?,” *American Economic Review* 105 (2015), 2725–2756.
- AMBERG, N., T. JANSSON, M. KLEIN AND A. ROGANTINI PICCO, “Five Facts about the Distributional Income Effects of Monetary Policy Shocks,” *American Economic Review: Insights* Forthcoming (2021).
- ANDERSEN, A. L., N. JOHANNESSEN, M. JØRGENSEN AND J.-L. PEYDRÓ, “Monetary Policy and Inequality,” Working Paper, 2021.
- ANDREASEN, M. M., J. FERNÁNDEZ-VILLAVERDE AND J. RUBIO-RAMÍREZ, “The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications,” *Review of Economic Studies* 85 (2018), 1–49.
- ARELLANO, M., R. BLUNDELL AND S. BONHOMME, “Earnings and Consumption Dynamics: A Nonlinear Panel Data Framework,” *Econometrica* 85 (2017), 693–734.
- ATTANASIO, O., E. HURST AND L. PISTAFERRI, “The Evolution of Income, Consumption, and Leisure Inequality in the United States, 1980–2010,” in C. D. Carroll, T. F. Crossley and J. Sabelhaus, eds., *Improving the Measurement of Consumer Expenditures* (University of Chicago Press, 2015), 100–140.
- BASU, S. AND B. BUNDICK, “Uncertainty Shocks in a Model of Effective Demand,” *Econometrica* 85 (2017), 937–958.
- BAYER, C., R. LÜETTICKE, L. PHAM-DAO AND V. TJADEN, “Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk,” *Econometrica* 87 (2019), 255–290.

- BILBIE, F. O., “Monetary Policy and Heterogeneity: An Analytical Framework,” Working Paper, 2021.
- BIRINCI, S. AND K. SEE, “Labor Market Responses to Unemployment Insurance: The Role of Heterogeneity,” *American Economic Journal: Macroeconomics* 15 (2023), 388–430.
- BLOOM, N., “The Impact of Uncertainty Shocks,” *Econometrica* 77 (2009), 623–685.
- BLUNDELL, R., L. PISTAFERRI AND I. PRESTON, “Consumption Inequality and Partial Insurance,” *American Economic Review* 98 (2008), 1887–1921.
- BORN, B. AND J. PFEIFER, “Policy Risk and the Business Cycle,” *Journal of Monetary Economics* 68 (2014), 68–85.
- BROER, T., J. DRUEDAHL, K. HARMENBERG AND E. ÖBERG, “The Unemployment-Risk Channel in Business-Cycle Fluctuations,” CEPR Discussion Paper series 16639, 2021.
- CAGGIANO, G., E. CASTELNUOVO AND N. GROSHENNY, “Uncertainty Shocks and Unemployment Dynamics in U.S. Recessions,” *Journal of Monetary Economics* 67 (2014), 78–92.
- CESA-BIANCHI, A. AND E. FERNANDEZ-CORUGEDO, “Uncertainty, Financial Frictions and Nominal Rigidities: A Quantitative Investigation,” *Journal of Money, Credit and Banking* 50 (2018), 603–636.
- CHALLE, E., “Uninsured Unemployment Risk and Optimal Monetary Policy in a Zero-Liquidity Economy,” *American Economic Journal: Macroeconomics* 12 (2020), 241–283.
- CHALLE, E., J. MATHERON, X. RAGOT AND J. F. RUBIO-RAMIREZ, “Precautionary Saving and Aggregate Demand,” *Quantitative Economics* 8 (2017), 435–478.
- CHO, D., “Unemployment Risk, MPC Heterogeneity, and Business Cycles,” *Quantitative Economics* Forthcoming (2023).
- COIBION, O., D. GEORGARAKOS, Y. GORODNICHENKO, G. KENNY AND M. WEBER, “The Effect of Macroeconomic Uncertainty on Household Spending,” Working Paper, 2021.
- COIBION, O., Y. GORODNICHENKO, L. KUENG AND J. SILVIA, “Innocent Bystanders? Monetary Policy and Inequality,” *Journal of Monetary Economics* 88 (2017), 70–89.

- DE GROOT, O., A. W. RICHTER AND N. A. THROCKMORTON, “Uncertainty Shocks in a Model of Effective Demand: Comment,” *Econometrica* 86 (2018), 1513–1526.
- DEN HAAN, W. J., G. RAMEY AND J. WATSON, “Job Destruction and Propagation of Shocks,” *American Economic Review* 90 (2000), 482–498.
- DOLADO, J. J., G. MOTYOVSKI AND E. PAPPA, “Monetary Policy and Inequality under Labor Market Frictions and Capital-Skill Complementarity,” *American Economic Journal: Macroeconomics* 13 (2021), 292–332.
- FERNÁNDEZ-VILLAYERDE, J., P. GUERRÓN-QUINTANA, K. KUESTER AND J. RUBIO-RAMÍREZ, “Fiscal Volatility Shocks and Economic Activity,” *American Economic Review* 105 (2015), 3352–3384.
- FERNÁNDEZ-VILLAYERDE, J., P. GUERRÓN-QUINTANA, J. RUBIO-RAMÍREZ AND M. URIBE, “Risk Matters: The Real Effects of Volatility Shocks,” *American Economic Review* 101 (2011), 2530–2561.
- FERNÁNDEZ-VILLAYERDE, J., J. MARBET, G. NUÑO AND O. RACHEDI, “Inequality and the Zero Lower Bound,” Working Paper, 2024.
- FREUND, L. B., H. LEE AND P. RENDAHL, “The Risk-Premium Channel of Uncertainty: Implications for Unemployment and Inflation,” *Review of Economic Dynamics* 51 (2023).
- GERTLER, M., L. SALA AND A. TRIGARI, “An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining,” *Journal of Money, Credit and Banking* 40 (2008), 1713–1764.
- GORNEMANN, N., K. KUESTER AND M. NAKAJIMA, “Doves for the Rich, Hawks for the Poor? Distributional Consequences of Monetary Policy,” Working Paper, 2021.
- GRAVES, S., “Does Unemployment Risk Affect Business Cycle Dynamics?,” Working Paper, 2022.
- HEATHCOTE, J., F. PERRI, G. L. VIOLANTE AND L. ZHANG, “More Unequal We Stand? Inequality Dynamics in the United States, 1967–2021,” *Review of Economic Dynamics* 50 (2023), 235–266.

- HOLM, M. B., P. PAUL AND A. TISCHBIREK, “The Transmission of Monetary Policy under the Microscope,” *Journal of Political Economy* 129 (2021), 2861–2904.
- JURADO, K., S. C. LUDVIGSON AND S. NG, “Measuring Uncertainty,” *American Economic Review* 105 (2015), 1177–1216.
- KAPLAN, G., B. MOLL AND G. L. VIOLANTE, “Monetary Policy According to HANK,” *American Economic Review* 108 (2018), 697–743.
- KRUEGER, D. AND F. PERRI, “Does Income Inequality Lead to Consumption Inequality? Evidence and Theory,” *Review of Economic Studies* 73 (2006), 163–193.
- LEDUC, S. AND Z. LIU, “Uncertainty Shocks Are Aggregate Demand Shocks,” *Journal of Monetary Economics* 82 (2016), 20–35.
- MCKAY, A. AND R. REIS, “The Role of Automatic Stabilizers in the U.S. Business Cycle,” *Econometrica* 84 (2016), 141–194.
- , “Optimal Automatic Stabilizers,” *Review of Economic Studies* 88 (2021), 2375–2406.
- MORTENSEN, D. T. AND C. A. PISSARIDES, “Job Creation and Job Destruction in the Theory of Unemployment,” *Review of Economic Studies* 61 (1994), 397–415.
- MUMTAZ, H. AND K. THEODORIDIS, “The International Transmission of Volatility Shocks: An Empirical Analysis,” *Journal of the European Economic Association* 13 (2015), 512–533.
- OH, J., “The Propagation of Uncertainty Shocks: Rotemberg versus Calvo,” *International Economic Review* 61 (2020), 1097–1113.
- PETRONGOLO, B. AND C. A. PISSARIDES, “Looking into the Black Box: A Survey of the Matching Function,” *Journal of Economic Literature* 39 (2001), 390–431.
- RAVN, M. O. AND V. STERK, “Job Uncertainty and Deep Recessions,” *Journal of Monetary Economics* 90 (2017), 125–141.
- , “Macroeconomic Fluctuations with HANK & SAM: an Analytical Approach,” *Journal of the European Economic Association* 19 (2021), 1162–1202.

ROTEMBERG, J. J., “Sticky Prices in the United States,” *Journal of Political Economy* 90 (1982), 1187–1211.

SHIMER, R., “Reassessing the Ins and Outs of Unemployment,” *Review of Economic Dynamics* 15 (2012), 127–148.

WU, J. C. AND F. D. XIA, “Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound,” *Journal of Money, Credit and Banking* 48 (2016), 253–291.

Appendices

A Data Description

We use data from various sources as described below.

A.1 Income and Consumption

We measure income and consumption at household-level using data from the Consumer Expenditure Surveys (CEX).

The CEX: The CEX consists of two surveys, the quarterly Interview Survey and the Diary Survey. They are collected by the Census Bureau for the Bureau of Labor Statistics. With the exception of the PSID over the period 2005-2019, the CEX is the only dataset that reports detailed information on household consumption expenditure for the U.S. The Diary Survey focuses on expenditure of small frequently purchased items, while the Interview Survey is more comprehensive and covers up to 95 percent of the typical household's consumption expenditure. Following [Coibion et al. \(2017\)](#) and [Heathcote et al. \(2023\)](#), we focus on the Interview Survey data. This is a rotating panel of households who are representative of the U.S. population. Each household is interviewed at most four consecutive quarters. Expenditure information is reported at quarterly frequency, while income information only in the first and last quarter.

Sample period: Our sample period spans 1994Q1-2019Q4. As noted in [Heathcote et al. \(2023\)](#), while the CEX has continuous data available since 1980Q1, the definitions for some consumption components are not consistent prior to 1994. For consistency, we start our analysis from 1994Q1.

Sample screening: [Heathcote et al. \(2023\)](#) compile samples at different level of aggregation. We use their Sample A, which is the most inclusive and should be the closest to NIPA aggregates. The applied selection criteria are as follows. Records are dropped if: a) there is no information on age for either the head or the spouse; b) either the head or the spouse has positive labor income, but zero annual hours; c) either the head or the spouse has an hourly wage less than half the corresponding Federal minimum wage that year; d) when consumption expenditure is implausible, i.e. quarterly equivalised food consumption is below \$100 in 2000 dollars.

Consumption: We rely on [Heathcote et al. \(2023\)](#) in defining consumption aggregates as follows. Nondurable consumption comprises food and beverages, tobacco, apparel and services, personal care, gasoline, public transportation, household operation, medical care, entertainment, reading material, and education. Durable consumption includes cars (expenses) and furniture/equipment.

The series are transformed into real per capita terms by dividing them by family size (the number of family members) and deflating them by CPI-U series. They are further seasonally adjusted using X-13-ARIMA.

Income: We define income as before-tax income, which is the sum of wages, salaries, business and farm income, financial income, and transfers.

A.2 Measure of Uncertainty

To measure uncertainty we use the macro uncertainty index of [Jurado et al. \(2015\)](#). The updated version of index is retrieved from the author's website, <https://www.sydneyludvigson.com/data-and-appendixes>. We use the quarterly average of their monthly series with $h = 3$ (i.e., 3-month-ahead uncertainty).

A.3 Aggregate Macroeconomic Series

Job finding rate and separation rate: We update the series of [Shimer \(2012\)](#). To be specific, we compute monthly transition rates using Current Population Survey data on unemployment and short-run unemployment. Using these series, we construct transition matrices across employment statuses for every month in the sample and then multiply those matrices over the three consecutive months of each quarter to obtain quarterly transition rates.

Policy rate: We use the quarterly average of the effective Federal funds rate. Since the sample includes a period during which the Federal funds rate hits the zero lower bound, from 2009Q1 to 2012Q3 we rely on the shadow Federal funds rate constructed by [Wu and Xia \(2016\)](#). This rate is not bounded below by zero and better summarizes the stance of monetary policy. The series is retrieved from the author's website, <https://sites.google.com/view/jingcynthiawu/shadow-rates>.

The remaining macro series: They are retrieved from the FRED of St. Louis Fed. The

downloaded series are the following (FRED series IDs are in parentheses): Gross Domestic Product (GDP), Gross Domestic Product: Implicit Price Deflator (GDPDEF), Civilian Unemployment Rate (UNRATE), Personal Consumption Expenditures: Nondurable Goods (PCND), Personal consumption expenditures: Nondurable Goods (Implicit Price Deflator) (DNDGRD3Q086SBEA), Personal Consumption Expenditures: Services (PCESV), Personal Consumption Expenditures: Services (Implicit Price Deflator) (DDURRD3Q086SBEA), Personal Consumption Expenditures: Durable Goods (PCEDG), Personal Consumption Expenditures: Durable Goods (Implicit Price Deflator) (DDURRD3Q086SBEA), Consumer Price Index for All Urban Consumers: All Items in U.S. City Average (CPIAUCSL), and Federal Funds Effective Rate (FEDFUNDS). Then, we obtain the quantity indices by deflating the expenditures. Per capita variables are divided by Population (B230RC0Q173SBEA).

B Robustness Checks for Empirical Analysis

The following Appendix conducts various robustness checks for our empirical analysis. Appendix [B.1](#) shows summary statistics and VAR results by income quintile, Appendix [B.2](#) controls for households' demographic characteristics, Appendix [B.3](#) exhibits responses of durable consumption, Appendix [B.4](#) compares CEX and NIPA, and Appendix [B.5](#) shows robustness for the VAR specification.

B.1 Empirical Results by Households Income Quintile

Table [B.1](#) reports descriptive statistics by income quintile of the households' distribution. Going from the bottom to the top quintile, there are increasingly more males, households are on average younger, bigger, more educated, and there is a higher share of white. They also earn, work, and consume more.

Figure [B.1](#) shows responses of consumption to a one-standard deviation uncertainty shock across different quintiles of the income distribution. Households in the first, second, and third quintile contract consumption significantly. The strongest contraction, which reaches -0.5% , is that of households in the bottom quintile, followed by that of households in the second and third quintile. In contrast, consumption response of households in the top two quintiles is not significant. Based on these responses across quintiles, our main analysis in Section [2](#) combines together consumption responses of households in the bottom 60% and the top 40% of the income distribution.

B.2 Controlling for Households' Demographic Characteristics

As households might differ along some dimensions over our sample span, we want to control for observable characteristics. Following [Blundell et al. \(2008\)](#) and [Arellano et al. \(2017\)](#), we construct our consumption series as residuals from regressing log real per capita consumption on a set of demographic characteristics, which include age, age squared, sex, race, education categories, and time fixed effects. We then use these residuals in our BVARs. Figure [B.2](#) shows impulse responses of consumption residuals for the bottom 60% and the top 40% of the income distribution, while Figure [B.3](#) displays responses across the five quintiles of the income distribution. These responses are very much in line with our baseline results, showing that our main analysis is robust to controlling for

households' observables.

B.3 Durable Consumption

In our main analysis we have focused on the responses of nondurable consumption. One might however conjecture that our baseline result – that the bottom 60% significantly contracts consumption in response to heightened macro uncertainty, while the top 40% does not – could change when considering durable consumption. As a matter of fact, higher-income households tend to have a wider share of consumption in durable goods than lower-income households – see Table B.1, which reports that the share of durable consumption in total consumption is roughly one seventh for the bottom quintile and increases to almost one third for the top quintile. In addition, consumption decisions about durables might differ from those about nondurables. To check this, Figure B.4 shows the response of durable consumption to a one-standard deviation positive shock in macro uncertainty. The contraction of durable consumption is now significant for households both in the bottom 60% and the top 40% of the income distribution. Moreover, the contraction is substantially bigger than that of nondurables – by a factor of four for the bottom 60%. While it is true that durable consumption is more volatile than nondurables, it is still the case that this sensitivity is higher for low-income households.

B.4 CEX versus NIPA

The primary source for the income and consumption data used in our empirical analysis is the CEX. While this is a very comprehensive survey, as is often the case with survey data there might be concerns related to its accuracy. As observed by [Heathcote et al. \(2023\)](#), there are two main challenges. First, the survey might not be fully representative and, in particular, it may under-represent households at the top of the income-distribution. Second, households who are included might under-report their income and consumption as pointed out by various studies (see, for example, [Krueger and Perri, 2006](#); [Blundell et al., 2008](#); [Aguiar and Bils, 2015](#); [Attanasio et al., 2015](#)). [Heathcote et al. \(2023\)](#) gauge the discrepancy between the NIPA series and the corresponding series aggregated from the CEX.

From their analysis two features emerge. First, when comparing per capita wages and salaries, the aggregated series computed from CEX are lower than the corresponding NIPA series. Second,

when looking at consumption expenditures, the CEX is lower than the NIPA for what concerns nondurable expenses, but is much closer to NIPA for durable expenses.

The relevant question for us is whether these features of the CEX are consequential for our empirical analysis. In particular, whether under-reporting of wages, salaries, and consumption would change our conclusion that households at the bottom of the income distribution contract consumption more in response to macro uncertainty than households at the top. Let's first think about the potential under-reporting of wages and salaries. What we are ultimately interested in when looking at income heterogeneity is the shape of the distribution, not necessarily the level. If under-reporting only shifts the distribution without changing its shape, this should not affect the classification of households into different quintiles. If, however, under-reporting is done only by some households and to a different extent, then the shape of the income distribution might vary, thus changing how households are binned into different quintiles. This is a caveat that one must be aware of when working with survey data from CEX.

Let's suppose now that we can trust the CEX for what concerns wages and salaries. Our results could still be biased by the lower reporting of consumption. Figure B.5 shows responses of nondurable and durable consumption aggregated from the CEX compared to those from NIPA. While as also noted by [Heathcote et al. \(2023\)](#), it is the case that the aggregated series from the CEX and the NIPA series are not the same, responses to an identified uncertainty shocks are qualitatively aligned.

B.5 Robustness Checks for the VAR Specification

To make sure that our results are robust to different Cholesky ordering and BVAR specifications, we conduct some robustness checks, which are shown in Figure B.6 and B.7. The first row of both figures displays responses of a BVAR where we put macro uncertainty as first in the recursive ordering of the variables. The second row reports responses of a BVAR with four lags.

Consistently with our baseline specification, Figure B.6 shows that the aggregate response of consumption is driven by the response of households in the bottom 60% of the income distribution. Moreover, as shown by B.7 following a positive uncertainty shock we get for both BVAR specifications: a drop in the finding rate, an increase in the separation rate and the unemployment rate, and a decrease in consumption and CPI.

Table B.1: Descriptive Statistics by Household's Income Quintile

	1 st Quintile	2 nd Quintile	3 rd Quintile	4 th Quintile	5 th Quintile
Male	0.36	0.45	0.52	0.57	0.62
Age	55.16	54.47	48.75	46.08	46.84
Family size	1.59	2.02	2.33	2.68	3.02
Less than high school	0.34	0.26	0.18	0.12	0.09
High school	0.27	0.31	0.27	0.22	0.12
Post-secondary	0.39	0.43	0.55	0.66	0.79
White	0.76	0.82	0.84	0.86	0.88
Black	0.19	0.13	0.11	0.08	0.05
Native American	0.01	0.01	0.01	0.01	0.00
Other	0.05	0.04	0.05	0.05	0.07
Income	28,921.96	75,361.88	133,490.03	222,059.94	482,312.84
Earnings	8,277.23	38,631.46	98,019.14	191,809.69	441,429.83
Hours worked per week	5.66	16.75	26.73	33.50	37.68
Nondurable consumption	7,586.73	10,153.38	12,996.10	16,875.47	26,052.77
Durable consumption	1,177.27	2,228.66	3,352.16	4,995.39	7,818.71

Note: Income, earnings, nondurable consumption, and durable consumption are in U.S. dollars, 2000 prices. They are annual averages by quintiles of household's pre-tax income.

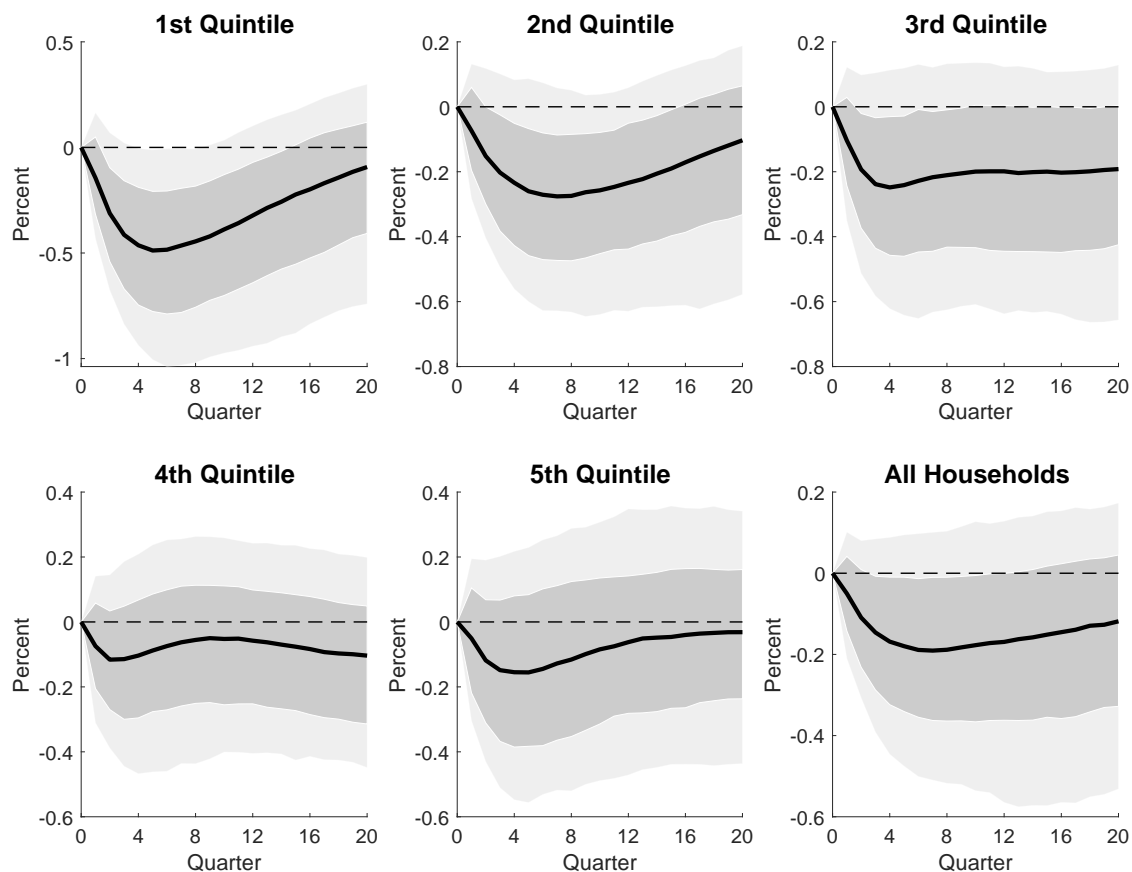


Figure B.1: Empirical Impulse Responses of Consumption across Income Quintile to One-Standard Deviation Macro Uncertainty Shocks

Note: “Bottom 60% Income” and “Top 40% Income” denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands.

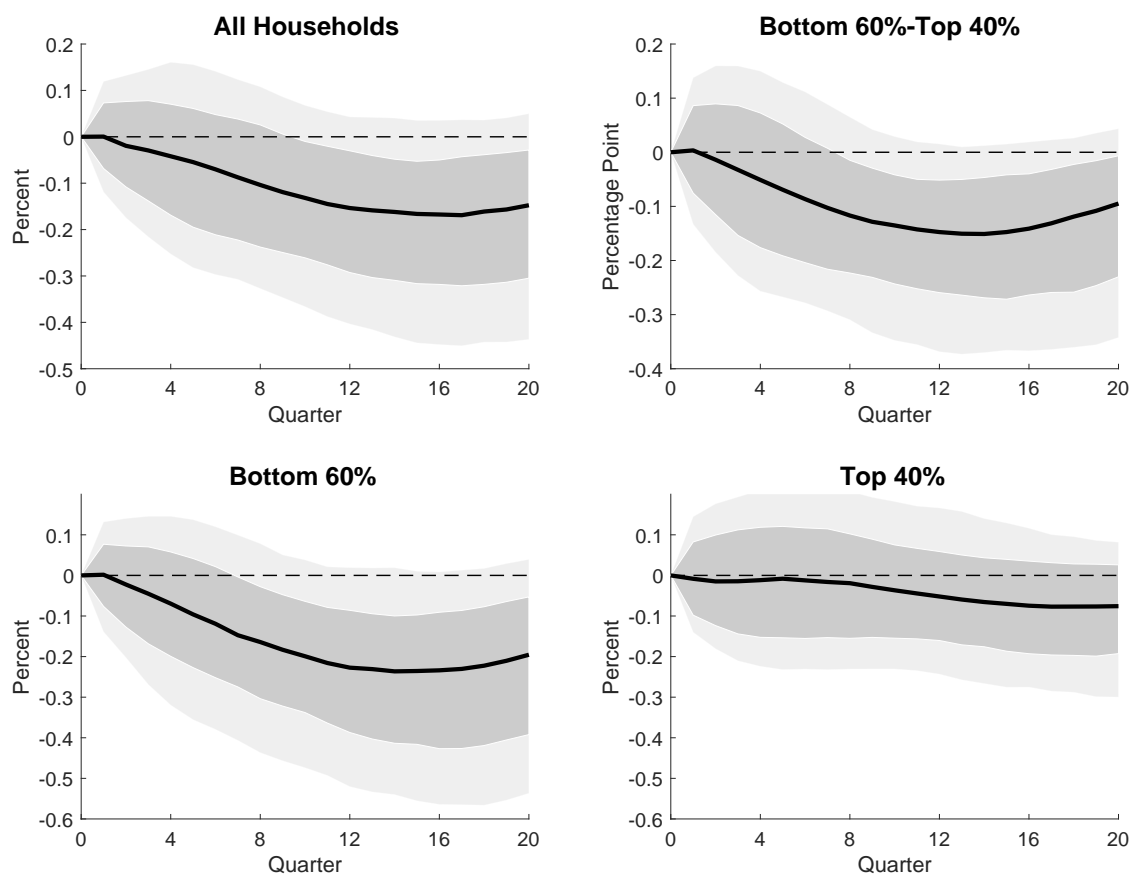


Figure B.2: Empirical Impulse Responses of Consumption Residuals across Income Distribution to One-Standard Deviation Macro Uncertainty Shocks

Note: “Bottom 60% Income” and “Top 40% Income” denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands. Consumption is computed as residuals from regressing log real per capita consumption on a set of demographic characteristics, which include age, age squared, sex, race, education categories, and time fixed effects.

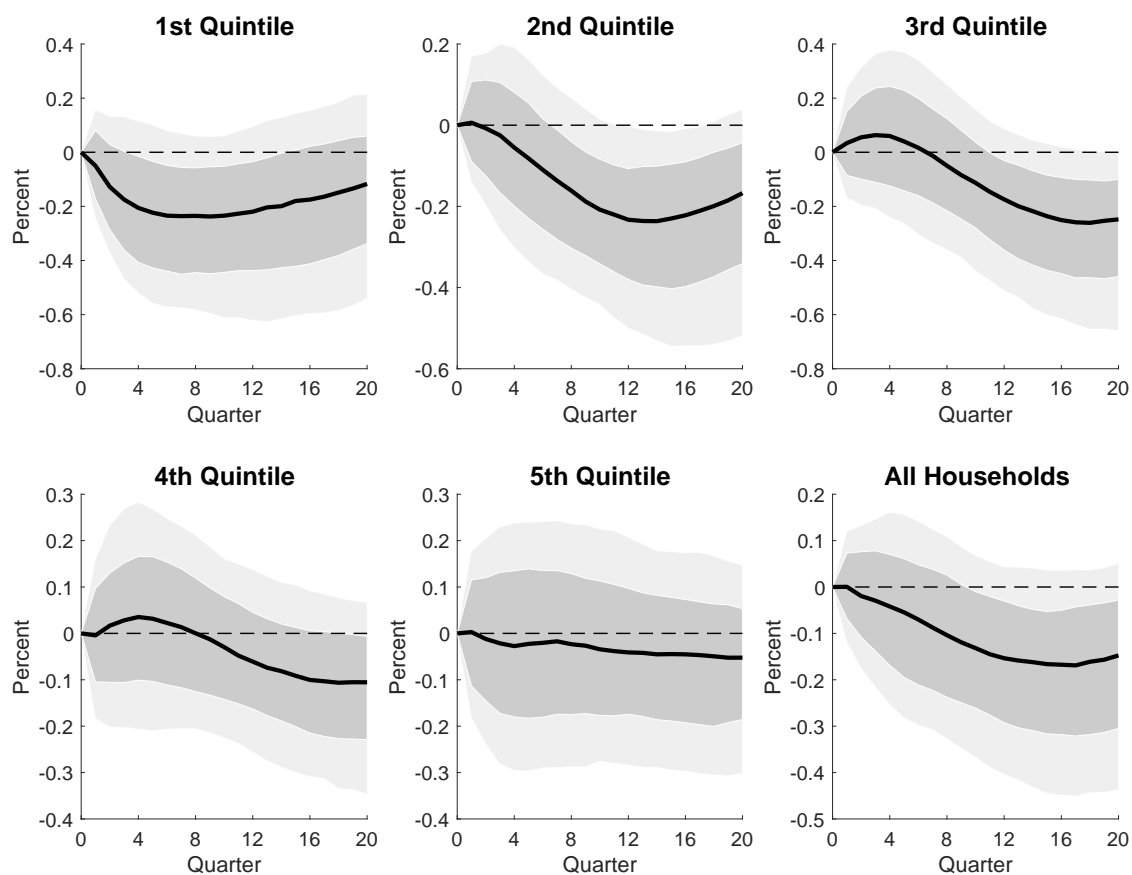


Figure B.3: Empirical Impulse Responses of Consumption Residuals across Income Quintile to One-Standard Deviation Macro Uncertainty Shocks

Note: “Bottom 60%” and “Top 40%” denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands. Consumption is computed as residuals from regressing log real per capita consumption on a set of demographic characteristics, which include age, age squared, sex, race, education categories, and time fixed effects.

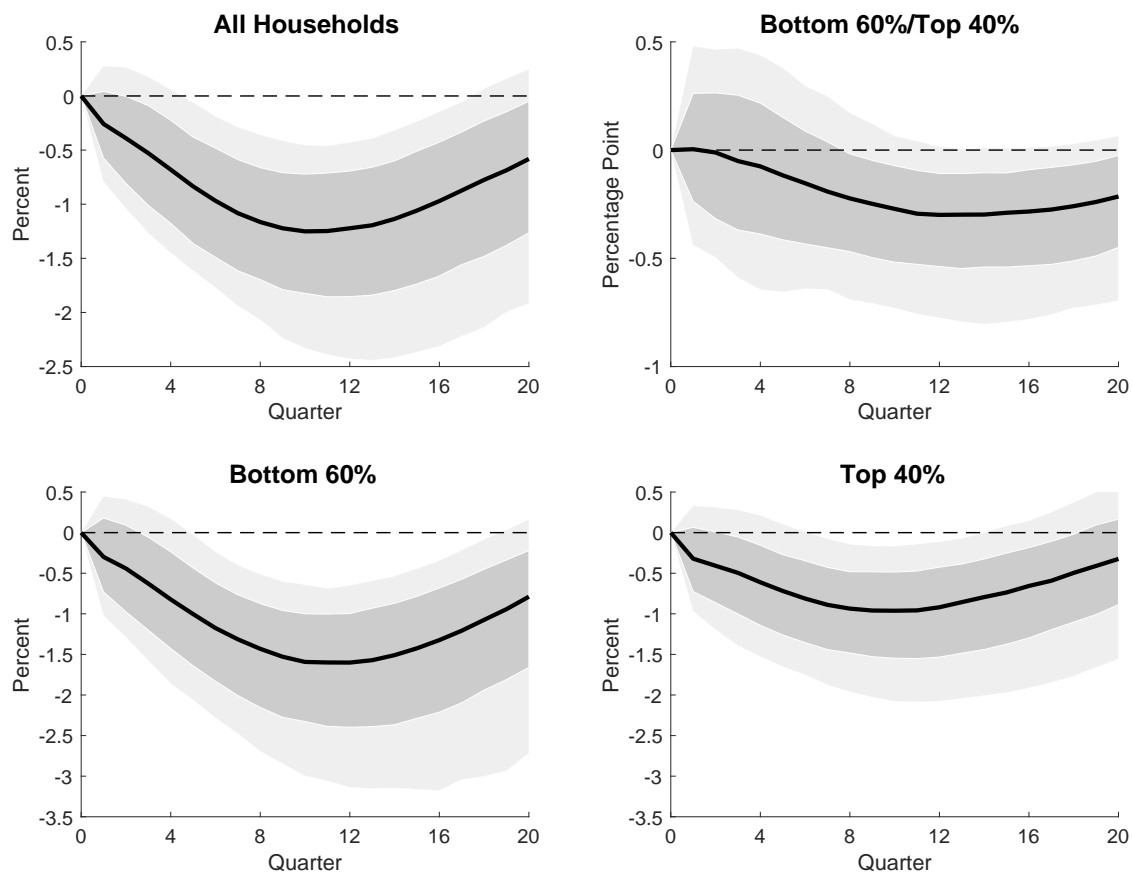


Figure B.4: Empirical Impulse Responses of Durable Consumption across Income Distribution to One-Standard Deviation Macro Uncertainty Shocks

Note: “Bottom 60% Income” and “Top 40% Income” denote the durable consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands.

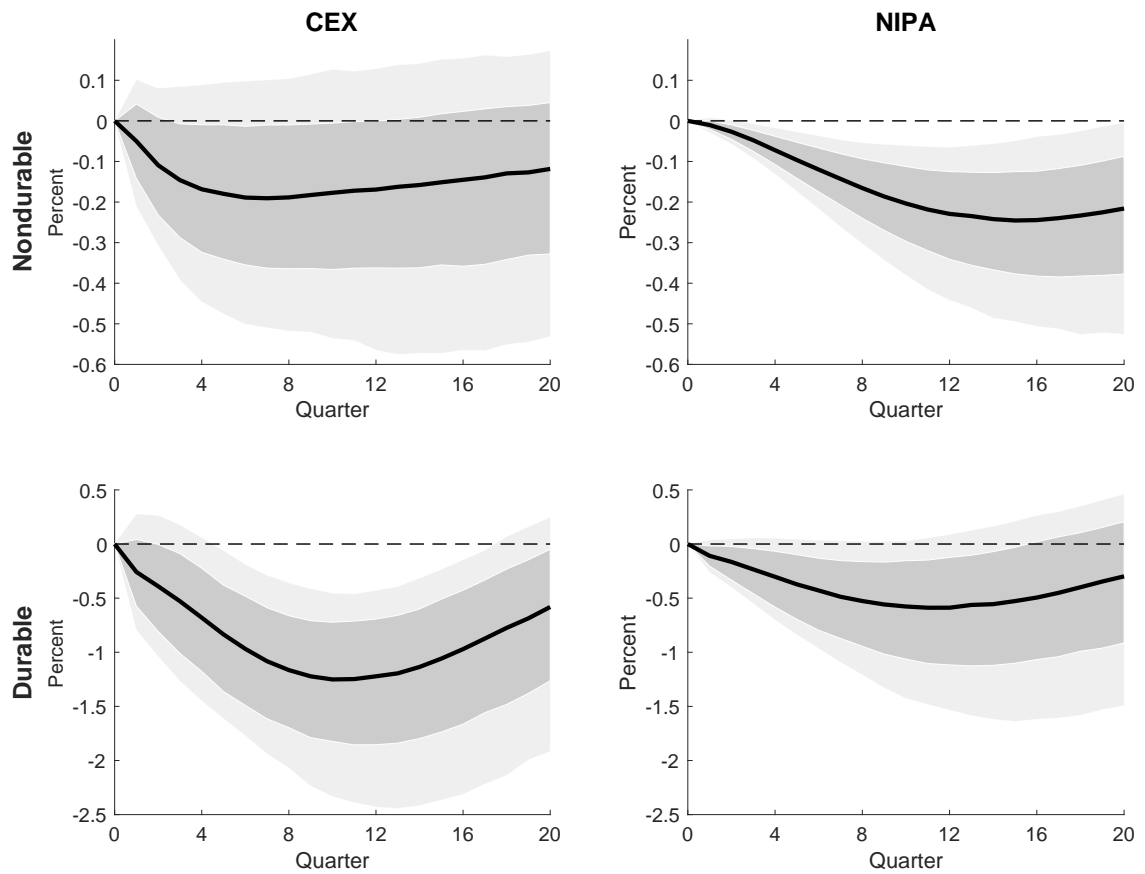


Figure B.5: Robustness Checks for Empirical Impulse Responses of Aggregate Nondurable and Durable Consumption from CEX and NIPA to One-Standard Deviation Macro Uncertainty Shocks

Note: Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands.

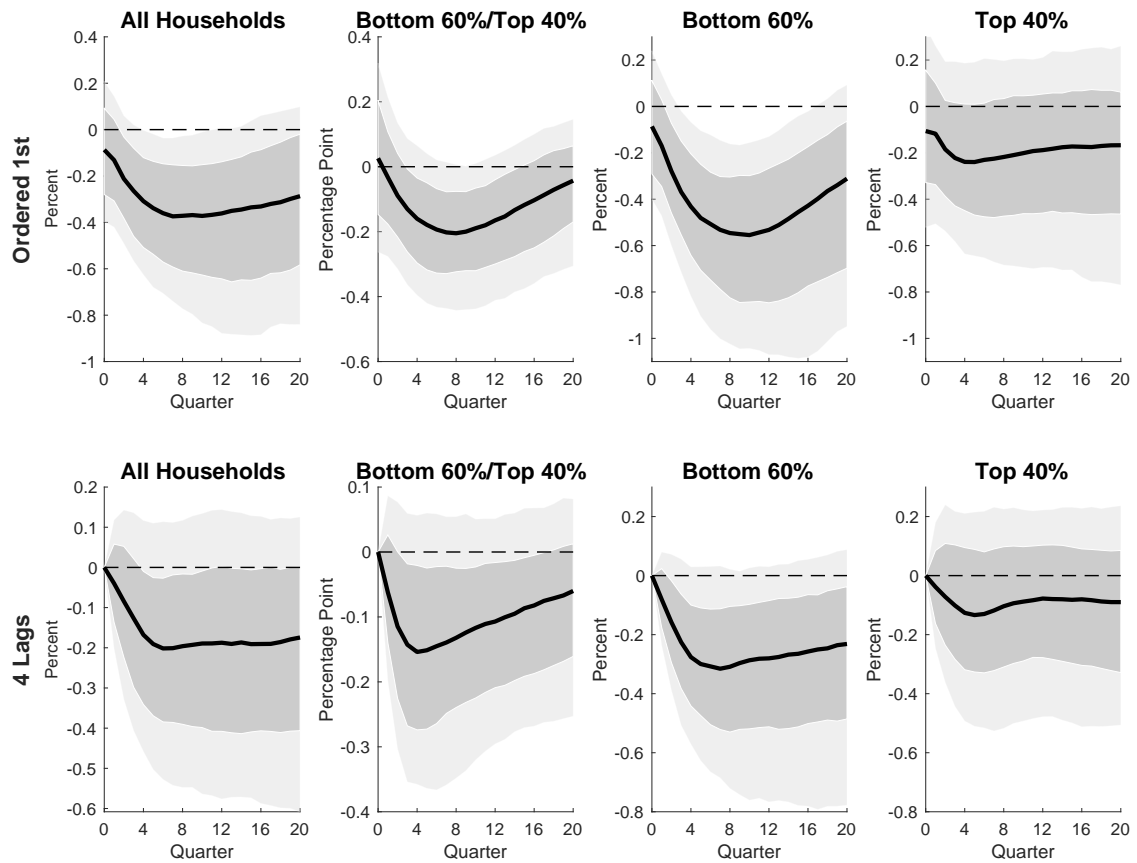


Figure B.6: Robustness Checks for Empirical Impulse Responses of Consumption across Income Distribution to One-Standard Deviation Macro Uncertainty Shocks

Note: “Bottom 60% Income” and “Top 40% Income” denote the consumption response of households respectively in the lowest 60% and the highest 40% of the income distribution. Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands.

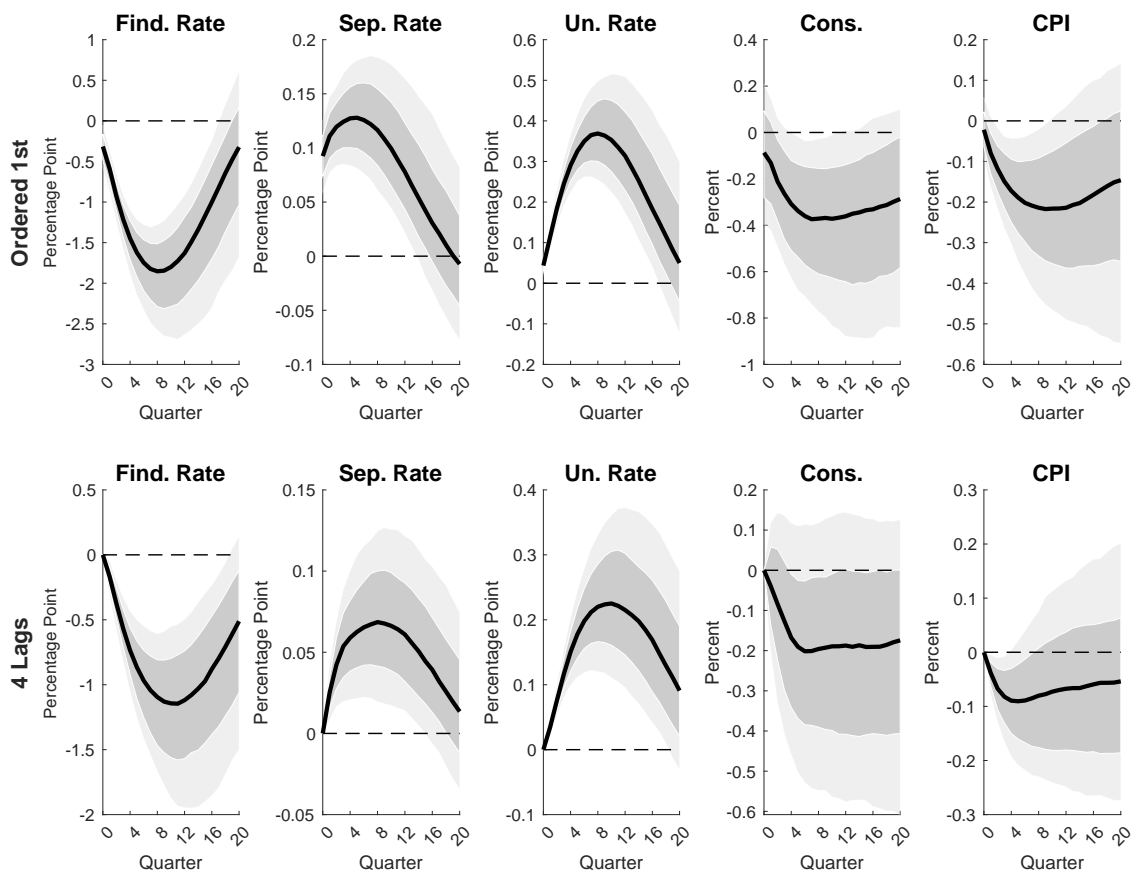


Figure B.7: Robustness Checks for Empirical Impulse Responses to One-Standard Deviation Macro Uncertainty Shocks

Note: Dark and light grey areas indicate respectively 68 and 90 percent bootstrap confidence bands.

C Robustness Checks for Theoretical Analysis

C.1 Summary of Equilibrium Conditions

We index all variables in the current period by t , and make use of the equilibrium and symmetry conditions in the main text to reduce the number of variables. The equilibrium is characterized by the following set of equations:

C.1.1 Workers

$$1 + r_t = \frac{1 + R_{t-1}}{1 + \pi_t}, \quad (\text{C.1})$$

$$M_{t-1,t}^P = \beta^P \frac{\lambda_t^P}{\lambda_{t-1}^P}, \quad (\text{C.2})$$

$$\lambda_t^P = (c_t^P - hc_{t-1}^P)^{-\sigma}, \quad (\text{C.3})$$

$$\mathbb{E}_t M_{t,t+1}^P (1 + r_{t+1}) = 1, \quad (\text{C.4})$$

$$M_{t-1,t}^e = \beta^I \frac{(1 - s_t) \lambda_t^e + s_t \lambda_t^{eu}}{\lambda_{t-1}^e}, \quad (\text{C.5})$$

$$\lambda_t^e = (c_t^e - hc_{t-1}^e)^{-\sigma}, \quad (\text{C.6})$$

$$\lambda_t^{eu} = (c_t^{eu} - hc_{t-1}^{eu})^{-\sigma}, \quad (\text{C.7})$$

$$\mathbb{E}_t M_{t,t+1}^e (1 + r_{t+1}) = 1, \quad (\text{C.8})$$

$$a_t + c_t^e = (1 - \tau_t) w_t + (1 + r_t) \frac{A_t}{n_t}, \quad (\text{C.9})$$

$$A_t = (1 - s_t) n_{t-1} a_{t-1} + f_t (1 - n_{t-1}) \underline{a}, \quad (\text{C.10})$$

$$c_t^{eu} = b^u + (1 + r_t) a_{t-1} - \underline{a}, \quad (\text{C.11})$$

$$n_t^{eu} = s_t n_{t-1}, \quad (\text{C.12})$$

$$c_t^{uu} = b^u + (1 + r_t) \underline{a} - \underline{a}, \quad (\text{C.13})$$

$$n_t^{uu} = 1 - n_t - n_t^{eu}, \quad (\text{C.14})$$

C.1.2 Firms

$$\eta \left(\frac{1 + \pi_t}{1 + \bar{\pi}} - 1 \right) \frac{1 + \pi_t}{1 + \bar{\pi}} = \eta \mathbb{E}_t M_{t,t+1}^P \left(\frac{1 + \pi_{t+1}}{1 + \bar{\pi}} - 1 \right) \frac{1 + \pi_{t+1}}{1 + \bar{\pi}} \frac{y_{t+1}}{y_t} + 1 - \varepsilon + \varepsilon p_{m,t}, \quad (\text{C.15})$$

$$Q_t = p_{m,t} \frac{y_{m,t}}{(\Omega + (1 - \Omega) \psi) n_t}, \quad (\text{C.16})$$

$$\frac{\kappa}{\lambda_t} = (\Omega + (1 - \Omega) \psi) (Q_t - w_t) + (1 - \rho) \mathbb{E}_t M_{t,t+1}^P \frac{\kappa}{\lambda_{t+1}}, \quad (\text{C.17})$$

$$n_t = (1 - \rho) n_{t-1} + \lambda_t v_t, \quad (\text{C.18})$$

$$m_t = \mu (1 - (1 - \rho) n_{t-1})^\chi v_t^{1-\chi}, \quad (\text{C.19})$$

$$f_t = \frac{m_t}{1 - (1 - \rho) n_{t-1}}, \quad (\text{C.20})$$

$$\lambda_t = \frac{m_t}{v_t}, \quad (\text{C.21})$$

$$s_t = \rho (1 - f_t), \quad (\text{C.22})$$

$$U_t = 1 - (1 - \rho) n_{t-1} - m_t, \quad (\text{C.23})$$

C.1.3 Wage

$$w_t = \bar{w} \left(\frac{n_t}{\bar{n}} \right)^{\phi_w}, \quad (\text{C.24})$$

C.1.4 Central Bank

$$\frac{1 + R_t}{1 + \bar{R}} = \left(\frac{1 + \pi_t}{1 + \bar{\pi}} \right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_y}, \quad (\text{C.25})$$

C.1.5 Aggregation and Market Clearing

$$y_{m,t} = z_t (\Omega + (1 - \Omega) \psi) n_t, \quad (\text{C.26})$$

$$y_t = y_{m,t} - \Phi, \quad (\text{C.27})$$

$$c_t = (1 - \Omega) c_t^P + \Omega (n_t c_t^e + n_t^{eu} c_t^{eu} + n_t^{uu} c_t^{uu}), \quad (\text{C.28})$$

$$y_t = c_t + \kappa v_t + \frac{\eta}{2} \left(\frac{1 + \pi_t}{1 + \bar{\pi}} - 1 \right)^2 y_t, \quad (\text{C.29})$$

$$(1 - \Omega) a_t^P + \Omega (A_t + (1 - n_t) \underline{a}) = 0, \quad (\text{C.30})$$

$$\tau_t w_t n_t = b^u (1 - n_t), \quad (\text{C.31})$$

C.1.6 Exogenous Processes

$$\log z_t = \rho_z \log z_{t-1} + \sigma_t^z \varepsilon_t^z, \quad (\text{C.32})$$

$$\log \sigma_t^z = (1 - \rho_{\sigma^z}) \log \bar{\sigma}^z + \rho_{\sigma^z} \log \sigma_{t-1}^z + \sigma^{\sigma^z} \varepsilon_t^{\sigma^z}. \quad (\text{C.33})$$

C.2 A TANK Version of the Model

To obtain a TANK version of the model, we replace Equations (C.8), (C.9), (C.11), and (C.13) with the following equilibrium conditions:

$$a_t = 0, \quad (\text{C.34})$$

$$c_t^e = w_t n_t, \quad (\text{C.35})$$

$$c_t^{eu} = w_t n_t, \quad (\text{C.36})$$

$$c_t^{wu} = w_t n_t. \quad (\text{C.37})$$

C.3 Different Source of Macro Uncertainty

In line with the vast majority of the literature on uncertainty propagation, we have so far focused on TFP uncertainty. Yet, the macro uncertainty index by [Jurado et al. \(2015\)](#) that we use in our empirical analysis captures a broader concept of uncertainty affecting the macro economy. Thus, in this section we extend our analysis to study how the economy reacts to an increase in uncertainty on the demand side. In particular, we modify Equation (41) by assuming that there is a monetary policy shock z^R , subject to time varying volatility σ^R as follows:

$$\frac{1 + R}{1 + \bar{R}} = \left(\frac{1 + \pi}{1 + \bar{\pi}} \right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}} \right)^{\phi_y} z^R, \quad (\text{C.38})$$

$$\log z^R = \rho_R \log z_{-1}^R + \sigma^R \varepsilon^R, \quad (\text{C.39})$$

$$\log \sigma^R = (1 - \rho_{\sigma^R}) \log \bar{\sigma}^R + \rho_{\sigma^R} \log \sigma_{-1}^R + \sigma^{\sigma^R} \varepsilon^{\sigma^R}. \quad (\text{C.40})$$

We parametrize the persistence and the volatility of the monetary policy shock to $\rho_R = 0.9$ and $\bar{\sigma}^R = 0.0025$, while we set the persistence and volatility of the monetary policy uncertainty shock to $\rho_{\sigma^R} = 0.96$ and $\sigma^{\sigma^R} = 0.103$, consistently with the persistence and volatility of the TFP uncertainty shock. Figure C.8 shows the responses to the monetary policy uncertainty shock. When there are only perfectly insured households (red dashed line), responses are quite small. However, as in the case of TFP uncertainty shocks, the presence of imperfectly insured households generates amplified responses thanks to the stronger precautionary behavior (blue solid line). Figure C.9 shows the consumption responses for the perfectly (dotted line) and imperfectly (dashed line) insured households. Being risk averse, both types of households contract consumption on impact. However, the imperfectly insured households have a stronger precautionary behavior that leads them to contract consumption more. As asset markets have to clear, their higher saving maps into a higher borrowing from the perfectly insured, who are now able to overturn their drop in consumption as it was the case in response to heightened TFP uncertainty.

C.4 Additional Sensitivity Analyses

This section illustrates sensitivity exercises on various parameters, which affect the strength of the precautionary saving motive for imperfectly and perfectly insured households.

The first row of Figure C.10 shows how consumption responds when we vary households' risk aversion σ . A higher risk aversion generates a stronger precautionary response of imperfectly insured households, who cannot fully insure against risk. The more risk-averse imperfectly insured households are, the bigger the shift of their response out of consumption towards savings. The mirror image of this is the consumption response of the perfectly insured households. While on impact a higher risk aversion pushes them to contract consumption more, after few periods this precautionary effect is counterbalanced by an opposite force. As asset markets have to clear, an increase in imperfectly insured households' savings has to be matched by higher perfectly insured households' borrowing. The rise in borrowing is strong enough to push perfectly insured households to increase their consumption and counteract the initial consumption contraction due to precautionary motives.

The second row of Figure C.10 shows sensitivity of the consumption response to various consumption differences between employed and unemployed households. Indeed, the bigger the con-

sumption differential between the two employment states is, the stronger the precautionary saving motive that leads employed imperfectly insured households to save more, thus triggering a sharper drop in consumption.

The third sensitivity exercise that we carry out is on imperfectly insured households' consumption share ($C60/C$). This share is important as it negatively affects the skill premium ψ of perfectly insured households over imperfectly insured ones (as shown in Table 2, we calibrate the skill premium by targeting the share of imperfectly insured households' consumption). The bigger the imperfectly insured households' consumption share, the more the precautionary saving behavior of imperfectly insured households affects aggregate consumption, thus amplifying the drop in consumption caused by an uncertainty shock.

The next sensitivity exercise is on the elasticity of substitution ε between two intermediate goods. As shown in Oh (2020), a higher elasticity makes the marginal profit curve of intermediate firms more convex and generates an amplified consumption response.

In our baseline model, we have assumed that there is no wage rigidity. Nevertheless, some degree of wage inertia may affect the consumption response of the households. We therefore check what happens when we modify Equation (40) to introduce some wage rigidity:

$$w = \mathbf{w}_{-1}^{\gamma_w} \left(\bar{w} \left(\frac{\mathbf{n}}{\bar{n}} \right)^{\phi_w} \right)^{1-\gamma_w}, \quad (\text{C.41})$$

where γ_w indicates the indexation to previous period wage. The first row of Figure C.11 shows the sensitivity of the consumption response to different levels of wage rigidity. The more rigid wages are, the less the consumption of both imperfectly and perfectly insured households contracts.

The next sensitivity exercises concern the parameters of the Taylor rule. In the baseline model we have assumed no persistence in the interest rate. We now check what happens when there is some persistence. We therefore modify Equation (41) as follows:

$$\frac{1+R}{1+\bar{R}} = \left(\frac{1+\mathbf{R}_{-1}}{1+\bar{R}} \right)^{\rho_R} \left(\left(\frac{1+\pi}{1+\bar{\pi}} \right)^{\phi_\pi} \left(\frac{y}{\mathbf{y}_{-1}} \right)^{\phi_y} \right)^{1-\rho_R}, \quad (\text{C.42})$$

where ρ_R is the parameter controlling the degree of persistence. The second row of Figure C.11 shows consumption responses when we vary the persistence ρ_R of the interest rate in the Taylor

rule. A higher interest rate persistence leads to a sharper drop in consumption for the imperfectly insured.

The third and fourth rows of Figure C.11 show the consumption responses to an uncertainty shock for different levels of monetary policy responsiveness. In particular, the more responsive monetary policy is to inflation (the higher ϕ_π), the smoother the real interest rate. A smoother real interest rate path reduces the inter-temporal substitution of imperfectly insured households, thus dampening the drop in consumption induced by an uncertainty shock. To the contrary, a stronger response to output deviations generates a sharper contraction in the consumption of the imperfectly insured households.

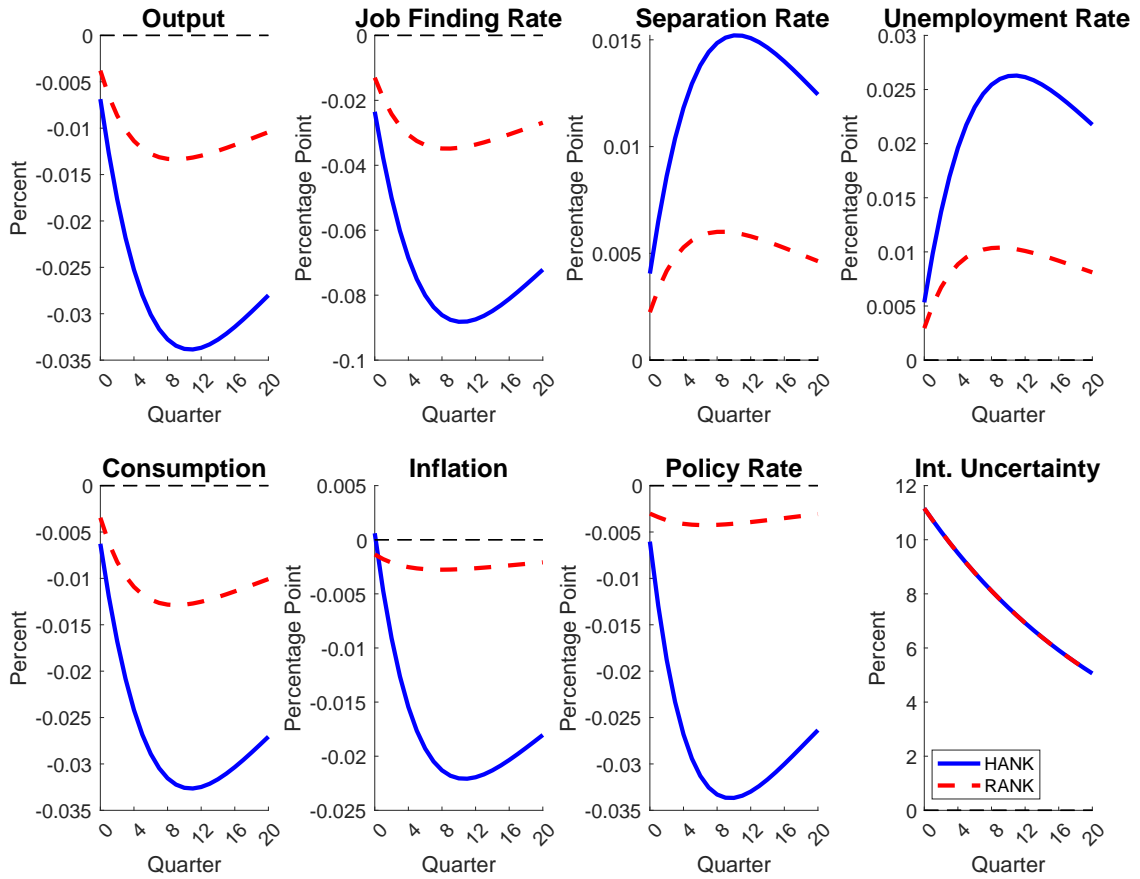


Figure C.8: Impulse Responses to One-Standard Deviation Interest Rate Uncertainty

Note: Impulse responses of output, consumption, and uncertainty are in percent deviation from their stochastic steady state, impulse responses of unemployment rate, job finding rate, and job separation rate are in percentage point deviations from their stochastic steady state, while inflation and policy rate are in annualized percentage point deviations from their stochastic steady state.

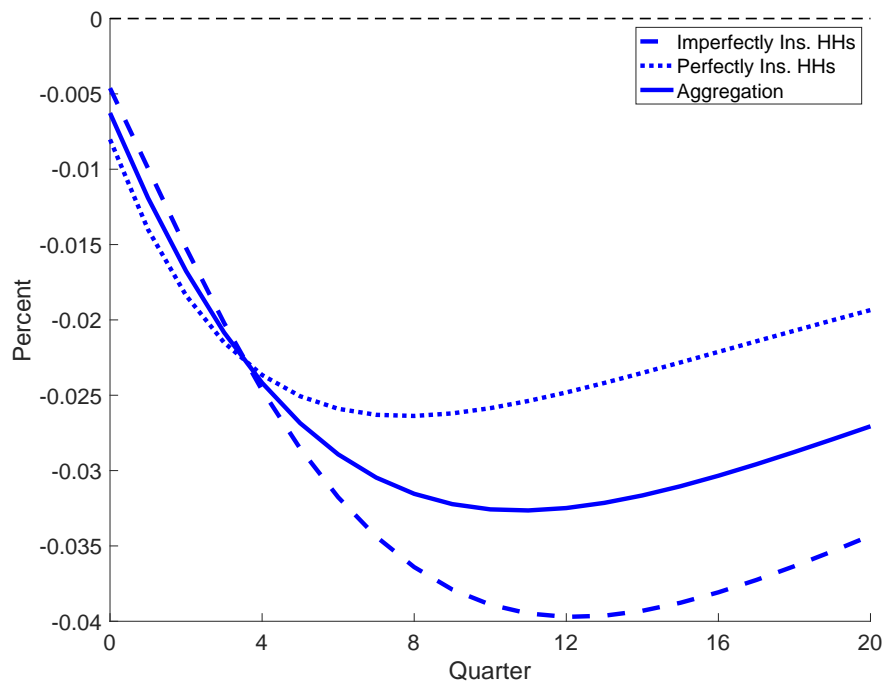


Figure C.9: Consumption Heterogeneity in Response to Interest Rate Uncertainty

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state.

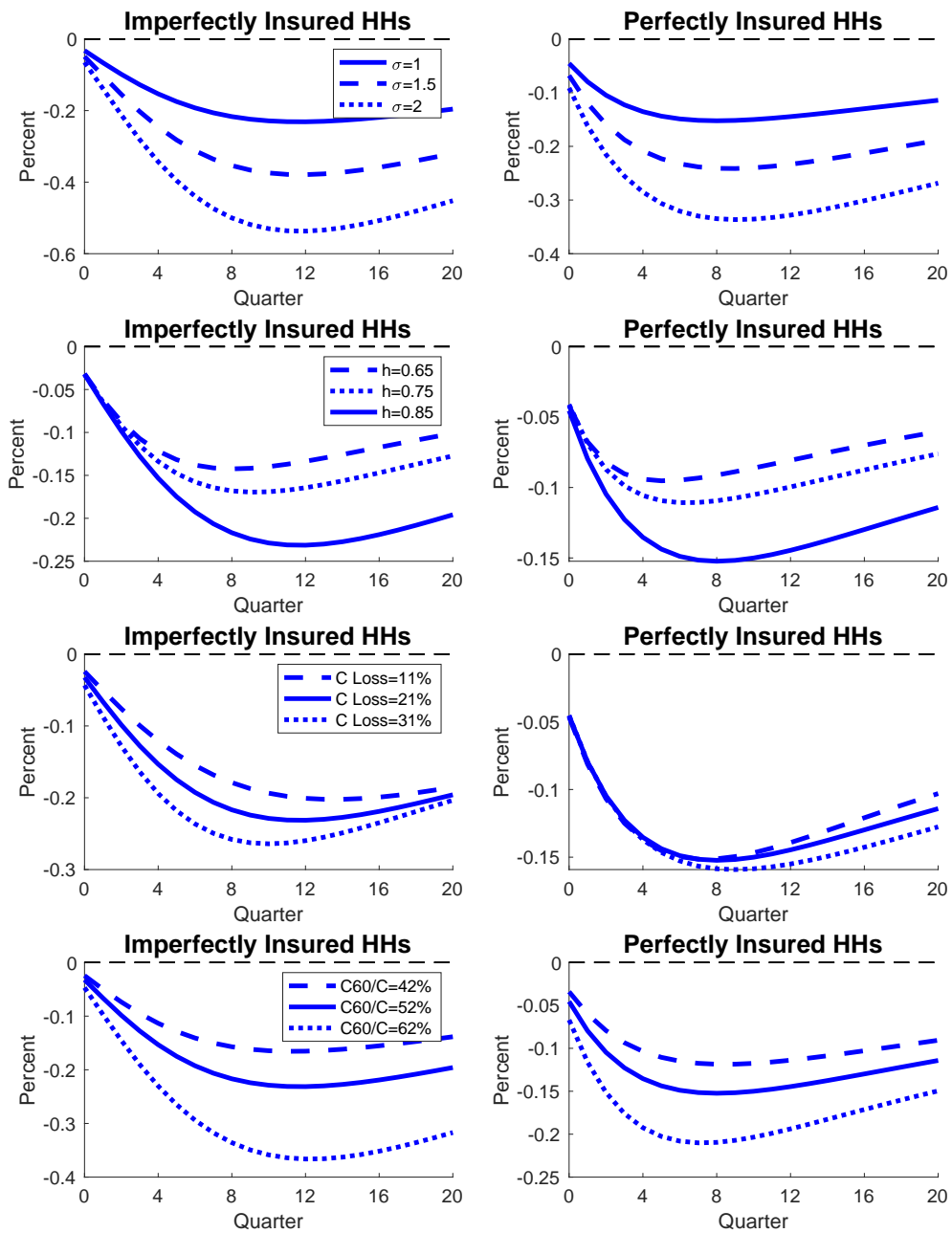


Figure C.10: Sensitivity Analyses 1

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state.

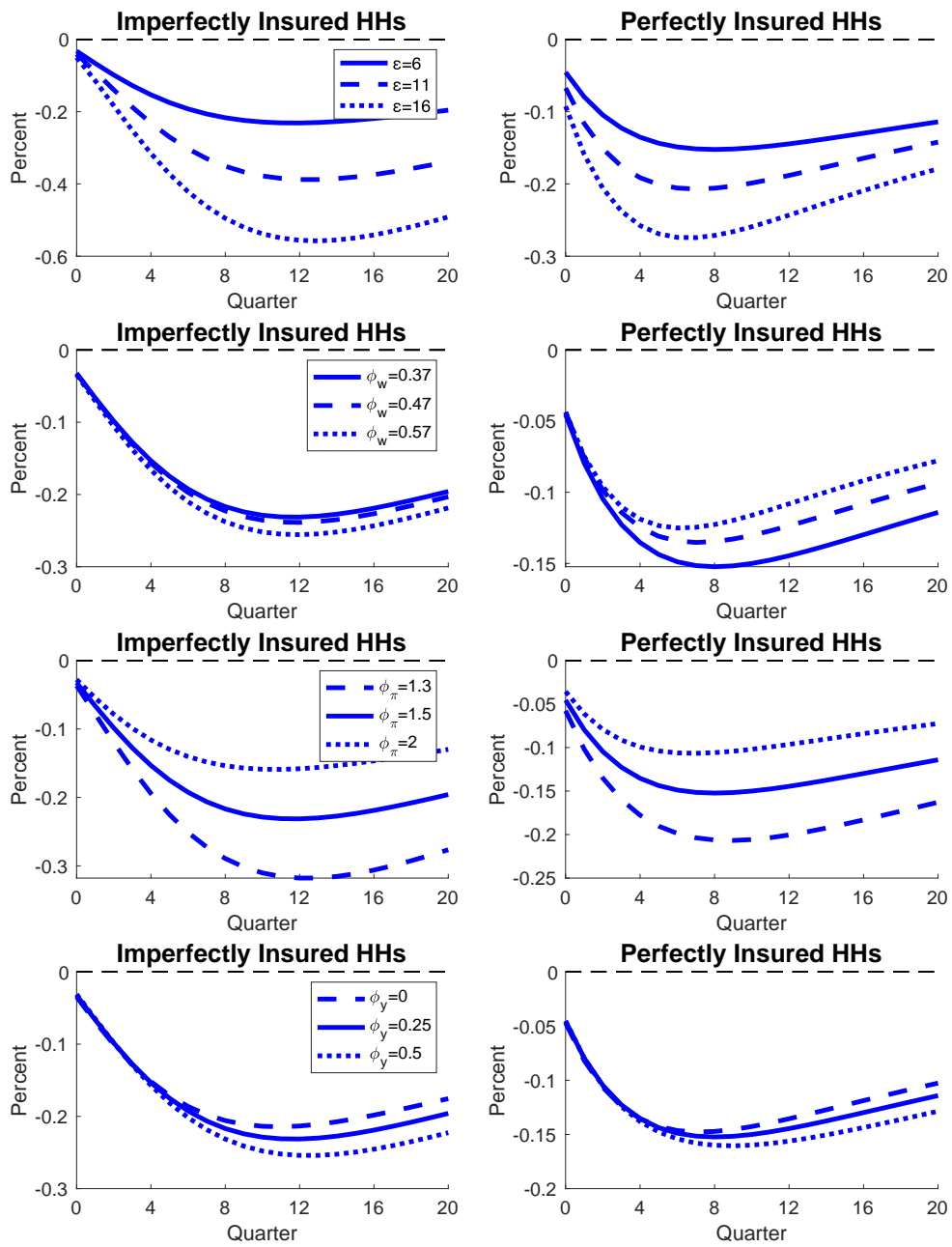


Figure C.11: Sensitivity Analyses 2

Note: Impulse responses of consumption are in percent deviation from their stochastic steady state.

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