

# Perceived Income Risks

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## Abstract

Workhorse incomplete-market macro models typically assume that agents have a perfect understanding of the size and nature of income risks that econometricians estimate from past income data. This paper examines if risk perceptions from a representative density survey align with these assumptions. I found that people have reasonable clues about income risks, in that the differences in risk perceptions can be partly explained by between-group differences in income volatility. Perceived earning risks are always lower than the standard estimates based on realized income volatility, suggesting the role of superior information. At the same time, there remains a large degree of heterogeneity. There is robust evidence for state dependence and past dependence. Risk perceptions countercyclically react to recent realizations and negatively correlated with the experiences of macro labor market outcomes. People also extrapolate their own recent experiences of earning volatility and unemployment when forming risk perceptions. These features in risk perceptions have three macroeconomic consequences. First, lower perceived risks on average helps account for the concentration of low liquid wealth holding among the population. Second, the heterogeneity in risk perceptions leads to additional heterogeneity in saving behavior and marginal propensity to consume (MPC). Third, state-dependent income risk perceptions induce additional precautionary saving motives, and depending on its cyclical, could further amplify or dampen the business cycle fluctuations of aggregate consumption. My ongoing work explores the quantitative importance of these predictions in a general-equilibrium incomplete market model.

**Keywords:** Income risks, Incomplete market, Perception, Precautionary saving

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# 1 Introduction

Income risks matter for both individual behaviors and aggregate outcomes. With identical expected income and homogeneous risk preferences, different degrees of risks lead to different saving/consumption and portfolio choices. This is well understood in models in which either the prudence in the utility function (Kimball (1990), Carroll and Kimball (2001)) or occasionally binding constraint induces precautionary savings or self-insurance. It is widely accepted based on various empirical research that idiosyncratic income risks are at most partially insured (Blundell et al. (2008)), such market incompleteness leads to ex-post wealth inequality<sup>1</sup> and different degrees of marginal propensity to consume (MPC) (Krueger et al. (2016); Carroll et al. (2017)). This also changes the mechanisms via which macroeconomic policies take into effect<sup>2</sup>. Furthermore, the aggregate movements in the degree of idiosyncratic labor risks drive time-varying precautionary saving motives, as another source of business cycle fluctuations<sup>3</sup>.

The size and the nature of the income risks are one of the central inputs in this class of incomplete-market macroeconomic models. One important assumption prevailing in these models thus far is that agents have a perfect understanding of the income risks, as the economists assume. Economists typically approximate income risks under a specified income process based on microdata and then treat the estimates as the true model parameters known by the agents making decisions in the model.<sup>4</sup> But given the mounting evidence that people form expectations in ways deviating from full-information rational expectation (FIRE)<sup>5</sup> leading to perennial expectational heterogeneity across agents, this assumption seems to be too stringent. On the flip side of the same

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<sup>1</sup>Aiyagari (1994); Huggett (1996); Carroll and Samwick (1997); Krusell and Smith (1998).

<sup>2</sup>Krueger et al. (2016), Kaplan et al. (2018), Auclert (2019).

<sup>3</sup>Challe and Ragot (2016); McKay (2017); Kaplan and Violante (2018); Den Haan et al. (2018); Bayer et al. (2019); Acharya and Dogra (2020); Ravn and Sterk (2021).

<sup>4</sup>Some recent examples include Krueger et al. (2016), Bayer et al. (2019), Kaplan et al. (2018).

<sup>5</sup>For instance, Mankiw et al. (2003), Reis (2006), Coibion and Gorodnichenko (2012), Wang (2021).

coin, economists who attempt to approximate the real size and nature of income shocks as perceived by the agents may also run into problems such as omitted variable and model mis-specification. Both possibilities may result in differences between perceived risks and the standard model assumptions.

This paper attempts to address these issues by utilizing the recently available density forecasts of labor income surveyed by New York Fed’s Survey of Consumer Expectation (SCE). I first characterize the differences between perceived risks reported in the survey and the standard income risk estimates used to parameterize macroeconomic models. My key finding is that perceived earning risks are lower than standard estimates and model parameters, possibly due to either “superior information” of the agents compared to economists, or under-perceiving of risks of the agents due to behavioral reasons. This is robust to various income processes used in the literature. Second, I explore a variety of drivers of heterogeneity in risk perceptions, including demographics, recent labor market conditions, and individual and macro experience, as detailed below. Third, I extend a standard incomplete market macro model a la [Huggett \(1993\)](#) with a subjective risk profile reflecting my empirical findings, allowing the risk perceptions to be different from the underlying income process. I show how such an extension admitting subjective heterogeneity in risk perceptions helps explain a number of the well-documented macroeconomic phenomenon: the concentration of households with little liquid wealth, a large fraction of agents with high  $MPC$ , and more wealth inequality.

The most important novelty of this paper compared to previous work studying partial insurance with expectational surveys <sup>6</sup> is that I particularly use the density survey which contains directly perceived risks. What is special about the density survey is that agents are asked to provide histogram-type forecasts of their earning growth over the next 12 months, together with a set of expectational questions about the macroeconomy. When the individual density forecast is available, a parametric density estimation can be made to obtain the individual-specific subjective distribution.

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<sup>6</sup>For instance, [Pistaferri \(2001\)](#), [Kaufmann and Pistaferri \(2009\)](#).

And higher moments reflecting the perceived income risks such as variance allow me to directly characterize the perceived risk profile without relying on external estimates from cross-sectional microdata. This provides the first-hand measured perceptions on income risks that are truly relevant to individual decisions.

I established the following novel facts about the perceived income risks.

- People do have reasonable clues about the income risks they are facing, in the sense that heterogeneity in risk perceptions across different groups are consistent with the between-group differences in income volatility revealed from past data. For instance, younger, low-income, being female, low-education with more volatile income growth also perceive higher risks.
- But huge heterogeneity remains. People with the same observable characteristics still show wide dispersion in risk perceptions.
- State-dependence. Perceived income risks counter-cyclically react to nationwide/regional labor market conditions.
- Extrapolation. People who have experienced earning volatility and unemployment have higher risk perceptions.
- Past-dependence. Higher experienced volatility and experience of negative labor market conditions is associated with higher perceived income risks.
- Decision. Perceived income risks translate into economic decisions in a way consistent with precautionary saving motives. In particular, households with higher income risk perceptions expect a higher growth in expenditure, i.e. lower consumption today versus tomorrow.

These empirical patterns in perceived income risks have clear implications for both the level of optimal savings and cross-sectional wealth inequality via its effects on precautionary saving motives.

As to the level, lower perceived risks than standard estimates imply lower precautionary savings, while the state-dependence and extrapolation both induce additional precautionary savings, as shown by [Caballero \(1990\)](#). Therefore, the quantitative implications of the survey-implied risk perceptions on the level of savings depend on the counterbalance of the two forces. The effect on wealth inequality is less ambiguous. First, allowing for heterogeneity in risk perceptions induce straightforward increase in wealth inequality simply because different risks induce different optimal savings. At the same time, there is a less direct effect via lower perceived risks. Lower perceived risks *ex ante* induce lower self-insurance motives, hence more *ex-post* wealth inequality.

I incorporate a mechanism of subjective risk perceptions into a standard incomplete market, overlapping-generation, and general equilibrium model to quantify these effects. The objective/benchmark model blends [Huggett \(1996\)](#), the income structure of [Carroll and Samwick \(1997\)](#), and persistent unemployment spells and unemployment benefits, a la [Krueger et al. \(2016\)](#) and [Carroll et al. \(2017\)](#). The subjective model features a single deviation by introducing an idiosyncratic subjective state that swings between low and high-risk perceptions, the process of which is estimated by the survey data. This assumption easily accommodates heterogeneity, state-dependence, and extrapolation of risk perceptions. In comparison with the objective model, the subjective model adds a state variable to individuals' consumption problems, and its dynamics also drive the distributional evolution of the economy in wealth. I characterize the economy with a stationary equilibrium. I also explore an extension of the subjective model by assuming the risk perception state depends on employment status of the individuals.

With the standard calibration of the model as in the literature, I *expect* to show that incorporating survey-implied risk perceptions separately helps generate sizable additional wealth inequality needed to match the data. It will also shed light on if the subjective income risk profiles on average result in a higher or lower level of aggregate savings in equilibrium. As a methodological

contribution, my exercises highlight the importance of introducing belief heterogeneity informed by expectational surveys into incomplete market macroeconomic models.

## Related literature

First, this paper closely builds on the literature estimating both cross-sectional and time trends of labor income risks and partial insurance. Early work estimating income risks includes [Gottschalk et al. \(1994\)](#); [Carroll and Samwick \(1997\)](#). Later, the literature explores time-varying patterns of the income risks. For instance, [Meghir and Pistaferri \(2004\)](#) allows for time-varying risks or conditional heteroscedasticity in the traditional permanent-transitory model. [Blundell et al. \(2008\)](#) uses the same specification to income to estimate partial insurance in conjunction with consumption data. More recently, [Bloom et al. \(2018\)](#) found the risks have declined in recent decades. Moreover, recent evidence relied upon detailed social security records and larger data samples highlight the asymmetry and cyclical behaviors of idiosyncratic earning/income risks ([Storesletten et al., 2004](#); [Guvenen et al., 2014](#); [Arellano et al., 2017](#); [Guvenen et al., 2019](#)). Besides, a separate literature focus on job-separation and unemployment risks([Low et al., 2010](#); [Davis and Von Wachter, 2011](#)). The novelty of this paper lies in the focus on the subjective perceptions of labor risks and how it is correlated with the realized income risks estimated from the income panel.

Second, it is related to an old but recently reviving interest in studying consumption/saving behaviors in models incorporating imperfect expectations and perceptions. For instance, the closest to the current paper, [Pischke \(1995\)](#) explores the implications of the incomplete information about aggregate/individual income innovations by modeling agent's learning about income component as a signal extraction problem. [Wang \(2004\)](#) extends the framework to incorporate precautionary saving motives. In a similar spirit, [Carroll et al. \(2018\)](#) reconciles the low micro-MPC and high macro-MPCs by introducing to the model an information rigidity of households in learning about

macro news while being updated about micro news. [Rozsypal and Schlafmann \(2017\)](#) found that households’ expectation of income exhibits an over-persistent bias using both expected and realized household income from Michigan household survey. The paper also shows that incorporating such bias affects the aggregate consumption function by distorting the cross-sectional distributions of marginal propensity to consume(MPCs) across the population. [Lian \(2019\)](#) shows that an imperfect perception of wealth accounts for such phenomenon as excess sensitivity to current income and higher MPCs out of wealth than current income and so forth. My paper has a similar flavor to all of these works in that I also explore the behavioral implications of households’ perceptual imperfection. But it has important two distinctions. First, this paper focuses on higher moments such as income risks. Second, most of these existing work either considers inattention of shocks or bias introduced by the model parameter, none of these explores the possible misperception of the nature of income shocks. <sup>7</sup>

Third, empirically, this paper also contributes to the literature studying expectation formation using subjective surveys. There has been a long list of “irrational expectation” theories developed in recent decades on how agents deviate from full-information rationality benchmark, such as sticky expectation, noisy signal extraction, least-square learning, etc. Also, empirical work has been devoted to testing these theories in a comparable manner ([Coibion and Gorodnichenko \(2012\)](#), [Fuhrer \(2018\)](#)). But it is fair to say that thus far, relatively little work has been done on individual variables such as labor income, which may well be more relevant to individual economic decisions. Therefore, understanding expectation formation of the individual variables, in particular, concerning both mean and higher moments, will provide fruitful insights for macroeconomic modeling assumptions.

Fourth, the paper is indirectly related to the research that advocated for eliciting probabilistic

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<sup>7</sup>For instance, [Pischke \(1995\)](#) assumes that agents know perfectly about the variance of permanent and transitory income so that they could filter the two components from observable income changes. This paper instead assumes that the agents do not observe the two perfectly.

questions measuring subjective uncertainty in economic surveys ([Manski \(2004\)](#), [Delavande et al. \(2011\)](#), [Manski \(2018\)](#)). Although the initial suspicion concerning to people’s ability in understanding, using and answering probabilistic questions is understandable, [Bertrand and Mullainathan \(2001\)](#) and other works have shown respondents have the consistent ability and willingness to assign a probability (or “percent chance”) to future events. [Armantier et al. \(2017\)](#) have a thorough discussion on designing, experimenting and implementing the consumer expectation surveys to ensure the quality of the responses. Broadly speaking, the advocates have argued that going beyond the revealed preference approach, availability to survey data provides economists with direct information on agents’ expectations and helps avoids imposing arbitrary assumptions. This insight holds for not only point forecast but also and even more importantly, for uncertainty, because for any economic decision made by a risk-averse agent, not only the expectation but also the perceived risks matter a great deal.

Lastly, the idea of this paper echoes with an old problem in the consumption insurance literature: ‘insurance or information’ ([Pistaferri \(2001\)](#), [Kaufmann and Pistaferri \(2009\)](#), [Meghir and Pistaferri \(2011\)](#)). In any empirical tests of consumption insurance or consumption response to income, there is always a worry that what is interpreted as the shock has actually already entered the agents’ information set or exactly the opposite. For instance, the notion of excessive sensitivity, namely households consumption highly responsive to anticipated income shock, maybe simply because agents have not incorporated the recently realized shocks that econometricians assume so ([Flavin \(1988\)](#)). Also, recently, in the New York Fed [blog](#), the authors followed a similar approach to decompose the permanent and transitory shocks. My paper shares a similar spirit with these studies in the sense that I try to tackle the identification problem in the same approach: directly using the expectation data and explicitly controlling what are truly conditional expectations of the agents making the decision. This helps economists avoid making assumptions on what is exactly in the



agents' information set. What differentiates my work from other authors is that I focus on higher moments, i.e. income risks and skewness by utilizing the recently available density forecasts of labor income. Previous work only focuses on the sizes of the realized shocks and estimates the variance of the shocks using cross-sectional distribution, while my paper directly studies the individual specific variance of these shocks perceived by different individuals.

## 2 Theoretical framework

### 2.1 Income process and risk perceptions

Conditional on employment at the same job and position and same hours of work, the log idiosyncratic earning of individual  $i$  from group  $c$  at time  $t$ ,  $y_{i,c,t}$  consists of a predictable component  $z_{i,c,t}$  and a stochastic component  $e_{i,c,t}$ . (Equation 1) In general, the group  $c$  is defined such that within-group workers share the same income process, therefore, same income risks. For instance, it could be defined based on age, gender, education or the years of entering job markets.

There is an extensive discussion in the literature about the exact time-series nature of the stochastic component  $e$ . For instance, it may consist of a permanent part and a transitory component.<sup>8</sup> Or some literature replaces the permanent component with a persistent component in the form of AR process.<sup>9</sup> The transitory component could be moderately serially correlated with a moving-average (MA).<sup>10</sup> I first proceed with the generic structure like in Equation 1 without differentiating these various specifications. I defer this discussion to Section 4.2.

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<sup>8</sup>Gottschalk et al. (1994), and Carroll and Samwick (1997).

<sup>9</sup>Storesletten et al. (2004) and Guvenen (2009).

<sup>10</sup>Meghir and Pistaferri (2004).

$$y_{i,c,t} = z_{i,c,t} + e_{i,c,t} \quad (1)$$

Hence, earning growth from  $t$  to  $t + 1$  consists of predictable changes from  $z_{i,c,t+1}$ , and those from realized income shocks.

$$\Delta y_{i,c,t+1} = \Delta z_{i,c,t+1} + \Delta e_{i,c,t} \quad (2)$$

Under the assumption of full-information rational expectation (FIRE), all shocks that have realized till  $t$  are observed by the agent at time  $t$ . Therefore, the expected volatility under FIRE (with a superscript  $*$ ), or what this paper will refer to as perceived risks (PR), is the expected variance of income growth from  $t$  to  $t + 1$ .

$$Var_t^*(\Delta y_{i,c,t+1}) = Var_t^*(\Delta e_{i,c,t+1}) = \sigma_{c,t+1|t}^2 \quad (3)$$

The predictable changes do not enter PR. Hence, the expected volatility in earning growth is the *conditional* expected variance of the change in the stochastic component. Notice here that  $Var_t^*(\Delta e_{i,c,t+1})$  crucially depends on its time-series nature.

The size of the risks, including the component-specific ones under a specified structure of  $e_{i,c,t}$ , are not directly observed by economists. Econometricians usually try to approximate it, relying upon a panel data of earnings. To be more specific, in these estimations, what is used as the proxy of the stochastic component  $e$  and latter further decomposed into various components, is the regression residual of individual earnings on all the observable characteristics of the individual in a

first-step regression. Denote it by  $\hat{e}_{i,c,t}$ .<sup>11</sup>

Different from the PR by the agent, the cross-sectional variance of the change in residuals,  $\Delta\hat{e}_{i,c,t}$ , usually referred to as the “income volatility” in the literature,<sup>12</sup> is an *unconditional* variance.

$$Var(\Delta\hat{e}_{i,c,t}) = \hat{\sigma}_{c,t}^2 + \hat{\sigma}_{c,t+1}^2 - 2Cov^c(\hat{e}_{i,c,t}, \hat{e}_{i,c,t+1}) \quad (4)$$

The distinction between the *conditional* PR by the agent and the *unconditional* volatility approximated by the economists is crucial. There are two important issues around the comparability of the two objects.

First, it is very likely that what is controlled for in the first-step income regression, namely  $\hat{z}_{i,c,t}$ , does not perfectly coincide with what is *predictable* from the point of view of the agent at time  $t$ . The reasons could be either due to the “superior information” problem<sup>13</sup> or incomplete information, model misspecification and behavioral bias of the agents. The former issue refers to the possibility that agents may have other information regarding their earning growth that is not available to econometricians. For instance, a worker may already anticipate a recent dispute with her boss may negatively affect her earning next year, but econometricians have no way of knowing this. At the same time, econometricians may have a better idea about the real generating process of earning than the individual agents and are less subject to psychological biases. The possible existence of both issues discussed here makes it challenging to attribute the differences between PR and estimated income volatility I report in the next section to a single course.

Second, the comparison is sensitive to the time-series nature of  $e_{i,c,t}$ . This is, again, because economists’ estimated volatility is unconditional, while the perception is conditional on the information till time  $t$ . To illustrate this point, imagine there is a very persistent component in the

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<sup>11</sup> $\hat{e}_{i,c,t} = y_{i,c,t} - \hat{z}_{i,c,t}$  ( $\hat{z}_{i,c,t}$  is the observable counterpart of  $z_{i,c,t}$  from data).

<sup>12</sup>For instance, Gottschalk et al. (1994), Moffitt and Gottschalk (2002), Sabelhaus and Song (2010), Dynan et al. (2012), Bloom et al. (2018).

<sup>13</sup>Pistaferri (2001); Kaufmann and Pistaferri (2009).

income shock, then under the aforementioned process, the estimated income volatility also includes the variance of the realized shock till  $t$ , which enters the information set of the agents already. Therefore, even if the econometricians perfectly recover the  $e_{i,c,t}$  in the first step regression, any differences in the perceived time-series nature of the  $e_{i,c,t}$  by agents and econometricians would lead to differences between PR and income volatility. I return to this discussion in Section 4.2.

A summary of the relationship between PR and income volatility. On one hand, across different groups, there is a positive correlation between income volatility and PR by the agents, namely, a group  $c$  with higher income volatility should be also with higher PR. But on the other hand, the relative size of the two is, in principle, ambiguous. PR could be smaller than the income volatility due to either superior information or under-perceiving of risks by agents. But PR also could be higher than the income volatility under imperfect understanding and incomplete information, or over-perceiving of risks. I test these predictions in the next section.

### 3 Data, variables and density estimation

#### 3.1 Data

The data used for this paper is from the core module of Survey of Consumer Expectation(SCE) conducted by the New York Fed, a monthly online survey for a rotating panel of around 1,300 household heads over the period from June 2013 to January 2020, over a total of 80 months. This makes about 95113 household-year observations, among which around 68361 observations provide non-empty answers to the density question on earning growth.

Particularly relevant for my purpose, the questionnaire asks each respondent to fill perceived probabilities of their same-job-hour earning growth to pre-defined non-overlapping bins. The question is framed as “suppose that 12 months from now, you are working in the exact same [“main”

if Q11>1] job at the same place you currently work and working the exact same number of hours. In your view, what would you say is the percentage chance that 12 months from now: increased by x% or more?”.

As a special feature of the online questionnaire, the survey only moves on to the next question if the probabilities filled in all bins add up to one. This ensures the basic probabilistic consistency of the answers crucial for any further analysis. Besides, the earning growth expectation is formed for exactly the same position, same hours, and the same location. This has two important implications for my analysis. First, these conditions help make sure the comparability of the answers across time and also excludes the potential changes in earnings driven by endogenous labor supply decisions, i.e. working for longer hours. Empirical work estimating income risks are often based on data from received income in which voluntary labor supply changes are inevitably included. Our subjective measure is not subject to this problem and this is a great advantage. Second, the earning expectations and risks measured here are only conditional on non-separation from the current job. It excludes either unemployment, i.e. likely a zero earning, or an upward movement in the job ladder, i.e. a different earning growth rate. Therefore, this only reflects a lower bound for the income risks facing the individuals. I will separately compare unemployment/separation expectations in [Section 4.5](#).

Unemployment and other involuntary job separations are undoubtedly important sources of income risks, but I choose to focus on the same-job/hour earning with the recognition that individuals' income expectations, if any, may be easier to be formed for the current job/hour than when taking into account unemployment risks. Given the focus of this paper being subjective perceptions, this serves as a useful benchmark. What is more assuring is that the bias due to omission of unemployment risk is unambiguous. We could interpret the moments of same-job-hour earning growth as an upper bound for the level of growth rate and a lower bound for the income risk. To

put it in another way, the expected earning growth conditional on current employment is higher than the unconditional one, and the conditional earning risk is lower than the unconditional one. At the same time, since SCE separately elicits the perceived probability of losing the current job for each respondent, I could adjust the measured labor income moments taking into account the unemployment risk.

## 3.2 Density estimation and variables

With the histogram answers for each individual in hand, I follow [Engelberg et al. \(2009\)](#) to fit each of them with a parametric distribution accordingly for three following cases. In the first case when there are three or more intervals filled with positive probabilities, it was fitted with a generalized beta distribution. In particular, if there is no open-ended bin on the left or right, then two-parameter beta distribution is sufficient. If there is open-ended bin with positive probability on either left or right, since the lower bound or upper bound of the support needs to be determined, a four-parameter beta distribution is estimated. In the second case, in which there are exactly two adjacent intervals with positive probabilities, it is fitted with an isosceles triangular distribution. In the third case, if there is only one positive-probability of interval only, i.e. equal to one, it is fitted with a uniform distribution.

Since subjective moments such as variance is calculated based on the estimated distribution, it is important to make sure the estimation assumptions of the density distribution do not mechanically distort my cross-sectional patterns of the estimated moments. This is the most obviously seen in the tail risk measure, skewness. The assumption of log normality of income process, common in the literature (See again [Blundell et al. \(2008\)](#)), implicitly assume zero skewness, i.e. that the income increase and decrease from its mean are equally likely. This may not be the case in our surveyed density for many individuals. In order to account for this possibility, the assumed den-

sity distribution should be flexible enough to allow for different shapes of subjective distribution. Beta distribution fits this purpose well. Of course, in the case of uniform and isosceles triangular distribution, the skewness is zero by default.

Since the microdata provided in the SCE website already includes the estimated mean, variance and IQR by the staff economists following the exact same approach, I directly use their estimates for these moments. At the same time, for the measure of tail-risk, i.e. skewness, as not provided, I use my own estimates. I also confirm that my estimates and theirs for the first two moments are correlated with a coefficient of 0.9.

For all the moment's estimates, there are inevitably extreme values. This could be due to the idiosyncratic answers provided by the original respondent, or some non-convergence of the numerical estimation program. Therefore, for each moment of the analysis, I exclude top and bottom 3% observations, leading to a sample size of around 53,180.

I also recognize what is really relevant to many economic decisions such as consumption is real income instead of nominal income. I use the inflation expectation and inflation uncertainty (also estimated from density question) to convert nominal earning growth moments to real terms. In particular, the real earning growth rate is expected nominal growth minus inflation expectation of the same individuals.

$$E_{i,t}(\Delta y_{i,t}) = E_{i,t}(\Delta y_{i,t+1}^n) - E_{i,t}(\pi_{t+1}) \quad (5)$$

The variance associated with real earning growth, if we treat inflation and nominal earning growth as two independent stochastic variables, is equal to the summed variance of the two. The independence assumption is admittedly an imperfect assumption because of the correlation of wage

growth and inflation at the macro level. So it should be interpreted with caution.

$$Var_{i,t}(\Delta y_{i,t+1}) = Var_{i,t}(\Delta y_{i,t+1}^n) + Var_{i,t}(\pi_{t+1}) \quad (6)$$

As there are extreme values on inflation expectations and uncertainty, I also exclude top and bottom 2% of the observations.

### 3.3 Labor income data

I use longitudinal data on individual labor earnings from the 2014-2017 and 2018 panels of the Survey of Income and Program Participation (SIPP)<sup>14</sup>. Each panel of the SIPP is designed to be a nationally representative sample of the U.S. population and surveys thousands of workers. The interviews are conducted once a year to collect the individual’s monthly earnings and labor force activity<sup>15</sup>. On average, each individual is surveyed for 33 months over the multiple waves of the survey.

For the purpose of this paper, there are obvious advantages with using SIPP over another commonly used dataset for income risk estimation, the most notable of which is the Panel Study of Income Dynamics (PSID). SIPP surveys monthly labor outcomes of workers such as earnings, hours of work, and other detailed records of job transitions, while PSID only provides biennial records of labor income for years since 1997. For the overlapping periods between SIPP and SCE, it is possible to make a direct comparison between realized income risks at the annual frequency and the ex-ante perceptions of the earners. This is particularly crucial if income risks are time-varying

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<sup>14</sup>Other recent work that estimates income risks using SIPP includes [Bayer et al. \(2019\)](#). Different from this paper, they use quarterly total household income, instead of the monthly job-specific earning of individuals.

<sup>15</sup>This causes the “seam” issue well documented in the survey literature([Moore, 2008](#))., which states that cross-wave transitions are systematically larger in magnitudes than within-wave changes. Therefore, I exclude the December-to-January earning growth in estimations to address this issue.



and dependent upon macroeconomic conditions. Besides, given the surveyed risk perception is conditional on the same job position and hours, income risks explicitly controlling for hours of work and conditional on the same job would make the two more comparable.

Given the earning risks expectations regard the single job for the equal hours of work, I divide the monthly earning from the primary job by the average hours of work for the same job and use it to estimate income risks. I restrict the sample used for estimating income risks by following criteria. (1) only working-age population between 22-59. (2) only private-sector jobs, excluding government and workers from the public sectors. (3) no days away from work during the reference month without the pay. (4) the same job from the last year. (5) monthly earnings that are greater than 1.9 times or smaller than 0.1 times of the average monthly earning are excluded. This leaves me with an average monthly panel of 1200-2000 individual earners for the sample period 2013m3-2019m12.

## 4 Perceived income risks: basic facts

### 4.1 Cross-sectional heterogeneity

This section inspects some basic cross-sectional patterns of the subject moments of labor income. In Figure 1, I plot the distribution of unexplained residuals of perceived income risks both in nominal and real terms after controlling for observable individual characteristics including age, age polynomial, gender, education, type of work, and time fixed effect, respectively.

There remains a sizable dispersion in perceived income risks. In both nominal and real terms, the distribution is right-skewed with a long tail. Specifically, most of the workers have perceived a variance of nominal earning growth ranging from zero to 20 (a standard-deviation equivalence of 4 – 4.5% income growth a year). But in the tail, some of the workers perceive risks to be as high as 7 – 8% standard deviation a year. To have a better sense of how large the risk is, consider a

median individual in our sample, who has an expected earnings growth of 2.4%, and a perceived risk of 1% standard deviation. This implies by no means negligible earning risk.<sup>16</sup>

[FIGURE 1 HERE]

How are perceived income risks different along important dimensions of observable individual characteristics? Empirical estimates of income risks of different demographic groups from microdata have been rare but not non-existent<sup>17</sup>. It is worth asking if subjective risk perceptions exhibit similar between-group differences. This helps evaluate to what extent heterogeneity in risk perceptions partly reflects the actual differences in income risks.

Figure 2 plots both perceived and realized income volatility over the life-cycle. In order to control for the differences in risks between gender and education, I calculate the average within gender and education groups. It is clear that the subjective risk perceptions decline over the life cycle, consistent with the estimated risk from realizations of income. It is important to notice, however, in principle, the reasons for which subjective risk perceptions decline as one age may not be exactly the same as the one for the same pattern of the actual profile. For instance, as one accumulates experience over time, it may also reduce the subjective uncertainty about the income dynamics of themselves.

[FIGURE 2 HERE]

Another important question is how income risk perceptions correlate with the realized labor income. This is unclear in theory because it could depend on both the true income process and

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<sup>16</sup>In the appendix, I also include histograms of expected income growth and subjective skewness, which show intuitive patterns such as nominal rigidity. Besides, about half of the sample exhibits non-zero skewness in their subjective distribution, indicating asymmetric upper/lower tail risks.

<sup>17</sup>For instance, Meghir and Pistaferri (2004) estimated that the high-education group is faced with higher income risks than the low-education group. This is further confirmed by my estimation using SIPP. In addition, Sabelhaus and Song (2010); Bloom et al. (2018) documented that income risks decrease with age, and vary with current income level in a non-monotonic U-shape.

the perception formation. For a subsample of around 4000 observations, SCE surveys the annual earning of the respondent along with their risk perceptions. I group individuals into 10 groups based on their reported earning (within the same time) and plot the average risk perceptions against the decile rank in Figure 3. Perceived risks decline as one's earnings increase. This is not exactly consistent with the uptick in income risks for the highest income group, as documented by Bloom et al. (2018) using tax records of income. The most likely explanation is that the small sample I used from SCE does not cover actual top earners. The average annual earning of the top income group is between \$45,000 and \$120,000 in our sample.

[FIGURE 3 HERE]

## 4.2 Decomposed risks of different persistence

One crucial aspect of income risks relevant to both economists' estimation and household decisions is its time-series nature. As to the former, perceived income risks by the agents at a particular point of time, say  $t$ , are conditional on the information that is available by  $t$ . A realized permanent/persistent shock carries information regarding future income growth path, while an entirely transitory shock does not. Therefore, in the two scenarios, agents perceive different degree of income risks. For the latter, permanent income risks affect consumption/savings more substantially than the transitory risks via induced precautionary saving motives, according to the Permanent-Income Hypothesis (PIH).

Therefore, in this section, I decompose observed income volatility from income realizations into two components with different degrees of persistence, as described in Equation ???. One component is  $p$  following a random-walk subject to shock  $\psi$  and the other one  $\theta$  is a purely transitory shock. The estimated perceived income risks under full-information rational expectation (FIRE) would be

exactly the summation of the variance of the two components  $\sigma_\psi^2 + \sigma_\theta^2$ .

Using the *GMM* approach in the literature,<sup>18</sup> I identified the time-varying variances of the permanent and transitory component of the monthly earning growth, i.e.  $\sigma_{\psi,t}^2$  and  $\sigma_{\theta,t}^2$ , using the *SIPP* data for the same period. Then I convert these monthly risks parameters into annual frequency to be compared to perceived risks about annual earning risks.<sup>19</sup>

Figure 4 plots the recovered permanent/transitory risks and the implied expected volatility about annual earning growth against the perceived income risks reported in the *SCE*, respectively. Under correct model-specification and FIRE of the agents, one may expect the perceived risks and expected volatility to be, if not equal, at least close to each other. But the results suggest there is a negligible correlation between the two series.

More importantly, the magnitudes of the perceived risks are significantly lower than the expected income volatility implied by the income risks estimations. For instance, the latter based on the full sample should be 10% in standard deviation a year, while the average earning risk perception in *SCE* is only 2%. The same pattern holds even if we separately estimate income risks for different gender, education and age. (See Table A.1.)

[FIGURE 4 HERE]

What are the reasons behind this substantial differences in magnitudes between risk perceptions and implied expected income volatility based on income data? There are various possible candidates, which may not be mutually exclusive.

The first reason is “superior information”, as recognized in the literature on consumption insurance. When economists estimate income risks, the best we can do is to try to control as many

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<sup>18</sup>See Carroll and Samwick (1997), Meghir and Pistaferri (2004), and Blundell et al. (2008). Essentially, this approach relies upon variance and auto-covariance of growth of income residuals.

<sup>19</sup>For permanent risks, the annual earning risk is the summation of monthly permanent risks over the next 12 months. The transitory risks of annual earnings, in contrast, is the sample average of monthly risks over the next 12 months.

as possible observable factors of individuals that may be anticipated by the agents to approach its true information set at time  $t$ . But it is almost surely so that what we treated as unanticipated income shock still contains information available to the agents at time  $t$ .

The second reason, however, is that agents are possibly overconfident, i.e. under-perceive income risks for psychological reasons.

The first reason essentially states economists estimating income risks run into an omitted-variable problem, while the second reason states the agents may mis-specifying the data generating process of the income model. Although it is an appealing question to ask, it is hard to differentiate the two possible explanations. The latter part of this paper accommodates both possibilities without taking a strong stance on which explanation is more correct. What matters is the empirical fact that perceived risks reported in the survey seem to be systematically lower than the standard estimates used to calibrate the incomplete market models.

### 4.3 Counter-cyclicity of perceived risk

Some studies have documented that income risks are counter-cyclical based on cross-sectional income data.<sup>20</sup> It is worth inspecting if the subjective income risk profile has a similar pattern. Figure 5 plots the average perceived income risks from SCE against the YoY growth of the average hourly wage across the United States, which shows a clear negative correlation. Table 1 further confirms such a counter-cyclicity by reporting the regression coefficients of different measures of average risks on the wage rate of different lags. All coefficients are significantly negative.

[FIGURE 5 HERE]

[TABLE 1 HERE]

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<sup>20</sup>But they differ in exactly which moments of the income are counter-cyclical. For instance, [Storesletten et al. \(2004\)](#) found that variances of income shocks are counter-cyclical, while [Guvenen et al. \(2014\)](#) and [Catherine \(2019\)](#), in contrast, found it to be the left skewness.

The pattern can be also seen at the state level. Table 2 reports the regression coefficients of the monthly average perceived risk within each state on the state labor market conditions, measured by either wage growth or the state-level unemployment rate, respectively. It shows that a tighter labor market (higher wage growth or a lower unemployment rate) is associated with lower perceived income risks. Note that our sample stops in June 2019 thus not covering the outbreak of the pandemic in early 2020. The counter-cyclicalities will be very likely more salient if it includes the current period, which was marked by catastrophic labor market deterioration and increase market risks.

[TABLE 2 HERE]

The counter-cyclicalities in subjective risk perceptions seen in the survey may suggest the standard assumption of state-independent symmetry in income shocks is questionable. But it may well be, alternatively, because people’s subjective reaction to the positive and negative shocks are asymmetric even if the underlying process being symmetric. The model to be constructed in the theoretical section explores the possible role of both.

## 4.4 Experiences and perceived risk

[TABLE 3 HERE]

Different generations also have different perceived income risks. Let us explore to what extent the cohort-specific risk perceptions are influenced by the income volatility experienced by that particular cohort. Different cohorts usually have experienced distinct macroeconomic and individual histories. On one hand, these non-identical experiences could lead to long-lasting differences in realized life-long outcomes. An example is that college graduates graduating during recessions have lower life-long income than others. (Kahn (2010), Oreopoulos et al. (2012), Schwandt and Von Wachter

(2019)). On the other hand, experiences may have also shaped people's expectations directly, leading to behavioral heterogeneity across cohorts (Malmendier and Nagel (2015)). Benefiting from having direct access to the subjective income risk perceptions, I could directly examine the relationship between experiences and perceptions.

Individuals from each cohort are borned in the same year and obtained the same level of their respective highest education. The experienced volatility specific to a certain cohort  $c$  at a given time  $t$  can be approximated as the average squared residuals from an income regression based on the historical sample only available to the cohort's life time. This is approximately the unexpected income changes of each person in the sample. I use the labor income panel data from PSID to estimate the income shocks.<sup>21</sup> In particular, I first undertake a Mincer-style regression using major demographic variables as regressors, including age, age polynomials, education, gender and time-fixed effect. Then, for each cohort-time sample, the regression mean-squared error (RMSE) is used as the approximate to the cohort/time-specific income volatility.

There are two issues associated with such an approximation of experienced volatility. First, I, as an economist with *PSID* data in my hand, am obviously equipped with a much larger sample than the sample size facing an individual that may have entered her experience. Since larger sample also results in a smaller RMSE, my approximation might be smaller than the real experienced volatility. Second, however, the counteracting effect comes from the superior information problem, i.e. the information set held by earners in the sample contains what is not available to econometricians. Therefore, not all known factors predictable by the individual are used as a regressor. This will bias upward the estimated experienced volatility. Despite these concerns, my method serves as a feasible approximation sufficient for my purpose here.

The right figure in Figure 7 plots the (logged) average perceived risk from each cohort  $c$  at year  $t$

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<sup>21</sup>I obtain the labor income records of all household heads between 1970-2017. Farm workers, youth and olds and observations with empty entries of major demographic variables are dropped.

against the (logged) experienced volatility estimated from above. It shows a clear positive correlation between the two, which suggests that cohorts who have experienced higher income volatility also perceived future income to be riskier. The results are reconfirmed in Table 4, for which I run a regression of logged perceived risks of each individual in SCE on the logged experienced volatility specific to her cohort while controlling individuals age, income, educations, etc. What is interesting is that the coefficient of *expvol* declines from 0.73 to 0.41 when controlling the age effect because that variations in experienced volatility are indeed partly from age differences. While controlling more individual factors, the effect of the experienced volatility becomes even stronger. This implies potential heterogeneity as to how experience was translated into perceived risks.

How does experienced income shock per se affect risk perceptions? We can also explore the question by approximating experienced income growth as the growth in unexplained residuals. As shown in the left figure of Figure 7, it turns out that a better past labor market outcome experienced by the cohort is associated with lower risk perceptions. This indicates that it is not just the volatility, but also the change in level of the income, that is asymmetrically extrapolated into their perceptions of risks.

[FIGURE 7 HERE]

## 4.5 Unemployment risk perceptions

My analysis so far only focuses on the earning risk conditional on employment. But it admittedly only constitutes a lower bound of the labor market risks since major events such as job loss and displacement usually result in more significant changes in labor income and affects household's welfare<sup>22</sup>. In addition, unemployment risks are usually another central input of the incomplete-market macroeconomic models. Similar to the approach with earning risks, the common practice

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<sup>22</sup>Low et al. (2010), Davis and Von Wachter (2011).



in these models is to model the process of labor market transitions based on externally estimated statistics and assume the agent correctly perceives it within the model. Therefore, by the same token as for the earning risk, this section examines if the survey-reported expectations of job separation align with realized aggregate dynamics revealed from the labor market statistics. Moreover, are perceived unemployment risks extrapolate from recent experiences of aggregate and individual labor market outcomes?

For a fair comparison between perceptions and realizations which are available at different horizons, we cast both probabilities into a continuous-time Poisson rate. Specifically, for the expectation, let the reported probability of separating from the current job in next 12 months be  $P_{i,t}(ue_{t+12}|e_t)$ , then the corresponding monthly Poisson rate of job-separation  $E_{i,t}(s_{t+1})$  is  $-\log(1 - P_{i,t}(ue_{t+12}|e_t))/12$ <sup>23</sup>. With the realized month-to-month flow rate estimated from CPS  $P(ue_{t+1}|e_t)$ , the corresponding realized Poisson rate  $s_{t+1}$  is  $-\log(1 - P(ue_{t+1}|e_t))$ .

Figure 6 plots the converted job-separation expectations and realizations against each other. A few important patterns emerge. First, the comparison confirms our earlier findings based on earning risks that individual perceptions did track the aggregate realizations relatively well, assuring us that people’s self-reported perceptions are not entirely groundless or naive. But on the other hand, there are systematic differences between perceptions and realizations.

[TABLE 6 HERE]

## 4.6 Perceived income risk and consumption spending

Finally, how individual-specific perceived risks affect household economic spending decisions? One of the key testable predictions is higher perceived risks should induce precautionary saving motive,

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<sup>23</sup>This follows from the following mathematical fact: for a continuous-time Poisson process with an event rate of  $\theta$ , the arrival probability over a period of  $\Delta t$  units of time is equal to  $1 - \exp^{-\theta\Delta t}$ .

hence lowering current consumption, or increasing expected consumption growth. SCE directly surveys the self-reported spending plan, i.e. expected spending growth over the next year, which exactly corresponds to the object of our interest <sup>24</sup>. Therefore, we can evaluate if higher perceived risks translate affects spending plan consistently with precautionary saving motives.

In general, expected consumption growth with uncertain labor income does not have analytical expression with perceived income risks in it. This is because the optimal consumption paths crucially depends on the income process as well as the nature of this perceived income risks. But under auxiliary assumptions, we could attain a close form expression of expected growth in consumption. Specifically, assume the agent maximizes discounted CRRA utility from consumption with discount rate  $\theta$  and exogenously given interest factor  $1 + r_t$ , and the coefficient of relative risk aversion is  $\rho$ . Under log normal income process, the expected consumption growth at time  $t$  can be approximated as the following when the borrowing constraint is not binding. The expected consumption growth is higher if the borrowing constraint is binding at time  $t$ .

$$E_{i,t}(\Delta c_{i,t+1}) \approx \frac{1}{\rho}(r_t - \theta) + \frac{\rho}{2}\sigma_{i,t}^2(c_{i,t+1}) \quad (7)$$

The second term on the right above captures the effect from precautionary saving motive or possibly binding constraint. We could think of both as a consequence of market incompleteness(Parker and Preston, 2005). Regardless of the particular cause of consumption fluctuations, the term increases with the size of expected consumption risks. But we do not directly observe the expected variance of consumption of the individuals. So an additional assumption regarding the degree of insurance of consumption from income risks is necessary to link expected consumption risks to perceived income risks. The scenario of zero insurance or full pass-through, namely

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<sup>24</sup>Other work that directly examines the impacts of expectations on readiness to spend includes Bachmann et al. (2015) and Coibion et al. (2020). Related to this, there is a recent literature that relies on survey answers to measure marginal propensities to consume, such as Fuster et al. (2020) and Bunn et al. (2018).

$\sigma_{i,t}^2(c_{i,t+1}) = \text{var}_{i,t}(\Delta y_{i,t+1})$ , is most likely to happen when the income risks perceived by the agents are permanent. Under partial insurance, the consumption risks anticipated by the agents should be smaller than the perceived income risks. Let the partial pass-through parameter being  $\kappa$ , then the relationship between expected spending growth and perceived income risks can be written as the following.

$$E_{i,t}(\Delta c_{i,t+1}) \approx \frac{1}{\rho}(r_t - \theta) + \frac{\rho}{2}\kappa^2 \text{var}_{i,t}(\Delta y_{i,t+1}) \quad (8)$$

Since  $\kappa \leq 1$ , an OLS estimate coefficient of expected spending growth on perceived income risks reveals a lower bound of the 1/2 of the size of relative risk aversion  $\rho$ . Table 5 reports the regression results of planned log spending growth over the next year on real and nominal perceived income risk in the variance terms<sup>25</sup>. Regardless of the specification, the perceived risk is indeed positively correlated with the expected spending growth as the precautionary saving motive would predict. Specifically, after controlling for individual fixed effect, i.e. discount rate, and time fixed effect i.e. interest rate, each unit increase in perceived variance leads to around a 3 percentage points increase in expected spending growth. This implies an estimated risk aversion coefficient in the range of 6-7. Besides, the precautionary saving motives are weaker for real earning risks than the nominal, but the two are not significantly different from each other.

[TABLE 5 HERE]

## 5 Risk perceptions and wealth inequality

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<sup>25</sup>There is an important econometric concern when I run regressions of the decision variable on perceived risks due to the measurement error in the regressor used here. In a typical OLS regression in which the regressor has i.i.d. measurement errors, the coefficient estimate for the imperfectly measured regressor has a bias toward zero. For this reason, if I find that expected spending growth is indeed positively correlated with perceived risks, taking into account the bias, it implies that the correlation of the two is greater in size.

## 5.1 An overlapping generation model

I set up a standard incomplete market/life-cycle model without aggregate risks. It is built on Huggett (1996), except for a more realistic income risk profile and economic environment a la Krueger et al. (2016); Carroll et al. (2017). Then, I add one single deviation from the benchmark to allow for the subjective income risk perceptions.

In each period, a continuum of agents is born. Each agent  $i$  lives for  $L$  and works for  $T$  ( $T \leq L$ ) periods since entering the labor market, during which he/she earns stochastic labor income  $y_\tau$  at the work-age of  $\tau$ . After retiring at age of  $T$ , the agent lives for another  $L - T$  periods of life and receive social security benefits. We assume away aggregate risks in the benchmark model, therefore there is no need to treat calendar time  $t$  from working age  $\tau$  as two separate state variables, hence we suppress time script  $t$ . All shocks are idiosyncratic, or to put it differently, specific to the individual  $i$ .

### 5.1.1 Consumer's problem

The consumer chooses the whole future consumption path to maximize expected life-long utility, under a discount factor  $\beta$  and constant survival probability  $(1 - D)$ .

$$\max \quad \mathbb{E} \left[ \sum_{\tau=0}^{\tau=L-1} (1 - D)^\tau \beta^\tau u(c_{i,\tau}) \right] \quad (9)$$

where  $c_{i,\tau}$  represents consumption at the work-age of  $\tau$ . The felicity function  $u(c)$  takes a standard CRRA form with relative risk aversion of  $\rho$ :  $u(c) = \frac{c^{1-\rho}}{1-\rho}$ .<sup>26</sup>

Denote total cash in hand at the beginning of the period  $\tau$  as  $m_{i,\tau}$ , the end-of-period saving in period  $\tau$  after consumption as  $a_{i,\tau}$ , the bank balance in period  $\tau$  as  $b_{i,\tau}$ . Also, assume  $R$  is the

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<sup>26</sup>There is a bequest motive and preference-shifter along life cycle, but these features can be easily incorporated.

gross real interest factor. The consumer starts with some positive bank balance in the first period of life,  $b_1$ , which this paper assumes to be from a lump-sum accidental bequest from the deceased population each period. The household makes consumption and saving decisions subject to the following intertemporal budget constraint.

$$\begin{aligned}
 a_{i,\tau} &= m_{i,\tau} - c_{i,\tau} \\
 b_{i,\tau+1} &= a_{i,\tau}R \\
 m_{i,\tau+1} &= b_{i,\tau+1} + (1 - \lambda)y_{i,\tau+1} \\
 a_{i,\tau} &\geq 0
 \end{aligned} \tag{10}$$

In addition, I impose an external zero borrowing constraint. Without the external borrowing constraint, the agent will still self-imposed a lower bound for  $a_\tau$  to avoid the extremely painful zero consumption next period in the case of the worst draw of income shocks.

### 5.1.2 Income process

Each agent receives stochastic labor income during working age from  $\tau = 0$  to  $\tau = T$  and receives social security benefit after retirement. The income processes in both sub-periods can be defined in a generic manner as described below. In particular, it is assumed to follow a slight variant of the standard permanent/transitory income process used in the literature<sup>27</sup> by allowing the possibility of persistent unemployment risks. Specifically,  $y_{i,\tau}$  is a multiplication of idiosyncratic labor productivity  $n_{i,\tau}$  and the economy-wide wage rate  $W$ . The former consists of one permanent component  $p_{i,\tau}$  and one potentially persistent or transitory  $\xi_{i,\tau}$ . The aggregate wage is to be determined by the

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<sup>27</sup>Carroll et al. (2017), Kaplan and Violante (2018), etc.

general equilibrium. <sup>28</sup>

$$\begin{aligned} y_{i,\tau} &= n_{i,\tau} W \\ n_{i,\tau} &= p_{i,\tau} \xi_{i,\tau} \end{aligned} \tag{11}$$

The permanent income component is subject to a mean-one white-noise shock  $\psi$  in each period and grows according to a deterministic life-cycle profile governed by  $G_\tau$  over the life cycle, which usually follows a hump-shape according to existing estimates. (Gourinchas and Parker, 2002)

$$\begin{aligned} p_{i,\tau} &= G_\tau p_{i,\tau-1} \psi_{i,\tau} \\ \log(\psi_{i,\tau}) &\sim N\left(-\frac{\sigma_\psi^2}{2}, \sigma_\psi^2\right) \end{aligned} \tag{12}$$

The persistent/transitory shock  $\xi_{i,\tau}$  takes different values depending on the transitory or persistent state of unemployment following a Markov process. <sup>29</sup>

$$\begin{aligned} \xi_{i,\tau} &= \begin{cases} \theta_{i,\tau} & \text{if } \nu_{i,\tau} = 0 \quad \& \quad \tau \leq T \\ \zeta & \text{if } \nu_{i,\tau} = 1 \quad \& \quad \tau \leq T \\ \mathbb{S} & \text{if } \tau > T \end{cases} \\ \log(\theta_{i,\tau}) &\sim N\left(-\frac{\sigma_\theta^2}{2}, \sigma_\theta^2\right) \end{aligned} \tag{13}$$

where  $\zeta$  is the replacement ratio of the unemployment insurance and  $\theta_{i,\tau}$  is the i.i.d. mean-one white noise shock to the transitory component of the income conditional on staying employed.

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<sup>28</sup>In the presence of aggregate risk, we need to allow  $W$  being time-varying and this also means we need to be explicit about the difference between the calendar year and working age.

<sup>29</sup>This formulation follows Krueger et al. (2016).

Notice that the process above also contains the income process after retirement at  $\tau = T$ . The agent receives social security with replacement ratio  $\mathbb{S}$ . Therefore, the effective pension benefit received is  $\mathbb{S}p_{i,\tau}W$ . This assumption makes the idiosyncratic permanent risks still relevant for the agent after retirement.

During work age, the transition matrix between employment ( $\nu_{i,\tau} = 0$ ) and unemployment ( $\nu_{i,\tau} = 1$ ) is the following.

$$\pi_{i,\tau+1|\tau} = \begin{bmatrix} \mathcal{U} & 1 - \mathcal{U} \\ 1 - E & E \end{bmatrix} \quad (14)$$

In general, this assumption implies some degree of the persistence of unemployment risks, but it conveniently nests the special case where the unemployment risk is purely transitory when  $\mathcal{U} = 1 - E$ , meaning the probability of unemployment is not dependent on the current status.

Notice that in the benchmark model laid out here, I assume the all parameters of income risks  $\sigma_\psi$ ,  $\sigma_\theta$ ,  $\mathcal{U}$ , and  $E$  to be age-invariant (equivalent to time-independent in this setting). By doing this, I avoid making explicit assumptions on the stochastic process of income risks. This is a common practice in the incomplete market macro literature since [Gourinchas and Parker \(2002\)](#) and [Cagetti \(2003\)](#). It is also not fundamentally different from assuming a deterministic age-specific risk profile, as in some variants of the models with the life-cycle component.<sup>30</sup> I relax this assumption by considering an explicitly specified stochastic process of the income volatility a la GARCH in the extension of the model (See the Appendix).

### 5.1.3 Value function and consumption policy

The following value function characterizes the consumer's problem.

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<sup>30</sup>See [Carroll et al. \(2017\)](#) and other examples.

$$V_{\tau}(\nu_{i,\tau}, m_{i,\tau}, p_{i,\tau}) = \max_{\{c_{i,\tau}, a_{i,\tau}\}} u(c_{i,\tau}) + (1 - D)\beta \mathbb{E}_{\tau} [V_{\tau+1}(\nu_{i,\tau}, m_{i,\tau+1}, p_{i,\tau+1})] \quad (15)$$

where the three state variables for the agents are current employment status  $\nu_{i,\tau}$ , total cash in hand  $m_{i,\tau}$  and permanent income  $p_{i,\tau}$ .  $\nu_{i,\tau}$  drops from the state variables in the special case of purely transitory unemployment shock ( $\mathcal{U} = 1 - E$ ).<sup>31</sup>

The solution to the problem above is the age-specific optimal consumption policies  $c_{\tau}^*(u_{i,\tau}, m_{i,\tau}, p_{i,\tau})$  and saving policies  $a_{\tau}^*(u_{i,\tau}, m_{i,\tau}, p_{i,\tau})$  both as a function of all state variables.

### 5.1.4 Technology

The economy has a standard CRS technology that turns the capital and supplied efficient units of labor into aggregate output.

$$Y = ZK^{\alpha}L^{1-\alpha} \quad (16)$$

The capital depreciates at a rate of  $\delta$  each period.

The factors of input markets are fully competitive. Euler Theorem implies that the output either becomes labor income or capital income.

### 5.1.5 Government

Government runs a balanced budget in each period. Therefore, outlays from unemployment insurances are financed by the income tax that is levied on both labor income and unemployment

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<sup>31</sup>Another trick used in the literature to reduce the number of state variables is to normalize the value function by permanent income level  $p_{\tau}$ , so that it drops from the state variable. I also use endogenous grid method (EGM) by [Carroll \(2006\)](#). See Appendix for the detailed solution algorithm.



benefit. Given a replacement ratio  $\zeta$ , and the proportion of employed population, the corresponding tax rate  $\lambda$  can be easily pinned down based on the equation below.<sup>32</sup>

$$\lambda [1 - \text{fraction of unemp} + \zeta \text{fraction of unemp}] = \zeta \text{fraction of unemp} \quad (17)$$

### 5.1.6 Demographics

For simplicity, we assume there is no population growth. With a deterministic life-cycle profile of survival probabilities, there exists a stable age distribution  $\{\mu_\tau\}_{\mu=1,2,\dots,L}$  such that  $\mu_{\tau+1} = (1 - D)\mu_\tau$  and  $\sum_{\tau=1}^L \mu_\tau = 1$ . The former condition reflects the probability of survivals at each age and the latter is a normalization that guarantees the fraction of all age groups sum up to 1.<sup>33</sup>

### 5.1.7 Stationary equilibrium

Denote  $x = \{m, p, \nu\} \in X$  as the idiosyncratic state of individuals. At any point in time, agents in the economy differ in age  $\tau$  and their idiosyncratic state  $x$ . The former is given by  $\{\mu_\tau\}_{\mu=1,2,\dots,L}$ . For the latter, using  $\psi_\tau(B)$  to represent the fraction of agents at age  $\tau$  whose individual states lie in  $B$  as a proportion of all age  $\tau$  agents. ( $B$  is essentially a subset of Borel  $\sigma$ -algebra on state space  $X$ .) The distribution of age  $\tau = 1$  agents depend on the initial condition of labor income outcomes and the size of accidental bequest. For any other age  $\tau = 2 \dots L$ , the distribution  $\phi_\tau(B)$  evolves as the following.

$$\psi_\tau(B) = \int_{x \in X} P(x, \tau - 1, B) d\psi_{\tau-1} \quad \text{for all } B \in B(X) \quad (18)$$

---

<sup>32</sup>This convenient result crucially depends on the assumption that unemployment insurance benefit is paid proportionally to permanent income.

<sup>33</sup>In a more general setting with a constant population growth rate  $n$  and age-specific survival probability  $1 - D_\tau$ , the condition becomes  $\mu_{\tau+1} = \frac{(1-D_{\tau+1})}{1+n} \mu_\tau \quad \forall \tau = 1, 2 \dots L$ , as discussed in [Ríos-Rull \(1996\)](#) and [Huggett \(1996\)](#).

where  $P(x, \tau - 1, B)$  is the probability for an agent to transit to  $B$  in the next period, conditional on the individual state  $x$  at age  $\tau - 1$ . It depends on the optimal consumption policy  $c^*(x, \tau)$  at age  $\tau$  and the exogenous transition probabilities of income shocks.

In the absence of the aggregate risk, I focus on the stationary equilibrium of the economy (StE) which consists of consumption and saving policies  $c(x, \tau), a(x, \tau)$ , constant production factor prices, including real interest rate  $R$  and the wage  $W$ , the initial wealth of newborn  $b_1$ , unemployment benefit  $\zeta$ , tax rate  $\lambda$  and the time-invariant distribution  $(\psi_1, \psi_2, \dots, \psi_L)$  such that

1. Consumption and saving policies are optimal given the real interest rate  $R$ , wage  $W$ , the tax rate  $\lambda$ .

$$c(x, \tau) = c^*(x, \tau)$$

$$a(x, \tau) = a^*(x, \tau)$$

2. Distributions  $(\psi_1, \psi_2, \dots, \psi_L)$  are consistent with optimizing behaviors of household, as described in Equation 18.
3. The factor markets are clearing.

$$\begin{aligned} \sum_{\tau} \mu_{\tau} \int_X a(x, \tau) d\psi_{\tau} &= K \\ \sum_{\tau} \mu_{\tau} \int_X \mathbb{1}(\nu = 1) n(x, \tau) d\psi_{\tau} &= L \end{aligned} \tag{19}$$

4. Firm optimization under competitive factor markets.

$$W = Z(1 - \alpha)(K/L)^{\alpha}$$

$$R = 1 + Z\alpha(K/L)^{\alpha-1} - \delta$$

5. Initial bank balance equal to accidental bequests.

$$b_1 = \sum_{\tau} \mu_{\tau} D \int_{x \in X} a(x, \tau) R d\psi_{\tau}$$

6. Government budget is balanced as described in Equation 17.

The economy may potentially arrive at different stationary equilibrium depending on the specific assumptions about objective or subjective models under the configurations.

## 5.2 Subjective risk perceptions

In the benchmark model, I maintain the FIRE assumption that the agents perfectly know the underlying parameters of income risks  $\Gamma = \{\sigma_{\psi}^2, \sigma_{\theta}^2, \mathcal{U}, E\}$  as assumed by the modelers and behave optimally accordingly.

But here, I relax the FIRE assumption by separately treating the “true” underlying risk parameters  $\Gamma$  and the risk perceptions held by the agents. The latter is denoted as  $\tilde{\Gamma}_i$ . This extension is meant to capture the four empirical patterns documented in the previous sections.

1. Underestimation of the earning risks (compared to what is assumed to be the truth in the model)
2. Heterogeneity in risk perceptions
3. Extrapolation of recent experiences
4. State-dependence of risk perceptions

The possible approaches of capturing these perceptual patterns are by no means unique. I adopt

one simple framework that does not require explicitly specified mechanisms of perception formation but sufficient to reflect these the patterns revealed from the survey data.

Assume that each agent  $i$  in the economy cannot directly observe the underlying risk parameters  $\Gamma$ , but instead make his/her best choices based on a subjective risk perceptions  $\tilde{\Gamma}_{i,\tau}$ , which swing between two states:  $\tilde{\Gamma}_l$  (low risk) and  $\tilde{\Gamma}_h$  (high risk). The transition between the two states is governed by a Markov process with a transition matrix  $\Omega$ . In the calibration of the model in latter sections, these subjective parameters can be estimated from survey data relied upon auxiliary assumptions.

Such an assumption automatically allows for heterogeneity in risk perceptions across different agents at any point of the time. All individuals are distributed between low and high risk-perception states. In one of the extensions, I also admit ex-ante heterogeneity, namely permanent differences in risk perceptions due to individual fixed effects.

The transition probability between low-risk and high-risk perception states can be also configured so that the average risk perception is lower than the true level of the risk. If we let the transition matrix  $\Omega$  to be dependent on individual unemployment status  $\nu_{i,\tau}$ , or macroeconomic conditions, we can also easily accommodate the possibility of experience extrapolation and state-dependence feature of risk perceptions.

Under the assumption of subjective perception, the subjective state of the risk perceptions  $\tilde{\Gamma}$  becomes an additional state variable entering the Bellman equation of the consumer's problem, restated in below.

$$\tilde{V}_\tau(\tilde{\Gamma}_\tau, \nu_\tau, m_\tau, p_\tau) = \max_{\{c_\tau\}} u(c_\tau) + (1 - D)\beta \mathbb{E}_\tau \left[ \tilde{V}_{\tau+1}(\tilde{\Gamma}_{\tau+1}, \nu_{\tau+1}, m_{\tau+1}, p_{\tau+1}) \right] \quad (20)$$

Notice here that I assume that the agents recognize the transition between two subjective perception states and take it into account when making the best choices. This assumption guarantees time-consistency and provides additional discipline to the model assumption.

The consumer's solution to the problem above is the age-specific consumption policy  $\tilde{c}_\tau^*(\tilde{\Gamma}_\tau, u_\tau, m_\tau, p_\tau)$  that is also a function of subject risk perception state  $\tilde{\Gamma}$ .

The distinction between objective and subject risk perception marks the single most important deviation of this paper from existing incomplete-market macro papers.<sup>34</sup> There is a long tradition of explicitly incorporating various kinds of heterogeneity in addition to uninsured idiosyncratic income shocks in these kinds of models to achieve better match with observed cross-sectional wealth inequality. One of the most notable assumptions used in the literature is the heterogeneity in time preferences (Krusell and Smith (1998), Carroll et al. (2017), Krueger et al. (2016)). My modeling approach shares the spirit with and are not mutually exclusive to these existing assumptions on preferential heterogeneity. But, to some extent, perceptual heterogeneity is more preferable as such patterns are directly observed from the survey data, as I show in the previous part of the paper.

A more fundamental justification for such deviations from the full information rational expectation assumption is that risk parameters  $\Gamma$  are not endogenous variables to be realized in the equilibrium of the model. Therefore, the conventional argument in favor of rational expectation assumption, namely equilibrium outcome drives the agents' perceptions to converge to the "truth", does not apply here. So far, the majority workhorse incomplete market macro literature has not incorporated any endogenous mechanisms that determine the level of income risks. The emerging literature that incorporates labor market search/match frictions in these models have relied upon simplifying assumptions to get tractability.<sup>35</sup>

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<sup>34</sup>For instance, Bewley (1976), Huggett (1993), Aiyagari (1994), Krusell and Smith (1998), Krueger et al. (2016), Carroll et al. (2017).

<sup>35</sup>See, for instance, McKay (2017); Acharya and Dogra (2020); Ravn and Sterk (2021), with the only exception being Ravn and Sterk (2017).

Incorporating subjective risk perceptions also alters aggregate dynamics of the distributions as described in Equation 18, as restated below.

$$\tilde{\psi}_{\tau-1}(\tilde{B}) = \int_{\tilde{x} \in \tilde{X}} \tilde{P}(\tilde{x}, \tau - 1, \tilde{B}) d\tilde{\psi}_{\tau-1} \quad \text{for all } \tilde{B} \in \tilde{B}(X) \quad (21)$$

The state variable  $\tilde{x}$  includes subjective state  $\tilde{\Gamma}$  in addition to those contained in  $x$ . The transition probabilities  $\tilde{P}$  now depend on the optimal consumption policies  $c^*(\tilde{x})$  as a function of belief state  $\tilde{\Gamma}$ , as well as the exogenous transition probabilities of the true stochastic income process  $\Gamma$ .

Then the new StE under subjective risk perceptions can be defined accordingly.

### 5.3 Objective versus subjective risk profiles

The key implications of the model lie in the differences in consumption functions of the agents in the economy. Therefore, this section devotes to presenting a comparison between the consumption policies under different model assumptions.

First, I consider the benchmark model, named objective model, under standard parameterization of income risk parameters  $\Gamma$  and assumes the unemployment risk to be entirely transitory.

The first version of the subjective model allows the transition between low and high risk subjective states, under which the average transitory and permanent earning risk is lower than the standard configurations but with the same objective unemployment risk. Call it subjective state-dependent volatility (SV) model.

The second version of the model further allows the risk perceptions to be dependent upon the idiosyncratic employment status, such that unemployed agents perceive both permanent and transitory risks to be higher than the employed workers do. Call this subjective extrapolation

model.

Figure 8 plots the consumption policies under objective and subjective risk profiles, where agents swing between low and high-risk perceptions. For illustration purpose, I assume the perception state is entirely transitory, which explains why the consumption policy do not differ between low-risk and high-risk perceptions. More generally, persistence in risk perceptions would induce differences between the two. Also, I configure the model such that the average permanent and transitory risks are exactly equal to the objective model. To put it differently, the subjective model can be seen as a mean-preserving spread of the risk profiles. Whether the precautionary saving motive is intensified in the subjective model or not depends on the level of wealth. For low level of wealth, consumption of consumption is lower than the objective model, as the consumer takes into account the possibility that the risk perceptions can be higher.

[FIGURE 8 HERE]

Figure 9 further compares the objective model under transitory unemployment risks versus the subjective model in which employment status leads to additional extrapolations in risk perceptions. Specifically, the latter model lets an unemployed worker be with the high-risk perceptions while the employed to be with the low-risk perceptions. This essentially makes the transition matrix  $\Omega$  exactly equal to  $\Pi$ . I also configure risk parameters specific to each state such that on average it preserves the same size of permanent and transitory risks compared to the objective model. This guarantees the difference between the two model is not induced by change in the average degree of precautionary saving motives.

[FIGURE 9 HERE]

The most obvious pattern seen in the figure is that within the objective model, unemployed workers have less consumption than employed workers. In addition, between the objective and

subjective-extrapolation model, an employed worker with lower risk perceptions actually consume less than the employed worker in the objective model.

## 5.4 Calibration

### 5.4.1 Estimation of subjective risk profiles

The parameters to be estimated from the panel data of risk perceptions from *SCE* are the state-dependent risk profile  $\tilde{\Gamma}_l = \{\tilde{\sigma}_\psi^l, \tilde{\sigma}_\theta^l, \tilde{U}^l, \tilde{E}^l\}$ ,  $\tilde{\Gamma}_h = \{\tilde{\sigma}_\psi^h, \tilde{\sigma}_\theta^h, \tilde{U}^h, \tilde{E}^h\}$  and  $\Omega$ , the transition matrix between the two states.

Denote the reported risk perception of the individual  $i$  at time  $t$  in the survey by  $\tilde{\Gamma}_{i,t}^s$ . It consists of the underlying risk perceptions relevant to individual decisions, or the model counterpart  $\tilde{\Gamma}_{i,t}$ , and an individual-specific, time-specific and an *i.i.d* shock to the survey responses, respectively. The realization of  $\tilde{\Gamma}_{i,t}$  depends on a hidden state  $J_{i,t}$  which is non-observable to economists working with the survey data. It takes value of 1 if the individual  $i$  is at a high-risk-perception state  $\tilde{\Gamma}_{i,t} = \tilde{\Gamma}_h$  and zero if at low-risk-perceptions  $\tilde{\Gamma}_{i,t} = \tilde{\Gamma}_l$ . The *i.i.d* shock  $\epsilon_{i,t}$  is assumed to follow a mean-zero normal distribution with variance  $\sigma_\epsilon^2$ .

$$\underbrace{\tilde{\Gamma}_{i,t}^s}_{\text{reported PR}} = \underbrace{\tilde{\Gamma}_l + \mathbb{1}(\underbrace{\widehat{J_{i,t}}}_{\tilde{\Gamma}_{i,t}} = 1)(\tilde{\Gamma}_h - \tilde{\Gamma}_l)}_{\tilde{\Gamma}_{i,t}} + \xi_t + \eta_i + \epsilon_{i,t}$$

$$\text{Prob}(J_{i,t+1}|J_{i,t}) = \Omega$$

Notice that the individuals do not separately report their perceived risks for the permanent and transitory shocks, but instead the overall expected income volatility. Therefore, I make an auxiliary assumption that the agent adopts a constant ratio of decomposition between permanent



and transitory risks,  $\kappa = \frac{\tilde{\sigma}_{i,t,\psi}}{\tilde{\sigma}_{i,t,\theta}}$ , the value of  $\kappa$  is externally estimated from the realized income data.

In addition, since the surveyed risk perceptions is at the monthly frequency, I estimate the underlying risk parameters for monthly shocks.<sup>36</sup>

For each individual  $i$ , we observe at most 12 observations of their perceived income volatility of the earning growth next year  $\tilde{v}ar_{i,t}$  from  $t$  to  $t + 12$  and their job-separation and job-finding expectations, respectively. The panel structure allows the individual fixed effect  $\eta_i$  and time-fixed effect  $\xi_t$  to be easily identified.

Then the parameters can be estimated with a modified 2-regime Markov switching model a la [Hamilton \(1989\)](#) using the maximum-log-likelihood (MLE). (See the detailed implementation in [Appendix A.6](#)). [Table 6](#) reports the baseline estimates of the parameters associated with the 2-state Markov model of subjective perceptions. All parameters are converted from monthly into quarterly counterparts to be consistent with the model frequency.

The estimates of subjective profile confirms a few empirical patterns we have shown in the previous sections. First, the estimated staying probabilities at low and high risk perceptions,  $q$  and  $p$ , are around 0.9, indicating a high degree of persistence in individual risk perceptions. Second,

[TABLE 6 HERE]

## 5.4.2 Other parameters

**Life-cycle** The model is set quarterly. The working age spans from 25 years old to 65 years old ( $T = 160$ ) and the agent dies with certainty at age of 90 ( $L = 260$ ). The constant death probability before the terminal age is set to be  $D = 0.625\%$ .

As to the deterministic income profile over the life-cycle  $G_\tau$ , I draw on an age polynomial

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<sup>36</sup>  $\tilde{v}ar_{i,t} = (12\tilde{\sigma}_{i,t,\psi}^2 + 1/12\tilde{\sigma}_{i,t,\theta}^2)exp^{\xi_t}exp^{\eta_i}exp^{\epsilon_{i,t}} \rightarrow \log \tilde{v}ar_{i,t} = \log(12\tilde{\sigma}_{i,t,\psi}^2 + 1/12\tilde{\sigma}_{i,t,\theta}^2) + \xi_t + \eta_i + \epsilon_{i,t} \rightarrow \log(\tilde{v}ar_{i,t}) = \log[(12 + \frac{1}{12\kappa^2})\tilde{\sigma}_{i,t,\psi}^2] + \xi_t + \eta_i + \epsilon_{i,t}$ .

regressions of the earning growth from SIPP, controlling for other observable demographic variables such as education, gender, occupation, and time-fixed effects, etc. This produces very similar estimation results to that in [Gourinchas and Parker \(2002\)](#), [Cagetti \(2003\)](#) and [Kaplan and Violante \(2014\)](#). I linearly interpolate the age-specific growth rates into quarterly frequency. The estimated income profile is plotted in [Appendix A.4](#).

**Income risks** Given the critical importance of the income risks assumption in my model, In addition to my estimates from SIPP, as reported in [Table A.1](#), I thoroughly survey the parameters used in the existing incomplete market macro literature, as summarized in [Table A.2](#) in the Appendix. For comparison, I convert all risks into the annual frequency (although the model is set quarterly). Whenever group-specific risks are assumed, i.e. depending on the education and age, I summarize it as a range. Also, for those models which assume a persistent instead of permanent income risk component, I treat their assumed size of the persistent risks as a lower bound for the permanent risk. (One can think of the permanent income shock as a limiting case of AR(1) shock, with the persistence parameter infinitely close to 1. The effective income risks increase with the persistence of the shock.) For models with income risks dependent on aggregate business cycles a la [Krusell and Smith \(1998\)](#), I compute the steady-state size of idiosyncratic risks using the transition probabilities of the aggregate economy used in the paper.

Despite the disagreements in these estimates or model inputs, the earning risks used in these models are constantly larger than those perceived reported in the survey. Meanwhile, the perceived risk of unemployment is higher in the survey than in these models and the perceived employment probability is lower in the survey than in these models. I use the median values of each parameter in the literature as the objective income risks profile  $\Gamma$ .

**Technology** Depreciation rate is  $\delta = 2.5\%$ . Capital share  $\alpha = 0.36$ .

**Government policies** Unemployment insurance replacement ratio is  $\mu = 0.15$ .

**Preference** The discount factor is set to be  $\beta = 0.98^{0.25}$ . The coefficient of relative risk aversion  $\rho = 1$ .

## 6 Model implications

### 6.1 Risk-perception heterogeneity and wealth inequality

### 6.2 “MIT shock” of the aggregate economy

## 7 Other extensions

### 7.1 Costly adjustment in consumption

In this section, I extend the benchmark consumption model to incorporate an additional discrete choice of costly extensive adjustment. This is meant to introduce one additional mechanism which helps calibrate the model to match a high level of marginal propensity to consume (MPC) seen in the empirical estimates using natural experiments. One recent example of such a model formulation is [Fuster et al. \(2021\)](#).

Two issues are worth clarifying here. First, this costly adjustment can be explicitly micro-founded by various monetary or mental obstacles that prevent agents from making optimal adjustments in consumption from period to period. Regardless of its specific micro foundations, it effectively leads to extensive adjustment in consumption. Second, the assumption also conveniently captures, in the one-asset setting, the essence of implications from costly adjustment of illiquid assets in the two-asset setting, which generates wealthy hands-to-mouth behaviors, as formulated in the [\(Kaplan and Violante, 2014\)](#).

Specifically, I assume that there is a utility cost the agents need to incur  $\chi$ , when changing the consumption in each period  $\tau$ . Recognizing this, in each period, the agents need to first make a discrete choice of whether making adjustments to the consumption. In the case of adjustment, the agents solve the optimal consumption optimally. In the case of non-adjustment, the consumption stays at the level as the previous period, since it is the default consumption choice. Note that since the consumer always has the choice of adjustment, this naturally guarantees that in the presence of negative income shock when staying at the same level of consumption is no longer feasible, the agents will adjust the consumption to obey the budget constraints.

The change in the nature of the problem can be summarized by the restated value functions below. I restate the problem only for a consumer with objective risk profiles, as the subjective agent only has idiosyncratic risk perceptions  $\tilde{\Gamma}_{i,\tau}$  as one additional state variable.

$$\begin{aligned}
V_\tau(c_{i,\tau-1}, u_{i,\tau}, m_{i,\tau}, p_{i,\tau}) &= \max \{V_\tau^A(u_{i,\tau}, m_{i,\tau}, p_{i,\tau}) - \chi, V_\tau^N(c_{i,\tau-1}, u_{i,\tau}, m_{i,\tau}, p_{i,\tau})\} \\
V_\tau^A(u_{i,\tau}, m_{i,\tau}, p_{i,\tau}) &= \max_{\{c_{i,\tau}\}} u(c_{i,\tau}) + (1 - D)\beta\mathbb{E}_\tau[V_{\tau+1}(u_{i,\tau}, R(m_{i,\tau} - c_{i,\tau}) + y_{i,\tau+1}, p_{i,\tau+1})] \\
V_\tau^N(c_{i,\tau-1}, u_{i,\tau}, m_{i,\tau}, p_{i,\tau}) &= u(c_{i,\tau-1}) + (1 - D)\beta\mathbb{E}_\tau[V_{\tau+1}(c_{i,\tau-1}, u_{i,\tau}, m_{i,\tau+1}, p_{i,\tau+1})]
\end{aligned} \tag{22}$$

where  $V^A$  and  $V^N$  represent value functions associated with adjustment and non-adjustment. Notice that in the case of non-adjustment, the consumption in previous period becomes an additional state variable. But essentially, there is no choice to be made as to consumption in the case of non-adjustment.

Solving consumption policies with the both intensive and extensive margin choices introduces additional computational challenges. In particular, it results in discrete jumps hence discontinuity in the value function over different values of state variables and the first order condition, namely the Euler equation, is no longer sufficient for the optimality of consumption. Although brutal

force value function maximization is able to produce solutions to the model, I adopt the “Discrete Choice Endogenous Grid Algorithm (DCEGM)” introduced by [Iskhakov et al. \(2017\)](#) to speed up the computation. (See Appendix for the detailed steps of the implementation.)

## 8 Conclusion

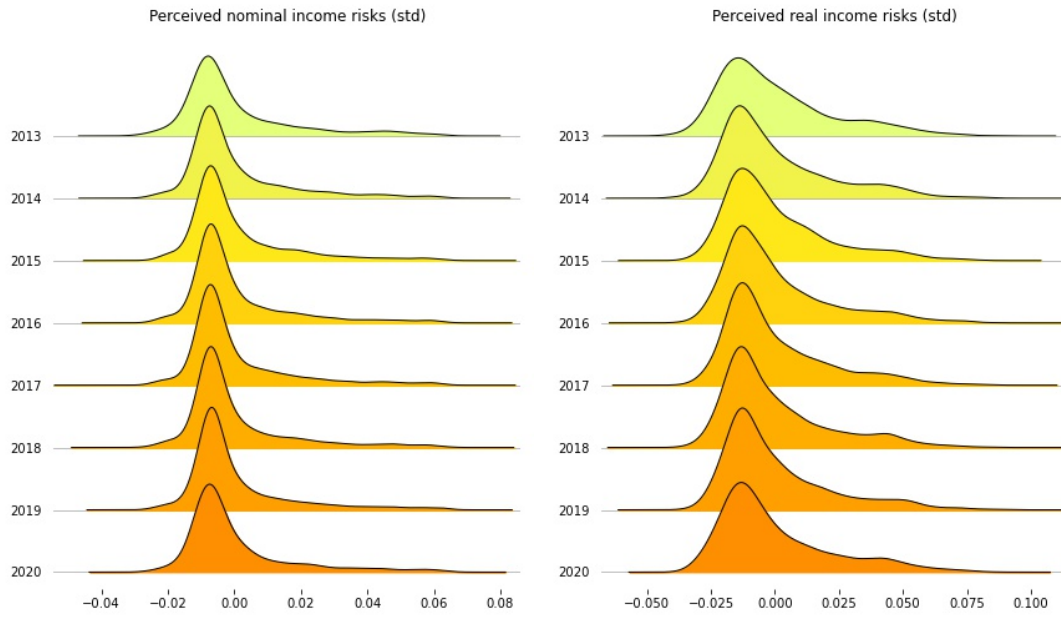
Incomplete-market macroeconomic models that admit uninsured idiosyncratic income risks have become the new paradigm of macroeconomic analysis in the past decade. This paper builds on this vibrant literature by relaxing the long maintained assumption in these models that agents perfectly understand the underlying size of income risks and behave optimally accordingly.

Utilizing the recently available large-scale survey data that elicits density forecast of earnings and labor outcome, I incorporate salient empirical patterns of income risk perceptions such as heterogeneity, extrapolation and state-dependence in these models. The survey evidence also indicates the possible “superior information” problem documented in the literature, confirming an upward bias in the assumed size of income risks in these models compared to what people report in surveys. This helps explain the low liquid asset holdings of a large fraction of consumers, or the presence of many hands-to-mouth consumers.

This paper also presents a demonstration of the rich possibility of incorporating survey data reflecting real-time heterogeneity in expectations/perceptions in heterogeneous-agent models. In a world with increasingly rich survey data that directly measures expectations, economists are no longer forced to make stringent assumption of rational expectations. Directly using survey-implied heterogeneity helps match empirical patterns of the macroeconomy.

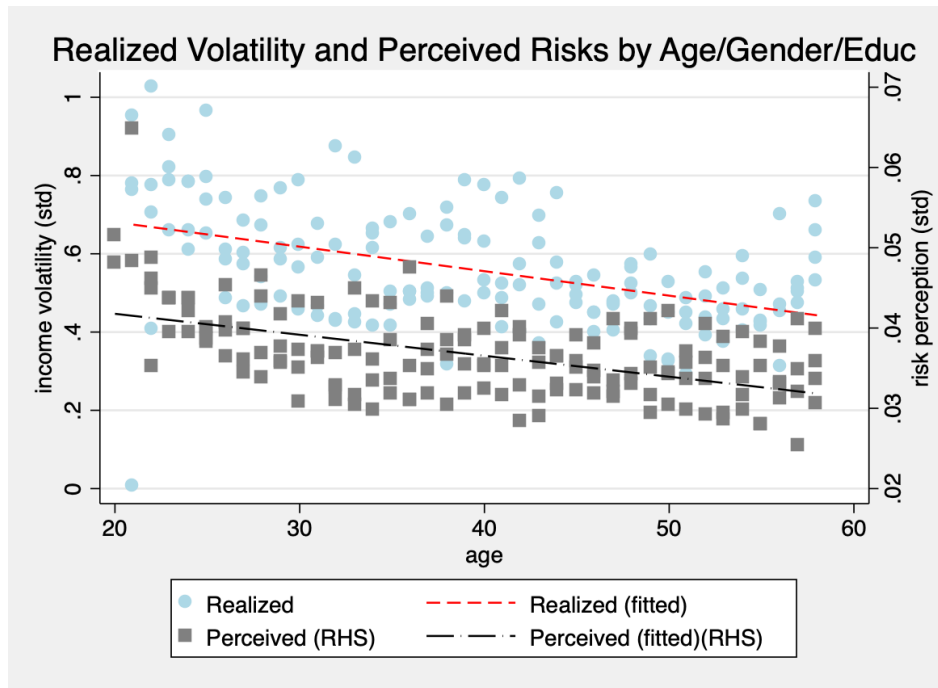
## Tables and Figures

**Figure 1:** Dispersion in Unexplained Perceived Income Risks



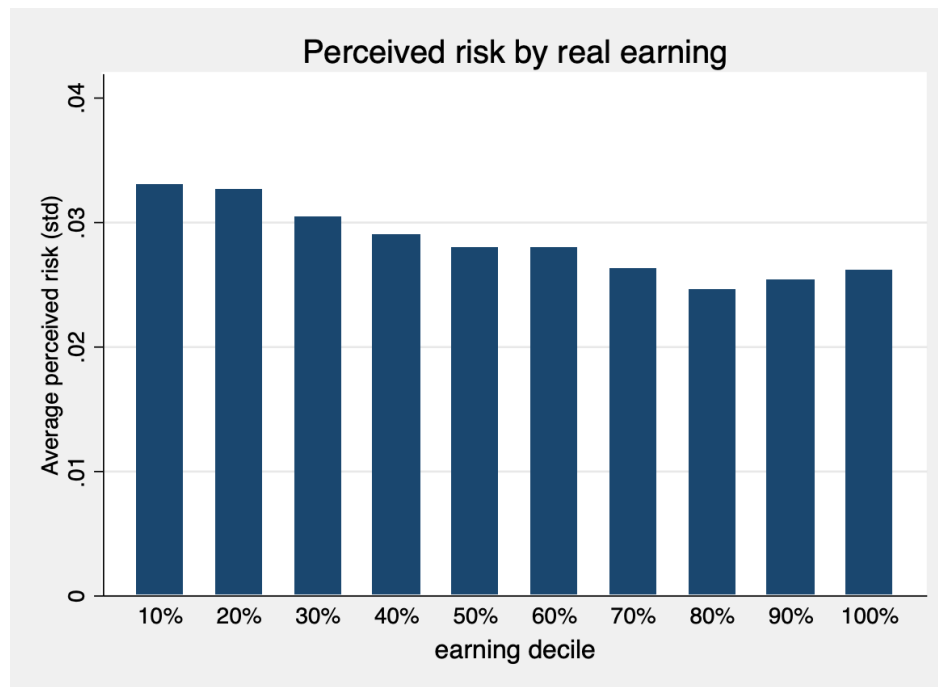
Note: this figure plots the distributions of residuals of the perceived standard deviation of 1-year-ahead earning growth in nominal (left) and real terms (right) after controlling age, age polynomial, gender, education, type of work, and time fixed effects. The real risk is the sum of the perceived risk of nominal income and inflation uncertainty.

**Figure 2:** Realized and Perceived Income Risks over the Life Cycle



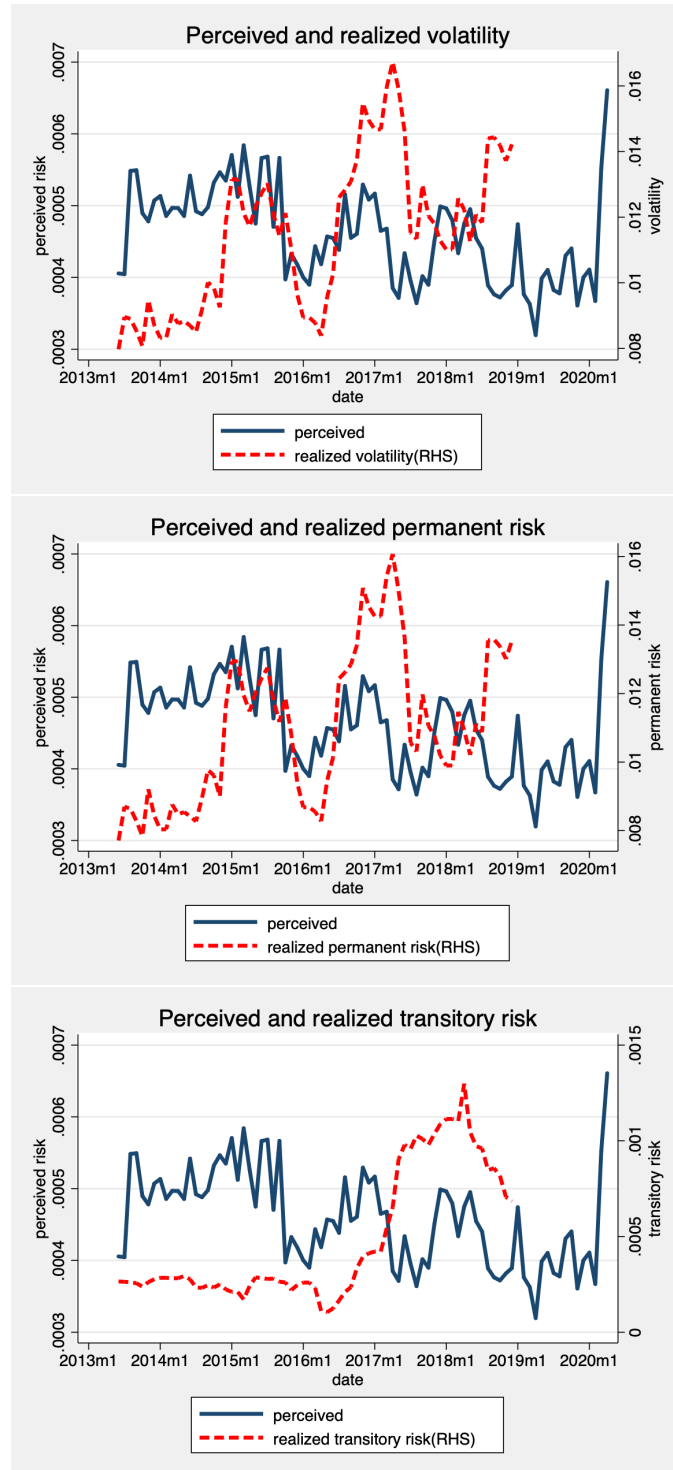
Note: this figure plots average realized income volatility and perceived risks of different age groups. The realized income volatility is approximated by the cross-sectional standard deviation of log changes in unexplained income residuals within age/education/gender group based on PSID.

**Figure 3:** Perceived Earning Risks by Earning Decile



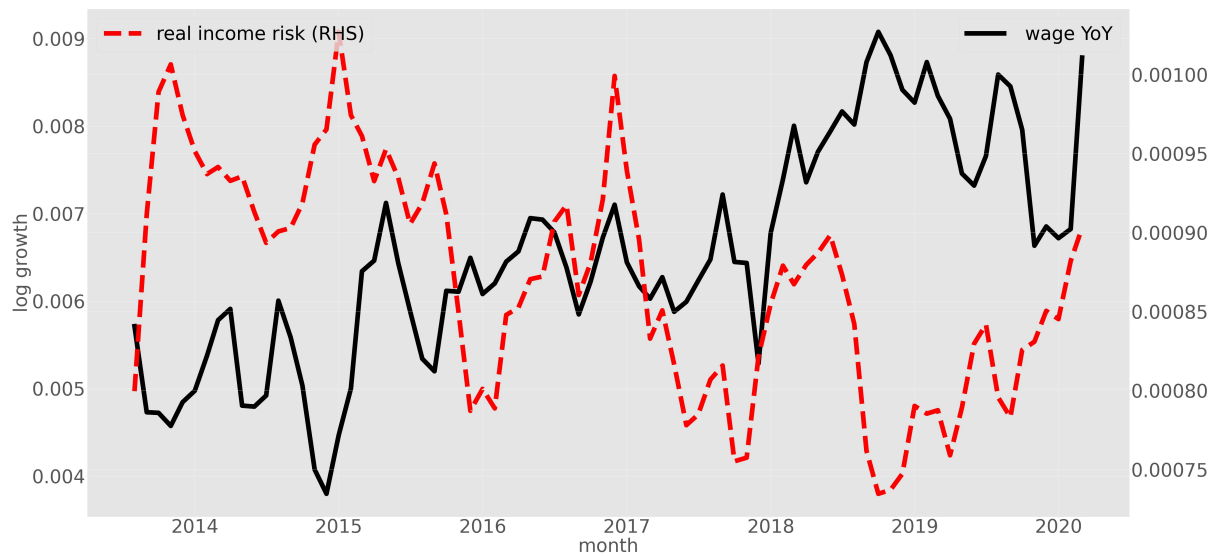
Note: this figure plots average perceived income risks by the decile of annual earning of the same individual.



**Figure 4:** Perceived and Realized Earning Risks

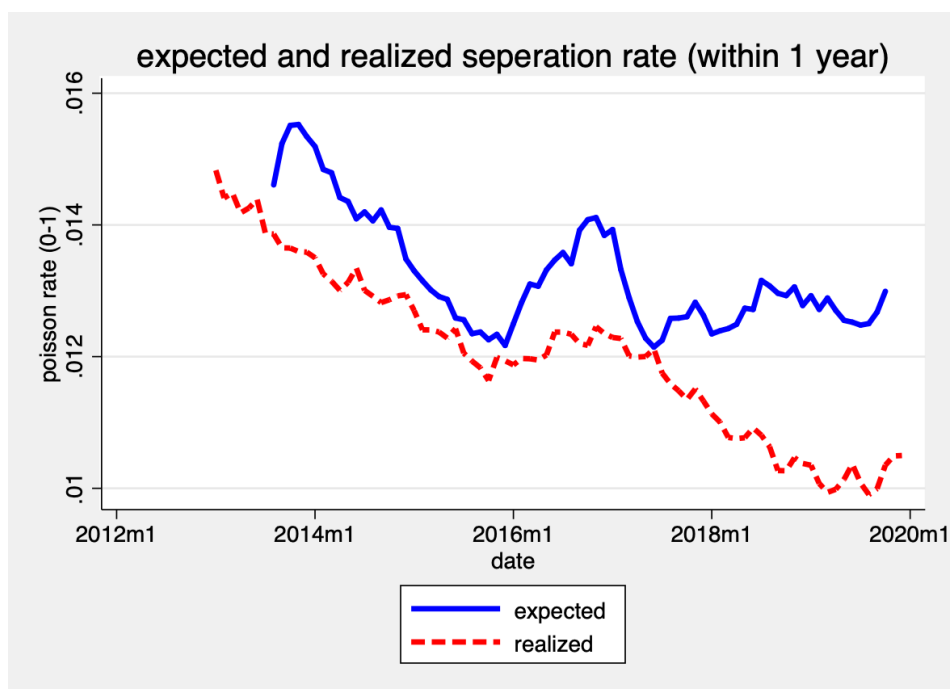
Note: this figure plots median perceived income risks in the whole SCE sample against the realized volatility, permanent, and transitory risks over the same period. The realized risks are first estimated monthly from SIPP and then aggregated into annual frequency. Specifically, the permanent risks are the sum of monthly permanent risks and the annual transitory risks are the simple average over the corresponding 12 months.

**Figure 5:** Recent Labor Market Conditions and Perceived Risks

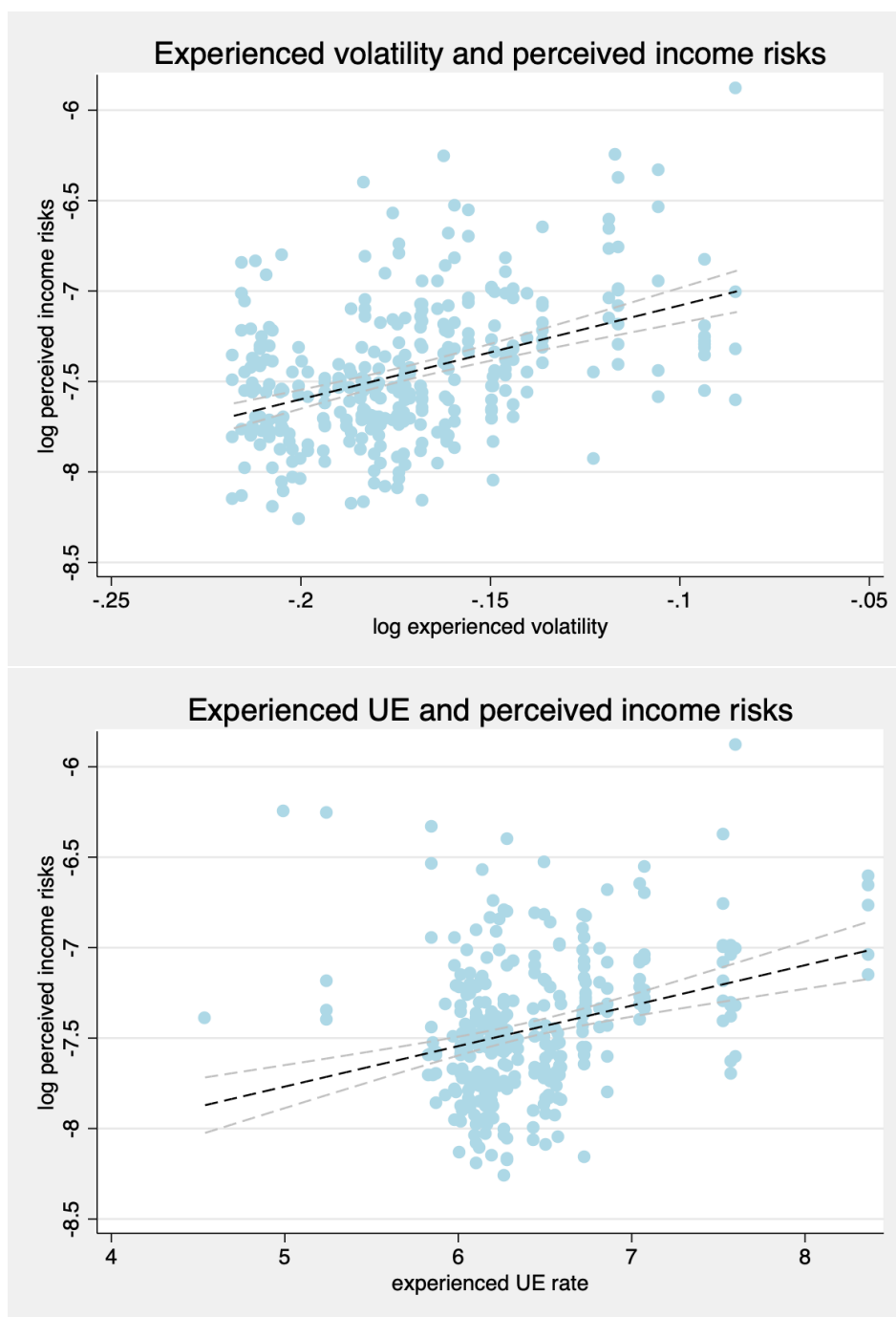


Note: recent labor market outcome is measured by hourly wage growth (YoY). The 3-month moving average is plotted for both series.

**Figure 6:** Expected and Realized Job-separation rate

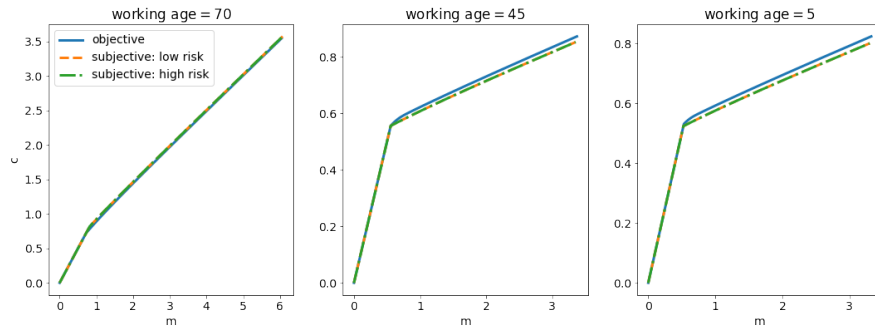


Note: realized job separation rate is computed from CPS. Both are expressed as Poisson arrival rates in continuous time with one month as the unit of time. The 5-month moving average expected rate is plotted.

**Figure 7:** Experience and Perceived Income Risk

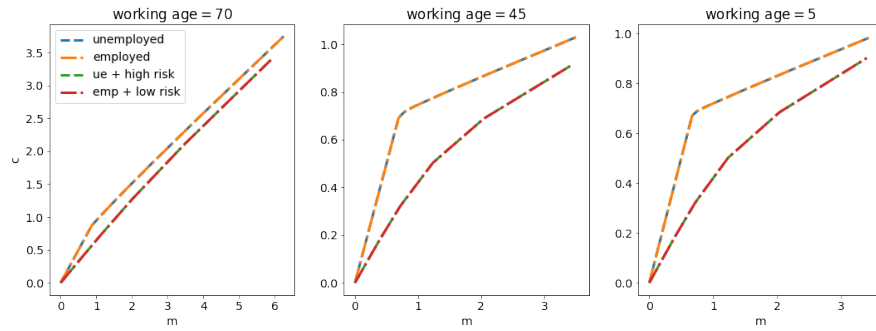
Note: the experienced income volatility is the cross-sectional variance of log change in income residuals estimated using a sub sample restricted to the lifetime of a particular group. For instance, the life experience of a 25-year old till 2015 spans from 1990-2015. The perceived income risk is the average across all individuals from the cohort in that year. Cohorts are time/year-of-birth specific and all cohort sized 30 or smaller are excluded.

**Figure 8:** Consumption functions under objective and subjective risk profiles



Note: this figure plots an example of age-specific optimal consumption policies under objective and subjective state-dependent income risk profiles, respectively. The two models use the exact same parameter configurations except for the subjective model having agents to stochastically draw a low or high risk perception. Both the average size of transitory and permanent risks are kept equal to that in the objective model.

**Figure 9:** Consumption functions under objective and state-dependent risk profiles



Note: this figure plots age-specific optimal consumption policies under objective and subjective extrapolative model. The former model includes persistent unemployment risks while the latter maintains the same transition probability of employment status but allows the risk perceptions to be dependent upon the employment status of the individual, i.e. unemployed perceive income risks to be higher than the employed.

**Table 1:** Current Labor Market Conditions and Perceived Income Risks

	mean:var	mean:iqr	mean:rvar	median:var	median:iqr	median:rvar
0	-0.28**	-0.42***	-0.48***	-0.16	-0.16	-0.53***
1	-0.44***	-0.54***	-0.51***	-0.02	-0.02	-0.53***
2	-0.39***	-0.44***	-0.43***	-0.05	0.0	-0.45***
3	-0.44***	-0.47***	-0.41***	-0.09	-0.06	-0.5***
4	-0.29**	-0.38***	-0.32***	-0.19	-0.14	-0.5***

\*\*\*  $p < 0.001$ , \*\*  $p < 0.01$  and \*  $p < 0.05$ .

This table reports correlation coefficients between different perceived income moments (inc for nominal and rinc for real) at time  $t$  and the quarterly growth rate in hourly earning at  $t, t - 1, \dots, t - k$ .

**Table 2:** Average Perceived Risks and State Labor Market

	(1) log perceived risk	(2) log perceived risk	(3) log perceived iqr	(4) log perceived iqr
Wage Growth (Median)	-0.05*** (0.01)		-0.03*** (0.01)	
UE (Median)		0.04* (0.02)		0.04*** (0.01)
Observations	3589	3589	3596	3596
R-squared	0.021	0.019	0.025	0.027

\*\*\* p<0.001, \*\* p<0.01 and \* p<0.05.

This table reports regression coefficient of the average perceived income risk of each state in different times on current labor market indicators, i.e. wage growth and unemployment rate. Monthly state wage series is from Local Area Unemployment Statistics (LAUS) of BLS. Quarterly state unemployment rate is from Quarterly Census of Employment and Wage (QCEW) of BLS.



**Table 3:** Extrapolation from Recent Experience

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
income shock squared	0.0225*** (0.00562)	0.0222*** (0.00570)	0.0217*** (0.00562)	0.0207*** (0.00564)	0.000773 (0.000743)	0.00205*** (0.000516)	0.000566 (0.000744)	0.00183*** (0.000515)	0.000614 (0.000745)	0.00184*** (0.000516)
recently unemployed				0.511* (0.260)	0.228*** (0.0330)	0.0895*** (0.0200)				
unemployed since m-8							0.161*** (0.0207)	0.0783*** (0.0121)		
unemployed since y-1									0.138*** (0.0193)	0.0701*** (0.0113)
Observations	3662	3662	3662	3662	3701	1871	3701	1871	3701	1871
R-squared	0.004	0.013	0.016	0.017	0.015	0.030	0.019	0.041	0.016	0.039

Standard errors are clustered by household. \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$  and \*  $p < 0.05$ .

This table reports regression of perceived risks and perceived unemployment risks on recent experiences of income volatility and the dummy indicating if the individual has recently experienced an unemployment.

**Table 4:** Perceived Income Risks, Experienced Volatility and Individual Characteristics

	incvar I	incvar II	incvar III	incvar IIII	incvar IIIII	incvar IIIIII
IdExpVol	4.58*** (0.33)	2.23*** (0.36)	2.69*** (0.39)	2.75*** (0.39)	2.95*** (0.38)	2.94*** (0.39)
AgExpVol	0.04 (0.04)	0.28*** (0.04)	0.34*** (0.05)	0.32*** (0.05)	0.18*** (0.05)	0.20*** (0.05)
AgExpUE	0.14*** (0.02)	0.08*** (0.02)	0.05** (0.02)	0.05* (0.02)	0.04* (0.02)	0.05** (0.02)
age		-0.02*** (0.00)	-0.02*** (0.00)	-0.02*** (0.00)	-0.02*** (0.00)	-0.02*** (0.00)
gender=male			-0.36*** (0.02)	-0.35*** (0.02)	-0.32*** (0.02)	-0.30*** (0.02)
nlit_gr=low nlit			0.09*** (0.02)	0.09*** (0.02)	0.10*** (0.02)	0.09*** (0.02)
parttime=yes					-0.01 (0.02)	-0.02 (0.02)
selfemp=yes					1.25*** (0.03)	-0.00*** (0.00)
UEprobAgg						0.02*** (0.00)
UEprobInd						0.02*** (0.00)
HHinc_gr=low income					0.16*** (0.02)	0.16*** (0.02)
educ_gr=high school				-0.10*** (0.02)	-0.13*** (0.02)	-0.09*** (0.02)
educ_gr=hs dropout				0.08 (0.11)	0.11 (0.11)	0.29*** (0.11)
N	41422	41422	34833	34833	33480	29687
R2	0.01	0.02	0.04	0.04	0.11	0.06

Standard errors are clustered by household. \*\*\* p<0.001, \*\* p<0.01 and \* p<0.05.

This table reports results associated a regression of logged perceived income risks (incvar) on logged idiosyncratic(IdExpVol), aggregate experienced volatility(AgExpVol), experienced unemployment rate (AgExpUE), and a list of household specific variables such as age, income, education, gender, job type and other economic expectations.

**Table 5:** Perceived Income Risks and Household Spending Plan

	(1)	(2)	(3)	(4)	(5)	(6)
perceived earning risk	8.394*** (1.175)	8.399*** (1.176)	3.642*** (0.533)	3.243*** (0.537)		
perceived earning risk (nominal)					3.656*** (0.990)	
perceived ue risk						0.353*** (0.0553)
R-squared	0.0010	0.00282	0.928	0.928	0.941	0.633
Sample Size	53178	53178	53178	53178	54584	6269
Time FE	No	Yes	No	Yes	Yes	No
Individual FE	Yes	No	Yes	Yes	Yes	Yes

Standard errors are clustered by household. \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$  and \*  $p < 0.05$ .

This table reports regression results of expected spending growth on perceived income risks (incvar for nominal, rincvar for real).

**Table 6:** Estimated subjective risk perceptions

	baseline
q	0.792
p	0.792
$\tilde{\sigma}_{\psi^l}$	0.456
$\tilde{\sigma}_{\theta^l}$	0.089
$\tilde{\sigma}_{\psi^h}$	0.456
$\tilde{\sigma}_{\theta^h}$	0.089
$\tilde{m}^l$	0.072
$\tilde{E}^l$	0.703
$\tilde{m}^h$	0.359
$\tilde{E}^h$	0.514

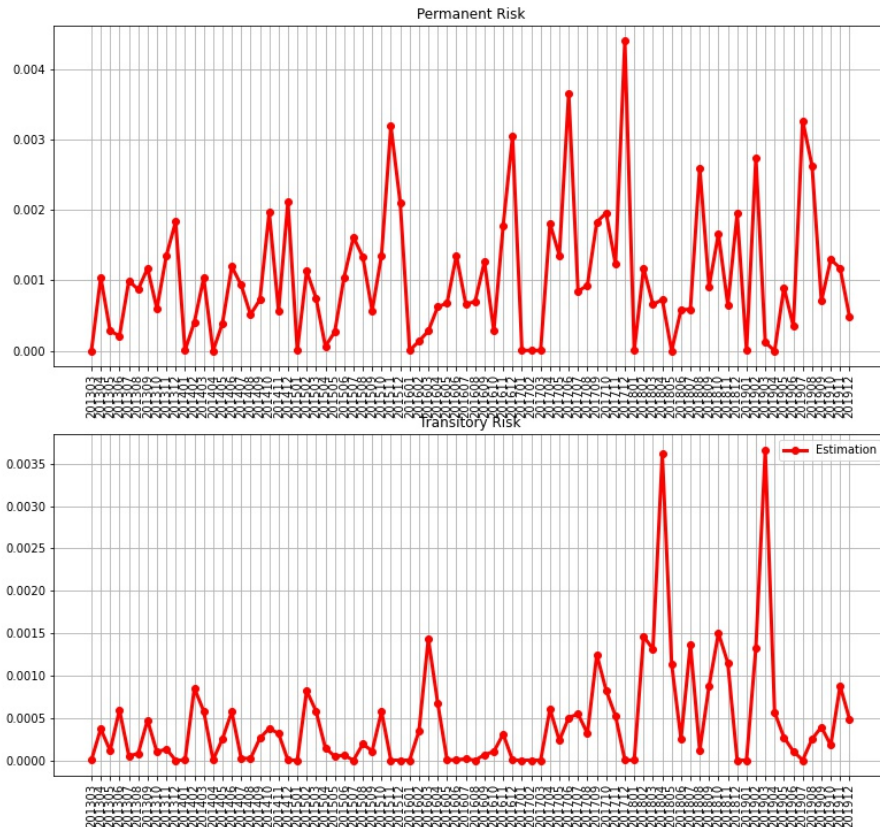
This table reports estimates of the parameters for the 2-state Markov switching model of subjective risk perceptions. Risks are at the monthly frequency.

## A Online Appendix

### A.1 Income risk decomposition under alternative processes

#### A.1.1 Baseline estimation

**Figure A.1:** Monthly permanent and transitory income risks



Note: this figure plots the estimated monthly permanent and transitory risks (variances) from SIPP between 2013m3-2019m12.

**Table A.1:** Estimated realized income risk and perceptions

	PerceivedRisk	PerceivedRisk(median)	RealizedGroupVolatility	RealizedPRisk	RealizedTRisk
full sample (100%)	0.029	0.021	0.090	0.101	0.016
gender					
1 (50%)	0.030	0.022	0.091	0.102	0.016
2 (49%)	0.028	0.022	0.089	0.101	0.016
education					
HS dropout (0%)	0.036	0.022	0.051	0.100	0.016
HS graduate (42%)	0.030	0.022	0.085	0.101	0.016
College/above (56%)	0.028	0.021	0.094	0.101	0.016
5-year age					
20 (2%)	0.037	0.031	0.072	0.102	0.015
25 (12%)	0.032	0.027	0.115	0.102	0.016
30 (12%)	0.030	0.023	0.091	0.101	0.016
35 (13%)	0.029	0.021	0.098	0.101	0.016
40 (13%)	0.028	0.020	0.084	0.101	0.016
45 (14%)	0.028	0.020	0.065	0.101	0.016
50 (15%)	0.027	0.019	0.078	0.101	0.016
55 (15%)	0.027	0.018	0.105	0.100	0.016

This table reports estimated realized annual volatility, risks of different components, and the expected income volatility of different groups. All are expressed in standard deviation units.

### A.1.2 A GARCH model of income risks

### A.1.3 Infrequent arrival of the transitory shocks

## A.2 Results with earning growth expectations

### A.3 Results with PSID data

### A.4 Life-cycle income profile

### A.5 Income risks in the existing literature

**Table A.2:** The size and nature of idiosyncratic income risks in the literature

	$\sigma_\psi$	$\sigma_\theta$	$\hat{U}$	$E$	Earning Process	Unemployment	Source
Huggett (1996)	[0.21, +]	N/A	N/A	N/A	AR(1)	No	Page 480
Krusell and Smith (1998)	N/A	N/A	[0.04, 0.1]	[0.9, 0.96]	N/A	Persistent	Page 876
Cagetti (2003)	[0.264, 0.348]	N/A	N/A	N/A	Random + MA innovations	No	Page 344
Gourinchas and Parker (2002)	[0.108, 0.166]	[0.18, 0.256]	0.003	0.997	Permanent +transitory	Transitory	Table 1
Meghir and Pistaferri (2004)	0.173	[0.09, 0.21]	N/A	N/A	Permanent +MA	No	Table 3
Storesletten et al. (2004)	[0.094; +]	0.255	N/A	N/A	Persistent + transitory	No	Table 2
Blundell et al. (2008)	[0.1, +]	[0.169, +]	N/A	N/A	Permanent + MA	No	Table 6
Kaplan and Violante (2014)	0.11	N/A	N/A	N/A	Persistent	No	Page 1220
Krueger et al. (2016)	[0.196, +]	0.23	[0.046, 0.095]	[0.894, 0.95]	Persistent +transitory	Persistent	Page 26
Carroll et al. (2017)	0.10	0.10	0.07	0.93	Permanent+transitory	Transitory	Table 2
Bayer et al. (2019)	0.148	0.693	N/A	N/A	Persistent time+MA	No	Table 1
My Estimates based on SIPP	0.10	0.016	N/A	N/A	Permanent +transitory	No	Table A.1

This table summarizes the conservative (lower bound) estimates/parameterization on idiosyncratic income risks at the annual frequency seen in the literature.

## A.6 Estimation of the 2-regime switching model of risk perceptions

For each individual  $i$ , we observe at most 12 observations of their perceived income volatility over the earning growth next year  $\tilde{v}ar_{i,t}$  from  $t = 1$  to  $t = 12$ . We assume the following relation between observed survey reported volatility and underlying perceived monthly permanent/transitory risks by the individual  $i$  at time  $t$ .

$$\log \tilde{v}ar_{i,t} = \log(12\tilde{\sigma}_{i,t,\psi}^2 + 1/12\tilde{\sigma}_{i,t,\theta}^2) + \xi_t + \eta_i + \epsilon_{i,t}$$

$\eta_i$  and  $\xi_t$  are individual and time fixed effect, respectively. The i.i.d shock  $\epsilon_{i,t}$  represents any factor that is not available to economists working with the survey, but affects  $i$ 's survey answers at the time  $t$ . We assume it is normally distributed.

Notice that  $\tilde{v}ar_{i,t}$  alone is not enough to separately identify the perceived permanent and transitory risks. To proceed, I make the following auxiliary assumption: the agent adopts a constant ratio of decomposition between permanent and transitory risks,  $\kappa = \frac{\tilde{\sigma}_{i,t,\psi}}{\tilde{\sigma}_{i,t,\theta}}$ , the value of  $\kappa$  is externally estimated from the realized income data.

With the additional assumption, we can rewrite the equation above, utilizing the fact that risks for one year are the cumulative sum of monthly ones for permanent shocks and the average of monthly ones for transitory shocks.

$$\log(\tilde{v}ar_{i,t}) = \log\left[\left(12 + \frac{1}{12\kappa^2}\right)\tilde{\sigma}_{i,t,\psi}^2\right] + \xi_t + \eta_i + \epsilon_{i,t}$$

We *jointly* estimate a Markov-switching model on perceived volatility  $\log(\tilde{v}ar_{i,t})$ , perceived probability on unemployment status  $\tilde{U}_{i,t}$ , and perceived probability on employment status  $\tilde{E}_{i,t}$ . The



vector model to be estimated can be represented as below.

$$\hat{\Gamma}_{i,t}^s = \tilde{\Gamma}^l + \mathbb{1}(J_{i,t} = 1)(\tilde{\Gamma}^h - \tilde{\Gamma}^l) + \tau_{i,t}$$

where  $\hat{\Gamma}_{i,t}^s = [\log(\hat{\text{var}}_{i,t}), \hat{\tilde{U}}_{i,t}, \hat{\tilde{E}}_{i,t}]'$  is a vector of sized three, consisting of properly transformed reported risk perceptions from the survey, excluding the time and individual fixed effects in a first step regression.  $J_{i,t} = 1$  for high risk state and  $= 0$  if at the low risk state.  $\tau_{i,t}$  is a vector of three i.i.d. normally distributed shocks.

The estimation of 2-regime Markov switching models produces estimates of  $\tilde{\Gamma}_l$ ,  $\tilde{\Gamma}_h$ , the staying probability  $q$ , and  $p$ , and the variance of  $\tau_{i,t}$ . Then the following relationship can be used to recover perceived permanent and transitory risks respectively.

$$\tilde{\Gamma}^l = [\log[(12 + \frac{1}{12\kappa^2})\tilde{\sigma}_\psi^{l2}], \tilde{U}_l, \tilde{E}_l]'$$

$$\tilde{\Gamma}^h = [\log[(12 + \frac{1}{12\kappa^2})\tilde{\sigma}_\psi^{h2}], \tilde{U}_h, \tilde{E}_h]'$$

**Estimation sample** I restrict the sample to SCE respondents who were surveyed for at least 6 consecutive months with non-empty reported perceived earning volatility, separation and job-finding expectations. This left with me 6457 individuals.

## A.7 Solution algorithm of the model

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