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ABSTRACT

Hours Risk and Wage Risk: Repercussions over the Life-Cycle*

We decompose earnings risk into contributions from hours and wage shocks. To distinguish between hours shocks, modeled as innovations to the marginal disutility of work, and labor supply reactions to wage shocks we formulate a life-cycle model of consumption and labor supply. For estimation we use data on married American men from the PSID. Permanent wage shocks explain 31% of total risk, permanent hours shocks 21%. Progressive taxation attenuates cross-sectional earnings risk, but its life-cycle insurance impact is much smaller. At the mean, a one standard deviation hours shock raises life-time income by 11%, a wage shock by 13%.

JEL Classification: D31, J22, J31

Keywords: labor supply, earnings risk, structural estimation, progressive taxation, consumption insurance

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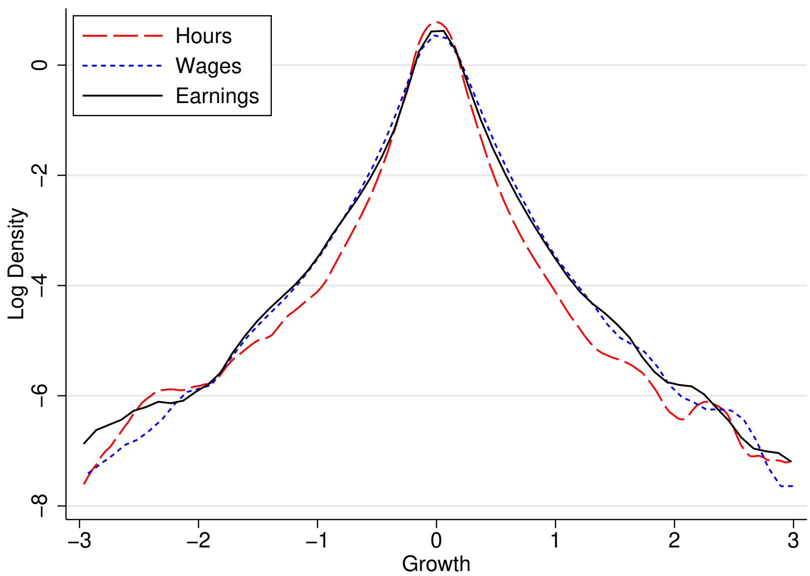
I Introduction

Earnings risk is a central determinant of individuals' welfare. It can be decomposed into wage risk and risk of hours of work. A first glance at the data in Figure 1 suggests that hours and wages contribute similarly to the variance of earnings growth in the United States.[1] While variances give us a first indication, the aim of this paper is to explain earnings risk, that is, unexpected changes in earnings. Hours and wage risk are driven by many ultimate sources, like unexpected changes in remuneration, health, and involuntary unemployment. Quantifying the contributions of wage and hours risk to earnings risk is important not only for our understanding of the common dynamics of these variables, but also to guide the evaluation of policy measures aimed at reducing earnings risk. For instance, if earnings risk was driven almost entirely by hours shocks, focusing on policies that reduce the impact of wage shocks would not be expedient.

Figure 1: Components of Annual Earnings Growth



Note: Log densities of first first differences in log earnings, hours, and wages using main estimation sample of prime age males in the PSID, years 1970-1997, see section III. Note that, as discussed in section III, the share of measurement error in hours is larger than the share of measurement error in wages. Thus, the figure tends to understate the relative importance of hours for the variance in earnings growth.

In this paper, we formulate a structural model of life-cycle labor supply that features earnings risk from both wage and hours shocks and assess the strength of their contributions to total

[1]Studies using data from other countries, namely the Netherlands (De Nardi et al. 2021), Norway (Halvorsen et al. 2020), and Germany (Pessoa et al. 2021), buttress this finding.

earnings risk and life-time earnings. We find that both types of shocks are quantitatively important. Further, we evaluate the insurance offered by progressive taxation, finding that it strongly attenuates cross-sectional earnings risk; transitory shocks more so than permanent ones.[2] Besides the important implications for economic policy, explicitly accounting for hours shocks also has relevant implications for economic modeling. In our model, for example, we find that the estimate of the Marshallian labor supply elasticity is sensitive to the inclusion of hours shocks.

In our model individuals face idiosyncratic shocks to their productivity of market work, captured as wage shocks. For instance, a promotion is a positive permanent wage shock and loss of human capital a negative one. Our concise extension of standard life-cycle models is to introduce hours shocks, which we model as innovations to the disutility of work, which ultimately affect hours of work. These shocks are conceptualized in an analogous fashion to wage shocks. As an illustration, consider the case of one's elderly parent falling ill or being in need of around-the-clock care. This increases the opportunity cost of market work sharply. Depending on the nature of the illness, the shock is permanent or fades out. In terms of observed choices, one would then notice a shock to hours of work. A positive hours shock could be a change in the task content in one's job leading to increased job satisfaction and thus a decrease in the marginal disutility of work. At first glance and considering these illustrations, it may appear that hours shocks capture a lot of very heterogeneous idiosyncratic variation and that—in contrast—wage shocks are narrowly defined and capture only variation in human capital. However, wage shocks also capture more than what one may suspect at first. To name a few examples, the wage shock variation may also come from changes in bargaining power both on the supply- and the demand-side and it may come from labor demand shocks to production. Later on, we show that hours shocks, much like wage shocks, are a pervasive phenomenon that cannot be pinned down to one shock source. Our main goal is the assessment of the relative importance of both channels for total risk, and thus, pinning down the ultimate sources of the shocks is not our primary concern.

In many models wage shocks are the sole drivers of earnings risk. Conveniently, the wage shock process can be estimated using only the moments of wage residuals. This does not hold for the hours shock process. In our setting, hours residuals contain hours shocks *in addition* to labor

[2] Our measure of insurance is the extent to which a mechanism reduces risk. Alternatively one could quantify individuals' willingness to pay for the reduction of specific risks, distinguishing between permanent and transitory shocks.

supply reactions to wage shocks. These reactions are determined by a transmission parameter, which measures the impact of permanent income shocks on the marginal utility of wealth. Thus, without identifying this parameter separating the two shock types is impossible. We suggest a new method to estimate the transmission parameter, which does not rely on the use of consumption data, which are frequently employed for this purpose. The transmission parameter is linked to consumption insurance. The larger it is, the larger is the impact of permanent wage and hours shocks on consumption, and the lower is the degree of insurance against risk. Thus, the parameter is a *sufficient statistic* for all channels of consumption insurance other than progressive taxation. This includes spousal labor supply, self-insurance through precautionary savings, and formal and informal insurance, e.g. disability insurance. We show that the comovement of consumption and earnings implied by our estimate is in line with estimates in Blundell et al. (2008). The identification of the parameter serves an additional purpose. It enables us to calculate the Marshallian labor supply elasticity without the use of consumption or asset data.[3]

We estimate our model using observations on married men in the US from the Panel Study of Income Dynamics (PSID). Our sample starts in 1970 and ends in 1997, when the survey frequency turned biennial. We focus on this group because the extensive labor supply margin plays a small role in their labor supply behavior and in order to compare to the previous literature. We find that the standard deviation of permanent wage shocks is larger than the standard deviation of transitory wage shocks. The same holds for hours shocks, where the standard deviation of permanent shocks is almost twice as large as that of transitory shocks. For the several sub-samples we consider, the standard deviation of permanent hours shocks is larger than that of permanent wage shocks.

The respective impact of various shocks on earnings risk cannot be inferred directly from these estimates. This is because the reaction to shocks depends on the degree of insurance. With the key components of earnings risk in hand, we pursue the variance decomposition that is the main contribution of the paper. We shut down each of the stochastic components except for

[3]Using similar considerations as in our study, the Marshallian elasticity has been estimated using the covariance of earnings and wages as well as asset data in Blundell et al. (2016, eq. A2.23). Heathcote et al. (2014) use the covariance of hours and consumption as well as of wages and consumption to estimate the Marshallian elasticity. In contrast, we rely only on hours and wage data. Heathcote et al. (2014) also estimate a variant that does not rely on consumption data. Their approach differs because their "island"-framework implies that the marginal utility of wealth is constant across individuals in the same age-year cell. We do not assume this.

one in order to quantify the respective contributions to overall earnings risk. Integrating over the distribution of the transmission parameter (as in an average marginal effect), we find that permanent wage shocks explain about 31% of earnings growth risk, while permanent hours shocks explain 21%. Transitory wage shocks dominate transitory hours shocks. Transitory shocks are responsible for about half of earnings growth risk, but only permanent shocks matter in the long run, since they have a substantial impact on life-time earnings. At the mean of the transmission parameter, a positive permanent hours shock of one standard deviation increases life-time earnings by 10.9%, a positive permanent wage shock of one standard deviation increases life-time earnings by 13.2%. At age 30, for an individual with annual net earnings of 50 000 dollars this corresponds to increases in remaining life-time earnings of 87 000 dollars and 106 000 dollars, respectively. Progressive taxation reduces the impact of a permanent shock on life-time income by 16%.

By attenuating the impact of shocks on earnings, progressive taxation offers insurance against earnings risk, reducing it by roughly 41%. The contribution of transitory shocks is reduced by 45%, the contribution of permanent shocks only by about 37%. The reason is that progressive taxation alters individuals' labor supply responses to shocks: it reduces the effect of shocks on the marginal utility of wealth, attenuating the income effect on labor supply.[4] Thus, the progressive tax system is a fairly blunt instrument. It offers insurance against transitory shocks, which is of little value, while it distorts labor supply decisions.

To evaluate the importance of allowing for hours shocks, we consider a set of alternative models that resemble those applied in the literature. Crucially, a model abandoning permanent hours shocks fits the data worse and leads to an overestimation—in absolute terms—of the Marshallian labor supply elasticity.

Finally, we show how our estimate of the transmission parameter can be used to calculate the pass-through of permanent wage shocks to consumption. Setting the parameter of relative risk aversion to two, we find that these pass-through parameters for different samples are roughly in line with those estimated in Blundell et al. (2016), who use consumption and earnings data to estimate this parameter. For the full sample this calculation implies that—on average—a

[4]While the substitution effect amplifies the impact of the shock on earnings, the income effect attenuates the impact of the shock.

permanent increase in wages by 1% leads to an increase in consumption by 0.62%.

Our paper is related to studies that decompose total income risk into persistent and transitory components, which derive from ideas by Friedman (1957) and Hall (1978) (see MaCurdy 1982; Abowd and Card 1989; Meghir and Pistaferri 2004; Guvenen 2007; Blundell et al. 2008; Guvenen 2009; Hryshko 2012; Heathcote et al. 2014; Blundell et al. 2016). Abowd and Card (1989) pioneered the analysis of the covariance structure of earnings and hours of work. They find that most of the idiosyncratic covariation of earnings and hours of work occurs at fixed wage rates.

A strand of the literature has focused on the insurance mechanisms against earnings risks. Blundell et al. (2016) and Blundell et al. (2018) build life-cycle models of family labor supply and, in case of the latter paper, time allocation and quantify the importance of several channels of consumption insurance finding added worker effects to be a relevant source of insurance. Similar to them, we allow for partial insurance of permanent wage shocks, but we depart from their approach by introducing (permanent) hours shocks. We do not differentiate added worker effects from other sources of insurance, rather capturing them all in our *sufficient statistic*, i.e. the transmission parameter of shocks to the marginal utility of wealth. Another related study is Wu and Krueger (2020), which shows, in a calibrated model along the lines of Blundell et al. (2016), the optimal tax progressivity to be much lower in the two-earner case compared to the one-earner case. De Nardi et al. (2021) find that the variance in hours of work is an important contributor to the variance in earnings in both the Netherlands and the US. Insurance through the progressive tax system is more important in the Netherlands, while household insurance plays a larger role in the US.

With a similar focus, Heathcote et al. (2014) analyze the transmission of wage shocks to hours in a setting where shocks are either fully insurable or not insurable at all ("island"-framework). They derive second hours-wage moments from which they identify variances of shocks, the Frisch elasticity of labor supply, and the coefficient of relative risk aversion. Our study differs in two important aspects: First, we assume that shocks are partially insurable as indicated by a consumption insurance parameter similar to Blundell et al. (2008, 2013, 2016). This parameter may differ between individuals. Second, we introduce hours shocks and estimate their variances as well as their contributions to earnings risk.[5]

[5]While Heathcote et al. (2014) allow for initial heterogeneity between agents in the disutility of work, they hold

Many microeconometric papers focus on specific ultimate shock sources and employ dynamic programming techniques for this purpose. Low et al. (2010) quantify the contributions of productivity shocks, job losses, and job offers to overall earnings risk. They find that wage risk is much more important than job destruction risk due to the transitory nature of the latter. They model labor supply as a discrete decision with fixed hours of work and the possibility of job loss, while we focus on the intensive margin of work hours and allow for hours adjustment and permanent as well as transitory shocks to hours. Similarly, Kaplan (2012) models consumption and hours of work and allows for involuntary unemployment shocks. These shocks along with a specific preference structure aid in the modeling of the declining inequality in hours worked over the first half of the life-cycle.

Altonji et al. (2013) quantify the earnings variance contributions of i.i.d. wage and hours shocks in addition to employment and job changes. Hoffmann and Malacrino (2019) decompose changes in annual earnings in Italy into changes in weekly earnings and changes in employment time. They find that the latter generate the tails in the earnings growth distribution. In Norwegian data, Halvorsen et al. (2020) find a prominent role for hours driving large earnings changes. In contrast to those papers, we work with a fully specified structural model, which allows us to quantify the contributions of hours and wage shocks to earnings risk.

In macroeconomics, modeling shocks to the disutility of work is quite common. In dynamic stochastic general equilibrium (DSGE) models these labor supply shocks, modeled as AR(1)-processes as in our model, are important determinants of output and real wage fluctuations (Smets and Wouters 2003; Adolfson et al. 2007; Galí et al. 2012; Justiniano et al. 2013; Foroni et al. 2018). However, in those models the shocks are to aggregate labor supply, while ours are individual-specific.

The next section outlines the life-cycle model of labor supply and consumption, in Section III we sketch the estimation procedure for shock variances and labor supply elasticities, while a detailed description is given in Online Appendix G. In Section IV we present the fit of our model and the parameter estimates for the wage and hours processes as well as the Frisch and Marshallian labor supply elasticities. Then we show decompositions of residual earnings growth variance and risk, which quantify the importance of wage and hours shocks as well as

this parameter constant over the life-cycle.

the impact of progressive taxation. Further, we calculate the impact of the two shock types on life-time earnings. In Section V we show shock process parameters in various subsamples, show results when varying the modeling assumptions, and benchmark our results by relating them to consumption insurance estimates in the literature. Section VI concludes.

II The Model

In our model of male labor supply, individuals maximize the discounted sum of utilities over their lifetime, which runs from t_0 to T. We omit individual-specific subscripts:

$$\max_{c_t,h_t} E_{t_0}\left[\sum_{t=t_0}^{T} \rho^{t-t_0} \mathrm{v}(c_t, h_t; b_t)\right], \tag{1}$$

where c_t is annual consumption, h_t denotes annual hours of work, and b_t contains taste shifters. ρ denotes a discount factor and $\mathrm{v}(\cdot)$ an in-period utility function.

The budget constraint is

$$\frac{a_{t+1}}{(1+r_t)} = a_t + \chi\,(w_t h_t)^{1-\tau} + (1-\tau_N)\,N_t - c_t, \tag{2}$$

where a_t represents assets, w_t the hourly wage, r_t the real interest rate, and N_t non-labor income, which contains spousal and other sources of income. We assume that there are no shocks to N_t, i.e., it is known in advance. We discuss this assumption below. We obtain net labor income from the power-function approximation (Feldstein 1969; Heathcote et al. 2017) with progressivity parameter $1-\tau$.[6] $1-\chi$ would be the tax rate if τ was equal to zero. Note that this specification also allows for transfers. Allowing for transfers is key as benefit programs are an important source of insurance of workers. In the PSID net income includes transfers and the fit of the approximation has been shown to be good even at low gross income where transfers are relevant (Heathcote et al. 2017). Net non-labor income is determined by the net-of-tax rate $(1-\tau_N)$.

[6]We use the power-function approximation for labor income taxation as it allows to model a progressive tax system, while staying tractable in the structural equations we derive for estimation. Related studies using this approximation are Blundell et al. (2016) and Heathcote et al. (2017). These studies show that the approximation fits the data very well with an R^2 often exceeding 0.9.

Instantaneous utility takes the additively-separable constant relative risk aversion (CRRA) form

$$\mathrm{v}_t = \frac{c_t^{1-\vartheta}}{1-\vartheta} - b_t \frac{h_t^{1+\gamma}}{1+\gamma}, \qquad \vartheta \geq 0, \gamma \geq 0. \tag{3}$$

We specify $b_t = \exp(\varsigma \Xi_t - \upsilon_t)$. Ξ_t is a set of personal characteristics. υ_t is an idiosyncratic disturbance with mean zero and innovations to this term are the hours shocks. They capture unexpected changes in the disutility of work, e.g., childcare or spousal needs, sickness, and unexpected changes in productivity at home. Thus, b_t captures taste-shifters in a very broad sense. In practice, hours shocks may also arise due to demand side restrictions on working hours, which is further explored below and in Appendix B. These restrictions are also captured by our estimates of hours shocks. Under certain conditions, shocks to the disutility of work are observationally equivalent to shocks to time endowment (as in Kaplan 2012). Thus, one can also think of υ_t as disturbances to available work time. Because we allow idiosyncratic heterogeneity only for b_t and wages, we impose a separation between those shocks that immediately affect hours and those that affect wages.

We model taste shifters as deriving from observed heterogeneity and a shock process. An alternative, given in Theloudis (2021), is to not explicitly choose a functional form for the disutility from work and, instead of a shock process, let both labor supply and consumption preferences vary. Seen from this alternative viewpoint, our shock processes may also capture heterogeneity in Frisch labor supply elasticities. Our estimation in first differences eliminates fixed heterogeneity in the level of labor supply. Importantly, Theloudis (2021) reports sizable preference heterogeneity in consumption preferences and fairly small heterogeneity in labor supply preferences.

We do not explicitly model female labor supply and assume that there are no shocks to spousal income, which is a simplification in line with our choice of the estimation sample consisting of households where males are prime earners. If leisure times of the spouses are neither complements nor substitutes, wage shocks to spouses are uncorrelated, and permanent female wage shocks do not significantly affect the marginal utility of wealth for males, our more parsimonious modeling choice is innocuous. In a different PSID sample, Blundell et al. (2016) find evidence that leisure times are complements. If the same was true for our sample, some of the reactions of male labor supply to changes in female labor supply are captured by hours shocks. We estimate the Frisch elasticity using IV, making the estimate robust to correlation in wage shocks of spouses. Further, Blundell et al. (2016) do not find any evidence that permanent wage shocks of males and females are correlated, which lends support to our more parsimonious specification. However, shocks to female wages may impact male labor supply through their impact on the marginal utility of wealth. The relevance of this channel rises with the share of female earnings in total household earnings. In our sample the share of male earnings is on average roughly 80% (see Appendix D). Thus, male earnings dominate household income. Still, our estimation of permanent hours shocks supposes no transmission. We use a back-of-the-envelope calculation to assess the importance of this assumption. When we set the Marshallian elasticity of male labor supply to female wage shocks and the variance of female permanent wage shocks to the estimates in Blundell et al. (2016), we find that about 14% of idiosyncratic earnings growth variance attributed to permanent shocks to male hours is due to permanent shocks to female wages.[7] Setting the Marshallian elasticity to the estimate in Blundell et al. (2016) is an upper bound as the share of male earnings in household earnings is about ten percentage points lower in their sample compared to our sample. To sum up, although we do not explicitly model female labor supply, we obtain unbiased estimates of the Frisch and Marshallian labor supply elasticities and our estimate of the permanent wage shock variance would be slightly smaller if we explicitly accounted for the effects of shocks to female earnings. Further, our estimate of the transitory hours shock variance will also be biased under non-separable preferences because it contains Frisch reactions to female wage shocks. However, transitory shocks are of minor importance from a welfare perspective.

Overall, the set-up of the model is standard, but our concise extension of the previous literature consists in introducing dynamics to the taste shifter.

Wage and hours shock processes — Denote by Δ the first difference operator. Wage growth is determined by human capital related variables X_t, which contains $\Delta\Xi_t$, and an idiosyncratic error

[7] $0.0382 \times 0.22^2/0.0136 = 0.1360$, where 0.0136 is our estimate for idiosyncratic earnings growth variance due to permanent shocks to male hours at the mean of the Marshallian labor supply elasticity (i.e., $\phi_t^\lambda = 1.3873$), see equation (I.31). Blundell et al. (2016) report a female permanent wage shock variance of 0.0382 and a Marshallian cross elasticity of men's hours to female wage shocks of -0.22.

ω_t:

$$\Delta \ln w_t = \beta X_t + \Delta\omega_t \tag{4}$$

Idiosyncratic hours (υ_t) and wage (ω_t) components consist of permanent and transitory components, $\mathcal{P}_t$ and $\mathcal{T}_t$, which follow a random walk and an MA(1)-process[8], respectively. For $x \in \{\upsilon, \omega\}$ these are given by:

$$\begin{aligned} x_t &= \mathcal{P}_t^x + \mathcal{T}_t^x \\ \mathcal{P}_t^x &= \mathcal{P}_{t-1}^x + \zeta_t^x \\ \mathcal{T}_t^x &= \theta_x \epsilon_{t-1}^x + \epsilon_t^x \\ E\left[\zeta_t^x \zeta_{t-l}^x\right] &= 0, \quad E\left[\epsilon_t^x \epsilon_{t-l}^x\right] = 0 \quad \forall l \in \mathbb{Z}_{\neq 0}. \end{aligned}$$

Permanent (ζ_t^x) and transitory shocks (ϵ_t^x) have mean zero and variances $\sigma^2_{\zeta,x}$ and $\sigma^2_{\epsilon,x}$, respectively. Note that hours and wage shocks contain only individual-specific shocks as Ξ_t contains year dummies. Note that we do not require the shocks to be distributed according to a specific probability function. A number of recent papers, e.g. Guvenen et al. (2021), find important non-normalities in earnings processes. As we do not estimate higher-order moments, we do not need to make any assumptions about these. Permanent and transitory hours and wage shocks are uncorrelated. If shocks in wages and hours were positively correlated, then we would underestimate transmission of wage shocks to the marginal utility of wealth (see Eq. (G.26) in the Online Appendix). In Appendix B, we discuss the implications of potential hours restrictions, which might be due to demand side constraints, for our estimations. If innovations in hours restrictions and wage shocks are uncorrelated, hours shocks additionally capture innovations to restrictions, while the interpretation of all other estimates remains unchanged. If, in contrast, innovations to restrictions are correlated with wage shocks, this biases the estimate of the transmission parameter.

[8] In a robustness check we change the transitory process to not have any persistence. This has a small impact on our main results: the transitory hours shock variances are slightly smaller and the permanent hours shock variances are slightly larger, while the transmission parameter and the Marshallian elasticity are almost unchanged. The results are shown in Table A.4.

Labor supply — We derive the intertemporal labor supply equation by approximating the first order condition of the optimization problem with respect to consumption (see MaCurdy (1981), Altonji (1986), and Online Appendix E):

$$\Delta \ln h_t = \frac{1}{\gamma + \tau} \left[-\ln(1 + r_{t-1}) - \ln \rho + (1 - \tau) \Delta \ln w_t - \varsigma \Delta \Xi_t + \eta_t + \Delta \upsilon_t \right], \tag{5}$$

where $\frac{1}{\gamma}$ is the Frisch elasticity of labor supply, $\frac{1-\tau}{\gamma+\tau}$ is the tax-adjusted Frisch elasticity, and η_t is a function of the expectation error in the marginal utility of wealth.[9] $\frac{1-\tau}{\gamma+\tau}$ is identified by estimating equation (5) using instrumental variables for $\Delta \ln w_t$.

In what follows, we want to estimate the variances of the permanent and transitory shock components contained in υ_t and η_t, where the latter contains adjustments to wage shocks. To this end, we first make explicit how wage and hours shocks transmit into changes in permanent income, which, in turn, result in changes in the marginal utility of wealth.

Denote by $\widehat{\Delta x}$ idiosyncratic changes in x. Then $\widehat{\Delta lny_t}$ are changes in log net earnings that result from wage and hours shocks, where $y_t = \chi (w_t h_t)^{1-\tau}$. It is useful to group these into transitory and permanent changes, distinguished by the superscripts $\mathcal{T}$ and $\mathcal{P}$, respectively:

$$\widehat{\Delta lny_t} = (1 - \tau) \left[\widehat{\Delta lnw_t^{\mathcal{P}}} + \widehat{\Delta lnw_t^{\mathcal{T}}} + \widehat{\Delta lnh_t^{\mathcal{P}}} + \widehat{\Delta lnh_t^{\mathcal{T}}} \right] \tag{6}$$

The expressions for transitory and permanent wage changes in terms of shocks are obtained directly from the wage process:

$$\widehat{\Delta lnw_t^{\mathcal{T}}} = \epsilon_t^{\omega} + (\theta_\omega - 1)\epsilon_{t-1}^{\omega} - \theta_\omega \epsilon_{t-2}^{\omega} \tag{7}$$

$$\widehat{\Delta lnw_t^{\mathcal{P}}} = \zeta_t^{\omega}. \tag{8}$$

Note that in the case of transitory wage changes, everything apart from ϵ_t^{ω} is known to the agent at $t-1$. In contrast, the idiosyncratic wage change due to permanent shocks is entirely

[9] $\eta_t = \frac{\varepsilon_{\lambda_t}}{\lambda_t} - O\Big(-1/2(\varepsilon_{\lambda_t}/\lambda_t)^2\Big)$, i.e., it contains the expectation error (ε_{λ_t}) of the marginal utility of wealth (λ_t) and the approximation error.

surprising. Write idiosyncratic hours changes as

$$\widehat{\Delta \ln h_t} = \widehat{\Delta ln h_t^{\mathcal{P}}} + \widehat{\Delta ln h_t^{\mathcal{T}}} = \frac{1}{\gamma + \tau} \left[(1-\tau)\widehat{\Delta \ln w_t} + \eta_t + \Delta \upsilon_t \right]. \tag{9}$$

We make the simplifying assumption that transitory shocks do not impact η_t.[10] Thus, the expressions for transitory hours changes in terms of shocks follow immediately from the stochastic processes of transitory shock components and the Frisch labor supply equation (9):

$$\widehat{\Delta ln h_t^{\mathcal{T}}} = \frac{1}{\gamma + \tau} \left(\epsilon_t^{\upsilon} + (\theta_{\upsilon} - 1)\epsilon_{t-1}^{\upsilon} - \theta_{\upsilon}\epsilon_{t-2}^{\upsilon} + (1-\tau) \left(\epsilon_t^{\omega} + (\theta_{\omega} - 1)\epsilon_{t-1}^{\omega} - \theta_{\omega}\epsilon_{t-2}^{\omega} \right) \right). \tag{10}$$

In our model, the expectation error η_t is a linear function of unexpected permanent changes to gross income. We derive the expression in Online Appendix F by approximating the life-time budget constraint as in Blundell et al. (2013, 2016).

$$\eta_t = -\phi_t^{\lambda}(1-\tau) \left(\widehat{\Delta ln w_t^{\mathcal{P}}} + \widehat{\Delta ln h_t^{\mathcal{P}}} \right), \quad \ln \phi_t^{\lambda} \sim N\left(\mu_{\phi}, \sigma_{\phi}^2\right). \tag{11}$$

The formula is intuitive: a permanent change in gross income, given by $\widehat{\Delta ln w_t^{\mathcal{P}}} + \widehat{\Delta ln h_t^{\mathcal{P}}}$, is transformed into a change in net income by the factor $(1-\tau)$, and this change in net income impacts the marginal utility of wealth with the factor ϕ_t^{λ}. The transmission parameter ϕ_t^{λ} is a *sufficient statistic* for consumption insurance. Consumption reactions to shocks are adjusted by $-\eta_t/\vartheta$.[11]

The degree of consumption insurance is determined by various factors. One crucial determinant is the ratio of human wealth to total wealth: for individuals who have accumulated substantial assets, remaining life-time earnings only play a relatively small role in their total wealth. These individuals do not adjust their consumption by much in response to a shock. But consumption insurance goes beyond self-insurance. For instance, it may be based on family

[10] A long time horizon implies that transitory shocks have a negligible impact on the marginal utility of wealth. Blundell et al. (2008) show that this holds empirically for their full sample and various subsamples.

[11] This can be seen by taking logs of the first derivative of equation (3) with respect to c_t, see equation (13) below. Under the assumptions for the proof in Online Appendix F, the transmission parameter ϕ_t^{λ} is determined by the preference parameter ϑ and the ratio of human wealth to total wealth.

insurance, e.g. when parents help their children out in case of a negative wage shock. In the case of full insurance, $\phi_t^\lambda = 0$ and shocks do not affect consumption. In the case of no insurance, $\phi_t^\lambda = \vartheta$. It is reasonable to expect that there is at least some degree of insurance, which implies that the estimate of $E[\phi_t^\lambda]$ is a lower bound for the average degree of relative risk aversion ϑ.

Positive income shocks lead to a decrease in the marginal utility of wealth, therefore ϕ_t^λ is positive and should follow a distribution with no support on negative values. Hence, we estimate the model under the assumption that ϕ_t^λ is lognormally distributed.

Note that the change in hours worked in equation (11) is an endogenous choice. Inserting equation (8) into (11) and subsequently (11) and (10) into (9) and solving for $\widehat{\Delta lnh_t^{\mathcal{P}}}$ yields the expression for idiosyncratic permanent changes in hours of work:

$$\widehat{\Delta lnh_t^{\mathcal{P}}} = \frac{(1-\tau)-(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}\zeta_t^\omega + \frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}\zeta_t^\upsilon \qquad (12)$$

The term $\kappa_t = \frac{(1-\tau)-(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ gives the uncompensated reaction to a gross permanent wage change, the tax-adjusted Marshallian labor supply elasticity. If $\tau = 0$, i.e. if the tax system is proportional, this reduces to the well-known expression $\frac{1-\phi_t^\lambda}{\gamma+\phi_t^\lambda}$, see, e.g., Keane (2011). If $\phi_t^\lambda = 0$, the case of perfect insurance, the Marshallian collapses to the tax-adjusted Frisch elasticity, the reaction to a transitory shock. The transmission coefficient for a permanent hours shock, $\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$, has the same property. The larger ϕ_t^λ, the more dampened are hours shocks. Likewise, an increase in ϕ_t^λ leads to a decrease in the Marshallian reaction to wage shocks. Thus, for positive Marshallian elasticities, ϕ_t^λ dampens the labor supply reaction to wage shocks, while it amplifies the negative labor supply reaction for negative Marshallians.[12]

Equations (5)-(12) describe how wage and hours shocks affect labor supply and in turn income. These equations serve to derive the moment conditions stated in Online Appendix G, which we use for the estimation.

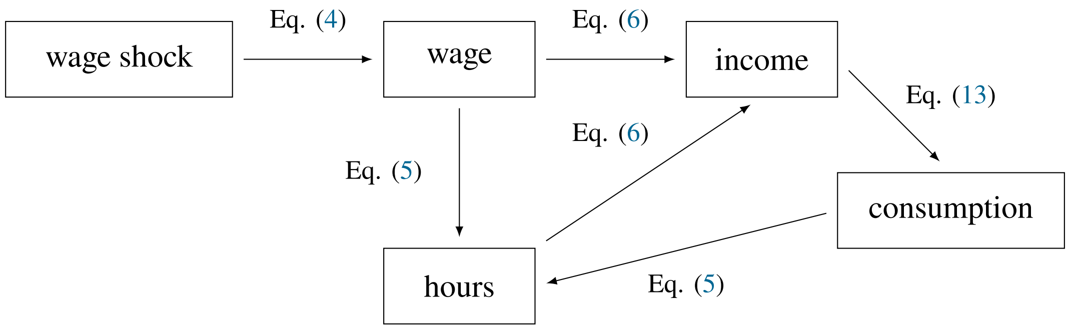
Consumption — The equation for consumption growth can be obtained analogously to equation (5) (see, e.g., Altonji 1986):

[12]Increasing labor supply in response to a negative wage shock is a way of self-insuring. These reactions mitigate the need for precautionary savings (Flodén 2006).

$$\Delta \ln c_t = \frac{1}{\vartheta} \left[\ln(1 + r_{t-1}) + \ln \rho - \eta_t\right] \tag{13}$$

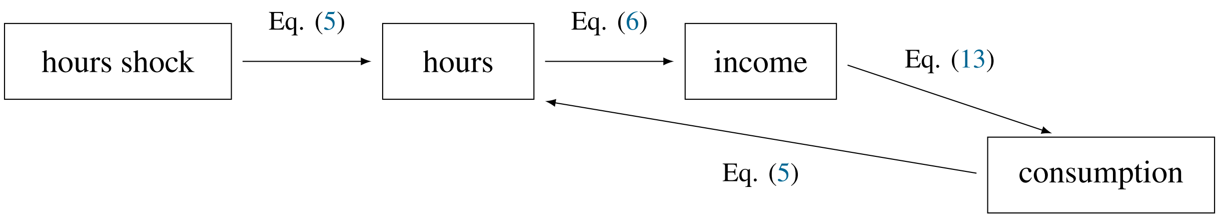
Thus income shocks are directly related to consumption growth by $-\eta_t/\vartheta$. The direct estimation of equation (13) using consumption data is beyond the scope of this study. Nonetheless, we shall benchmark our results in Section V by calculating the reaction of consumption to a permanent wage shock by setting the value of ϑ.

Figure 2: Transmission of Permanent Wage Shock



Note: Labels of arrows indicate corresponding equations.

Figure 3: Transmission of Permanent Hours Shock



Note: Labels of arrows indicate corresponding equations.

Overview — Figures 2 and 3 show how each type of permanent shock propagates through the various quantities of interest. The major distinction for the two shock types is that wage shocks do not only have a direct effect on income, but also affect the choice of hours through the Marshallian elasticity. The arrow from consumptions to hours indicates income effects, i.e., the fact that the marginal utility of consumption impacts the hours choice.

III Methodology and Data

In this section we sketch how the labor supply elasticities as well as the standard deviations of the permanent and transitory parts of idiosyncratic wage components, ω_t, and hours components, υ_t, are recovered in the estimation. We give full details on the procedure in Online Appendix G. After the sketch, we present the procedure to correct for measurement errors and describe the data.

Identification strategy — We proceed through four stages:

1. We regress the log of post-government income on the log of pre-government income to obtain an estimate of the tax progressivity parameter τ. The result of the estimation is found in Table A.1 in Appendix A. Online Appendix G.1 details the procedure.

2. We use OLS to obtain residuals of the wage equation (4) and IV to obtain residuals of the hours equation (5) as well as an estimate for the tax-adjusted Frisch labor supply elasticity. We use human capital related variables and their nonlinear interactions as instruments following MaCurdy (1981); namely we include age, education, education^2, age$\times$education, age $\times$ education^2, age^2 $\times$ education, and age^2 $\times$ education^2. These instruments predict the expected part of wage growth and are thus uncorrelated with innovations in the marginal utility of wealth and measurement error. Using the estimate of τ we can then calculate the unadjusted Frisch elasticity $1/\gamma$. Online Appendix G.2 contains further details on this step. As discussed, e.g., in Pistaferri (2003), the instruments might also be taste shifters, which would threaten their validity. Therefore we also pursue the alternative strategy of setting the Frisch elasticity to different values based on the literature and using constrained least squares to obtain hours residuals, see Table A.3 in the appendix.[13]

3. We estimate the variances of transitory and permanent wage shocks and the persistence parameter of transitory wage shocks by fitting the theoretical variance as well as the first and second autocovariance of residual wage growth to their empirical counterparts using the method of moments. See Online Appendix G.3.

[13]Further, we estimate models for the hours equation that explicitly control for cohort fixed effects. The resulting model estimates, shown in Table A.4, are very similar to our main results. The model fit is also very similar as Figure A.1 shows.

4. To estimate hours shock variances we fit the corresponding autocovariance moments of the hours residuals to the data using the method of moments. The hours residuals contain η_t, which depends on the labor supply reactions to permanent wage shocks, governed by ϕ_t^λ. Therefore, an additional moment, namely the covariance of residual hours and wage growth, is used to identify the mean of ϕ_t^λ. The variance of hours residuals contains both the variance of permanent hours shocks and the variance of ϕ_t^λ as unknown parameters. An equivalent transmission parameter for income shocks to the marginal utility of wealth is estimated in Alan et al. (2018), who assume a lognormal distribution for this parameter. We use their value to calibrate the variance of ϕ_t^λ. In a robustness check in Section V, we show that our estimates are robust to varying this calibration. See Online Appendix G.4 for the derivation of the moment conditions we use for estimation and additional details.

Step 4 builds on steps 1, 2, and 3 as it uses estimates for the wage process parameters and the Frisch elasticity. In total, over all steps, we use seven moments (variance and first and second autocovariance of first differences in log hours and log wages as well as the covariance of differenced log hours and log wages) to estimate seven parameters (three parameters each for the hours and wage processes and the mean of the transmission parameter). The estimated parameters allow us to calculate the tax-adjusted Marshallian labor supply elasticity.

Unless otherwise noted we obtain standard errors using the block bootstrap. Following Blundell et al. (2016), we apply a normal approximation to the interquartile range of draws to avoid standard errors being affected by extreme draws.

Measurement errors — In Online Appendix G we state the variance-covariance moments with measurement error in hours and wages. Measurement error is modeled as having no intertemporal and cross-sectional correlation, but we do allow for correlation between measurement errors in hours and wages to account for division bias. Denote by

$$\ln \tilde{x}_t = \ln x_t + me_{x,t} \tag{14}$$

the observed value for the log of variable x, where $me_{x,t}$ is the mean zero measurement error with variance $\sigma^2_{me,x}$. The variances encountered in the moment conditions are $\sigma^2_{me,h}$, $\sigma^2_{me,w}$, and $\sigma^2_{me,h,w}$, which are the variances of measurement errors in log hours, log wages, and their covariance.

Following Meghir and Pistaferri (2004) and Blundell et al. (2016) we use estimates from the validation study by Bound et al. (1994) for the signal-to-noise ratios of wages, hours, and earnings. As in Blundell et al. (2016), we assume that the variance of the measurement error of hours is $\sigma^2_{me,h} = 0.23var(\ln h)$, the variance of the measurement error of wages is $\sigma^2_{me,w} = 0.13var(\ln w)$, and the variance of the measurement error of earnings is $\sigma^2_{me,y} = 0.04var(\ln y)$, where $var(\ln h)$, $var(\ln w)$, and $var(\ln y)$ denote the variances of the levels of log wages, log hours, and log earnings. The covariance of the measurement errors of log wages and hours is given by $\sigma^2_{me,h,w} = (\sigma^2_{me,y} - \sigma^2_{me,w} - \sigma^2_{me,h})/2$. We correct the theoretical moments using these estimates for the parts that are attributable to error.[14]

The data — We use annual data from the PSID for the survey years 1970 to 1997, which gives 27 years usable for first-differenced estimations. After this point in time the PSID is biennial. In total we have 46 340 observations across individuals and years. Annual hours of work and earnings refer to the previous calendar year. We use hours constructed in the CNEF file of the PSID, that is the sum of annual hours worked including overtime (Lillard 2018). Earnings consist of wages and salaries from all jobs and include tips, bonuses, and overtime. We calculate the hourly wage by dividing gross earnings by hours of work. As hours and earnings are measured with error, a negative correlation between measured hours and wages is induced, which we correct for as described in the previous paragraph. Our sample consists of working, married males aged 28 to 60, who are the primary earners of their respective households. Table 1 shows summary statistics of the main sample. Monetary variables are adjusted to 2005 real values using the CPI-U.

[14]Our estimate for the variance of measurement error in wages is 0.0464, for hours 0.0230, and for the covariance of hours and wage measurement errors -0.0261.

Table 1: Descriptive Statistics - Estimation Sample

	mean	s.d.
Age	41.35	8.66
Annual hours of work	2220.28	530.11
Hourly wage	26.86	22.83
Number of kids in household	1.64	1.39
N	46340	

Note: Monetary values inflated to 2005 real dollars.

IV Main Results

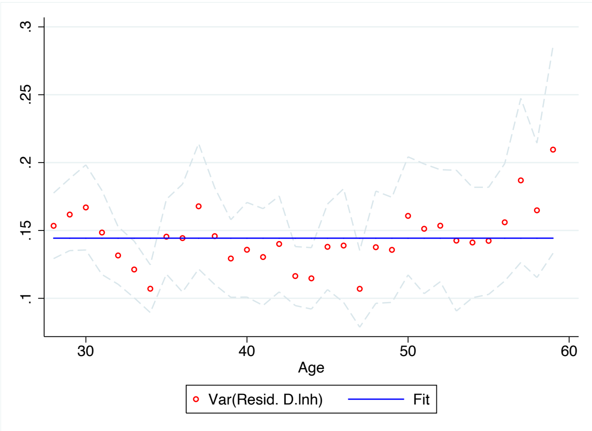
In this section we show the results of our estimation procedure as well as the central exercise of this paper: the decomposition of earnings risk into contributions from wage and hours shocks. We show estimates for the main sample and for three sub-samples. We have constructed these sub-samples because they might differ with respect to their labor supply behavior and exposure to shocks and because they enable consistency checks with the related literature. The first sub-sample excludes young workers under 40, the second consists of individuals with more than high school education, and the third comprises individuals without children younger than seven years in the household.

Model Fit — Figures 4a, 4b and 4c show the hours and wage residual variance series and the covariance over age. The current model does not allow for variation in these targeted variances over age groups and thus imposes that their pattern is essentially flat over the life-cycle. The figures show that these variances do not vary substantially over the life-cycle and do not exhibit a clear life-cycle trend.

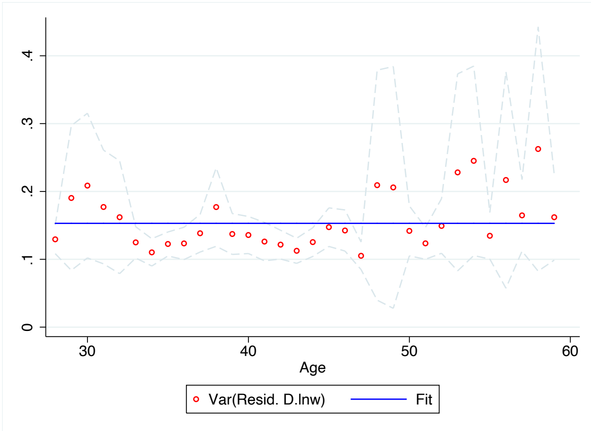
Standard deviations of wage shocks — Table 2 reports the standard deviations of permanent and transitory wage shocks as well as the parameter of transitory shock persistence. First, while the magnitude of the standard deviation of permanent shocks ($\sigma_{\zeta,\omega}$) is similar in the four samples, excluding young workers leads to a decline of this figure. This is in line with the finding of slightly

Figure 4: Fit of Variance and Covariance Moments over the Life-Cycle

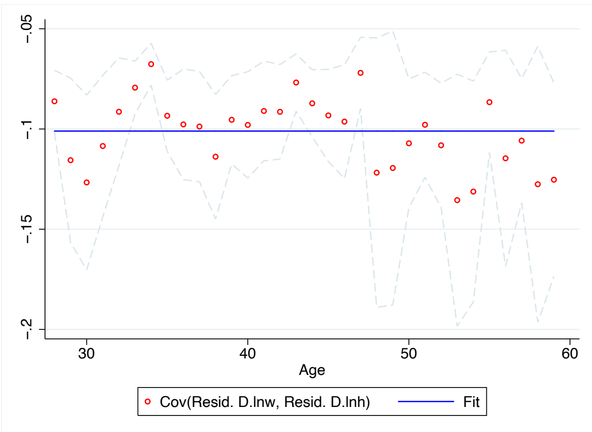
(a) Variance of Hours Residuals



(b) Variance of Wage Residuals



(c) Covariance of Hours and Wage Residuals



Note: Empirical and theoretical variance and covariance moments of residuals obtained from the estimation of equations (4) and (5) for the main sample with bootstrapped 95% confidence interval.

higher variances of permanent wage shocks at younger ages as in Blundell et al. (2016) and Meghir and Pistaferri (2004). Second, for all samples the standard deviation of transitory shocks ($\sigma_{\epsilon,\omega}$) is smaller than that of permanent shocks. Third, the highly educated face a substantially lower standard deviation of transitory shocks than the full sample. Lastly, for those without young children the standard deviations of permanent and transitory shocks are slightly lower than for the full sample.

Table 2: Wage Process Parameters

		I	II	III	IV
		Full sample	Age≥40	High educ	No children <7
θ_ω	persistence	0.2701	0.3450	0.2737	0.1832
	parameter	(0.1167)	(0.2276)	(0.6443)	(0.1356)
$\sigma_{\epsilon,\omega}$	SD transitory	0.1337	0.1382	0.0772	0.1166
	shocks	(0.0238)	(0.0422)	(0.0225)	(0.0361)
$\sigma_{\zeta,\omega}$	SD permanent	0.1770	0.1554	0.1765	0.1639
	shocks	(0.0135)	(0.0176)	(0.0087)	(0.0140)
	N	46340	20607	19831	24547

Note: Bootstrapped standard errors in parentheses (200 replicates).

Standard deviations of hours shocks — The first three rows in Table 3 show the parameters of the process of shocks to the disutility of work. For ease of interpretation and to compare them to wage shocks, which enter the wage equation directly, the parameters are reported as they enter the hours equation (5), i.e. multiplied with $1/(\gamma + \tau)$. The estimates for the standard deviations of the hours shocks are of comparable size to those of the wage shocks. The standard deviation of permanent hours shocks drops when we consider only the highly educated. Apart from that, permanent shocks to the disutility of work are of a fairly consistent size across the samples. For all three subsamples the standard deviation of transitory shocks is lower than in the full sample, however, the persistence of the shocks also differs across samples, being considerably higher for those over 40 and without young children. The magnitude of the standard deviation of permanent hours shocks is a first indicator that these shocks play a significant role for overall earnings risk. However, as described in Section II, the effect of innovations in the marginal disutility of work on earnings depends on the degree of consumption insurance.

In Table A.3 we report results for the main sample, where we do not obtain the tax-adjusted Frisch elasticity via IV, but instead set it to different values and use constrained least squares to obtain hours residuals. Three observations can be made. First, the persistence parameter of transitory hours shocks is larger, the larger the value set for the Frisch elasticity. Second, the standard deviations of hours shocks are robust to changes in the Frisch elasticity. Third, the larger the value of the Frisch elasticity, the smaller the tax-adjusted Marshallian elasticity. For a tax-adjusted Frisch elasticity of 0.1, the tax-adjusted Marshallian is 0.1, while for a tax-adjusted Frisch of 0.6 it is -0.3. The reason is that the covariance between wage residuals and hours residuals, which identifies the Marshallian (see Online Appendix G.4), is smaller, the larger the Frisch elasticity.

Table 3: Hours Process Parameters and Labor Supply Parameters

		I	II	III	IV
		Full sample	Age>=40	High educ	No children <7
$\theta_{\upsilon}/(\gamma+\tau)$	persistence	0.1875	0.4966	0.1406	0.3074
	parameter	(0.0361)	(0.0844)	(0.0975)	(0.1239)
$\sigma_{\epsilon.\upsilon}/(\gamma+\tau)$	SD transitory	0.1113	0.0730	0.0710	0.0787
	shocks	(0.0137)	(0.0169)	(0.0216)	(0.0176)
$\sigma_{\zeta.\upsilon}/(\gamma+\tau)$	SD permanent	0.1990	0.2102	0.1647	0.1915
	shocks	(0.0122)	(0.0425)	(0.0158)	(0.0256)
$(1-\tau)/(\gamma+\tau)$	tax-adjusted	0.3614	0.4020	0.2851	0.3148
	Frisch elasticity	(0.0856)	(0.3778)	(0.0975)	(0.1080)
$E[\phi_t^{\lambda}]$	transmission	1.8917	1.4084	0.5669	0.9564
	parameter	(1.0664)	(2.1307)	(0.5947)	(1.0853)
$E[\kappa_t]$	tax-adjusted	-0.0767	-0.0023	0.1302	0.0631
	Marshallian elasticity	(0.1382)	(0.3234)	(0.1244)	(0.1969)

Note: Clustered standard errors for $(1-\tau)/(\gamma+\tau)$, bootstrapped standard errors for other coefficients in parentheses (200 replicates).

Frisch elasticity — Row 4 in Table 3 reports the estimates of the tax-adjusted Frisch elasticity. In contrast to related papers (Heathcote et al. 2014; Blundell et al. 2016), we obtain the Frisch elasticity directly through IV estimation and not through covariance moments.[15] The estimated

[15] Table A.2 in the appendix additionally displays the Kleibergen and Paap (2006) F statistic, indicating that only sample II might suffer from weak instrument bias and should therefore be interpreted with more caution.

tax-adjusted Frisch elasticity for the main sample is 0.36, which is in line with the literature (Keane 2011). The point estimate of this elasticity increases when excluding younger individuals. In our model this is due to a larger curvature in disutility of labor of the young. An alternative explanation lies outside of our model: Younger individuals could be less willing to reduce their hours of work in the case of a decrease in the hourly wage because the accumulation of human capital impacts their opportunity costs of time (Imai and Keane 2004). Similarly, human capital considerations are more important for the highly educated, where the Frisch elasticity is relatively low.

Transmission parameter ϕ_t^λ — Row 5 in Table 3 shows the estimated mean of the parameter that measures the transmission of shocks to the marginal utility of wealth, $E[\phi_t^\lambda]$. The smaller this parameter, the more insured are individuals against shocks. A value of zero indicates that permanent shocks do not impact the marginal utility of wealth at all. We expect households with larger accumulation of assets relative to human wealth to exhibit smaller values of $E[\phi_t^\lambda]$. The point estimate drops only slightly relative to the full sample when excluding young workers. The estimate is substantially smaller when focusing on those without young children and even smaller when focusing on the highly educated. These changes compared to the main sample are expected because these samples contain older individuals who have higher asset-to-human-wealth ratios.

Marshallian elasticity κ_t — Row 6 in Table 3 reports the average of the tax-adjusted Marshallian elasticity defined in equation (12) as the reaction to a permanent wage shock.[16] The wealth effect outweighs the substitution effect, leading to a negative and small estimate for the main sample, in line with the related literature.[17] The negative Marshallian implies that hours move in the opposite direction of wages and thus function as a consumption smoothing device. When excluding younger workers, the estimate moves closer to zero, signifying virtually no long-term adjustment in hours for older workers. The smaller the average transmission parameter, the closer is the average Marshallian to the Frisch elasticity because the shock has a smaller effect on

[16] We calculate $E[\kappa_t]$ as the numerical expectation $E\left[\frac{(1-\tau)-(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}\right]$.

[17] Blundell et al. (2016, p.414) and Heathcote et al. (2014) find Marshallian elasticities for men of -0.08 and -0.16, respectively. The latter number is obtained by inserting the parameter estimates in the formula for the labor supply reaction to an uninsurable shock (Heathcote et al. 2014, p. 2120). Altonji et al. (2013) report a coefficient that determines "the response to a relatively permanent wage change" of -0.08.

the marginal utility of wealth. The smaller wealth effect for older workers is expected because individuals close to the end of their life-cycle experience the same change to their marginal utility of wealth from either a transitory or a permanent shock. In the sample of households without young children the estimate is positive, thus the substitution effect is the dominant force as the average transmission parameter is relatively small for this sample. The highly educated show the highest positive tax-adjusted Marshallian elasticity due to their very small average transmission parameter. Relatedly, De Nardi et al. (2021) find that the negative covariance between hours changes and wage changes (without adjusting for measurement error) is largest for low-income households and close to zero at higher incomes.

Importance of hours and wage shocks — With the estimation completed, we can proceed to quantify how much the idiosyncratic components contribute to the variation in the growth of wages, working hours, and finally earnings. We start with the total variance of wage and hours growth. The first column in Table 4 shows the total variances of wage and hours growth net of measurement error. The second entry in the first line shows the variance of the predicted component obtained from the OLS estimation of equation (4) and the third entry its share in the total variance of wage growth. The fourth entry shows the variance of the residual of this regression. The fifth entry shows that the residual is responsible for 98.08% of the entire wage growth variance. The predicted component in line two is recovered from the prediction of the second stage of the IV estimation of equation (5), i.e., it contains deterministic hours growth including Frisch reactions to deterministic wage growth. Note that this procedure yields residuals, which contain $\frac{1-\tau}{\gamma+\tau}\Delta\omega_t$, i.e. Frisch reactions to wage shocks, in addition to $\frac{\eta_t+\Delta\upsilon_t}{\gamma+\tau}$, the error term of equation (5). The idiosyncratic component in the fourth column contains hours shocks as well as Frisch and Marshallian reactions to wage shocks. It accounts for 98.65% of the total hours growth variance. In sum, the stochastic components determine the lion's shares of both hours and wage growth variances. Note that the idiosyncratic components can equivalently be calculated from the parameter estimates of the wage and hour processes and the structural parameters reported in Tables 2 and 3.

Table 4: Decomposition of Wage and Hours Growth Variance

	I	II	III	IV	V
	Total	Predicted	% Predicted	Idiosyncratic	% Idiosyncratic
wages	0.0612	0.0012	1.91*	0.0600	98.08
hours	0.0451	0.0006	1.35**	0.0445	98.65

Note: Total variance is computed from observed wage and hours growth net of measurement error. Variances of idiosyncratic terms are the variances of $\Delta\omega_t$ and $\frac{1}{\gamma+\tau}\left((1-\tau)\Delta\omega_t + \eta_t + \Delta\upsilon_t\right)$, respectively, and can be calculated using the estimates in Tables 2 and 3, i.e., excluding measurement error.

*: Variance of the deterministic components in equation (4) estimated via OLS.

**: Variance of the prediction of the second stage of the 2SLS estimation of equation (5).

In the next step, we decompose the cross-sectional variance of stochastic net earnings growth $\left(V\left(\widehat{\Delta \ln y}\right)\right)$ in order to quantify how the residual components shape income. The stochastic component without measurement error is given by the sum of the idiosyncratic wage and hours terms, whose variances are reported in Table 4. Equation (I.30) in Online Appendix I describes how the variance of stochastic net earnings growth is calculated. Note that the variance of stochastic net earnings growth depends on the mean and the variance of the transmission parameter ϕ_t^λ, which are known to individuals. Additionally the realization of transitory components of wage and hours growth are partially known in advance, see equations (7) and (10). Therefore this variance does not equal earnings risk.

The first row of Table 5 shows this variance for the main sample. Rows 2-5 show the contributions of each shock component, i.e., the variance of stochastic net earnings growth when the variances of all other shock components are set to zero. Over the columns we vary the progressivity of the tax system: the first reports values computed with our estimate of τ from Table A.1, the second sets τ equal to zero (proportional tax system), and the third shows the reduction in the variance due to progressivity of the tax system. First, we see that about 44% of the variance is due to transitory wage shocks. Permanent wage shocks are the second biggest contributor driving about a quarter of the variance. Transitory and permanent hours shocks contribute equally to the variance; about 16%. Eliminating progressive taxation increases the total variance considerably. With a proportional tax system, the relative importance of transitory shocks increases slightly because the progressive tax system reduces the variance contribution of transitory shocks of either kind by 45%. In the case of permanent shocks this reduction amounts to 37%. The reduction in total variance due to progressive taxation is 42%.

Table 5: Decomposition of Variance of Idiosyncratic Earnings Growth Variance

	I	II	III
	$\tau = 0.192$	$\tau = 0$	% reduction
$V\left(\widehat{\Delta \ln y}\right)$	0.0786	0.1360	42.17
Contribution of			
trans. wage shocks ($\sigma_{\epsilon,\omega}$)	0.0347	0.0637	45.44
perm. wage shocks ($\sigma_{\zeta,\omega}$)	0.0188	0.0296	36.52
trans. hours shocks ($\sigma_{\epsilon,\upsilon}$)	0.0122	0.0224	45.44
perm. hours shocks ($\sigma_{\zeta,\upsilon}$)	0.0128	0.0202	36.52

Note: First line: variance of $\widehat{\Delta \ln y}$ given by equation (I.30). Lines 2-5 show the variance of $\widehat{\Delta \ln y}$ when all other shock variances are set to zero. Column II shows variances without progressive taxation. Column III shows the variance reduction from column II to I.

As mentioned above, the variance shown in Table 5 does not equal earnings risk. In Table 6 we repeat the exercise of Table 5 using earnings growth risk. Note that permanent changes in net income lead directly to changes in consumption, only mediated through the consumption insurance parameter. Thus earnings risk translates to consumption risk and has immediate welfare implications for risk averse individuals. When evaluating the *risk* of idiosyncratic earnings growth instead of its cross-sectional *variance*, everything that is known to the individual at $t-1$ must be excluded from equation (I.30) and ϕ_t^λ must be treated as non-stochastic. Equation (I.31) in Online Appendix I gives earnings growth risk conditional on the individual's information set in $t-1$, denoted I_{t-1}.[18]

Risk, reported in the first line of Table 6, is roughly 78% of the idiosyncratic net earnings growth variance. The proportions of contributions of hours and wage shocks are quite similar to

[18]For the calculation in Table 6, we integrate over the values of ϕ_t^λ to calculate an average measure of risk. We provide an analogous calculation with ϕ_t^λ set to the sample mean in Table A.5. The results are similar.

the proportions of contributions to the earnings variance. The contributions of transitory shocks are smaller while the absolute contributions of permanent shocks are the same. The reason is that ϕ_t^λ is treated as stochastic for both the calculation of the income variance and the expectation of earning risk over all values of ϕ_t^λ and changes in the permanent wage and hour components are entirely surprising to the individual.[19] Permanent wage shocks contribute 31%, while permanent hours shocks contribute about 21% to total earnings risk.

Table 6: Decomposition of Average Earnings Risk

	I	II	III
	$\tau = 0.192$	$\tau = 0$	% reduction
$V\left(\widehat{\Delta \ln y} \vert I_{t-1}\right)$	0.0614	0.1044	41.18
Contribution of			
trans. wage shocks ($\sigma_{\epsilon,\omega}$)	0.0216	0.0397	45.44
perm. wage shocks ($\sigma_{\zeta,\omega}$)	0.0188	0.0296	36.52
trans. hours shocks ($\sigma_{\epsilon,\upsilon}$)	0.0081	0.0148	45.44
perm. hours shocks ($\sigma_{\zeta,\upsilon}$)	0.0128	0.0202	36.52

Note: The first line shows total earnings risk given by equation (I.31) integrating over the values of ϕ_t^λ. Lines 2-5 show the risk when all other shock variances are set to zero. Column II shows risk without progressive taxation. Column III shows the reduction from column II to I.

Progressive taxation can sensibly be used to insure against permanent shocks, as first discussed by Varian (1980), and recently quantified by Heathcote et al. (2017). The case for using progressive taxation to insure against transitory shocks is much weaker. Individuals can use (dis)saving to self-insure against transitory shocks.[20] Ideally, progressive taxation would only act upon the permanent component of earnings and leave the decisions following transitory shocks undistorted. Yet, progressive taxation acts upon both components, distorting labor supply decisions. In the case of transitory shocks the distortion is not countervailed through valuable insurance. The table reveals that a larger share of transitory shocks than of permanent shocks is insured through progressive taxation. The reason is that the tax-induced attenuation of the labor

[19]Setting ϕ_t^λ to the sample mean (Table A.5) changes these contributions.

[20]In the case of credit constraints, transitory shocks transmit to consumption.

supply reaction to a transitory shock is stronger than the attenuation for a permanent shock. This is because both the income and the substitution effect are dampened by the tax system, and only the latter effect is relevant in the case of transitory shocks.[21]

While transitory shocks are an important driver of the cross-sectional earnings growth variance, only permanent shocks have a large impact on the present value of life-time earnings, which directly relates to individuals' consumption and thus utility. At the mean of the consumption insurance parameter, a positive wage shock of one standard deviation raises earnings by 13.2%, while a one standard deviation hours shock raises earnings by 10.9%.[22] The effect on labor supply of a permanent wage shock of one standard deviation is a decrease of 1.4%, while a one standard deviation permanent hours shock increases labor supply by about 13.5%. Under the scenario of no progressive taxation, a one standard deviation wage shock would decrease labor supply by 4.8%, while an analogous hours shock would raise labor supply by 13.5%. Shocks of the same magnitude with the opposite sign would lead to reactions of the same size as described above but oppositely signed. The calculations above are generally only possible within a structural model. Thus, our way of benchmarking the results is to compare our parameter estimates to those in the literature. Since our estimates for the preference parameters and the wage process are in line with the literature, it follows that the implied magnitudes for shock impacts are also in line with the literature. As concerns life-time impact, a back-of-the-envelope calculation[23] reveals that for an individual with an annual net labor income of 50 000 dollars, aged 30 and retiring at 65, a one-standard-deviation positive permanent wage shock increases the present value of life-time

[21] As an illustration, consider the hours response to a transitory and a permanent hours shock, which derive from Eq. (10) and (12). The impact of a transitory shock on hours is $\frac{1}{\gamma+\tau} * \Delta\upsilon_t$ and when there is no progressive taxation τ is zero. Thus, the relative attenuation through progressive taxation is $1 - \frac{\gamma}{\gamma+\tau}$. Likewise, for permanent shocks the impact is $\frac{1}{\gamma+\tau+(1-\tau)\phi_t^{\lambda}}\xi_t^{\upsilon}$ making the relative attenuation $1 - \frac{\gamma+\phi_t^{\lambda}}{\gamma+\tau+(1-\tau)\phi_t^{\lambda}}$. The attenuation of the income effect can be seen in the denominator. The difference between transitory and permanent attenuation is $\frac{(1+\gamma)\tau\phi_t^{\lambda}}{(\gamma+\tau)(\gamma+\tau+(1-\tau)\phi_t^{\lambda})}$, which is positive. An analogous result can be derived for wage shocks.

[22] These values are obtained from Eq. (6) and sequentially substituting in for the permanent changes from Eqs. (8) and (12). The change in log income due to a one-standard deviation wage shock is $(1-\tau)\left(1 + \frac{(1-\tau)-(1-\tau)E[\phi_t^{\lambda}]}{\gamma+\tau+(1-\tau)E[\phi_t^{\lambda}]}\right)\sigma_{\zeta,\omega}$. The first term in the second set of parentheses gives the direct effect of the wage shock, while the second term gives the effect through the adjustment of labor supply. The change in log income due to a one-standard deviation hours shock is $(1-\tau)\frac{1}{\gamma+\tau+(1-\tau)E[\phi_t^{\lambda}]}\sigma_{\zeta,\upsilon}$.

[23] The present value of life-time earnings is given by the geometric series of discounted earnings up to retirement $y(1-1/R^{65-age})/(1-1/R)$, where the real interest rate R is 1.0448 based on World Bank figures for our period. This present value is multiplied by the percentage change due to the permanent wage and hours shocks to calculate the impact on life-time earnings. The calculation abstracts from deterministic earnings growth, that is, it makes the simplifying assumption that earnings would remain constant without shocks.

earnings by about 106 000 dollars, while a one-standard-deviation positive permanent hours shock increases it by 87 000 dollars.[24] One-standard-deviation permanent wage and hours shocks at age 50 for this individual increase life-time income by 65 000 and 54 000 dollars, respectively.

Without progressive taxation, that is, setting $\tau = 0$, a one-standard-deviation positive permanent wage shock for this individual at age 30 increases life-time income by 125 000 dollars, a one-standard-deviation hours shock increases life-time income by 103 000 dollars. Thus, progressive taxation reduces the impact of permanent shocks over the life-cycle by 16%. In sum, both permanent hours and wage shocks are significant drivers of both cross-sectional and life-time earnings risk and progressive taxation is an important insurance mechanism to reduce the impact of these shocks.

The impact of permanent shocks depends largely on the consumption insurance parameter. In the benchmark case of full insurance with $\phi_t^\lambda = 0$ individuals adjust their hours of work much more in response to a shock to the disutility of work. In this case and with progressive taxation, the impact of a one-standard-deviation permanent wage shock at age 30 is 178 000 dollars because here the Frisch labor supply reaction amplifies the wage shock. The analogous impact of a one-standard-deviation hours shock is 147 000 dollars. These figures correspond to increases by 20% and 16%, respectively.

Another policy that might be used to insure workers against earnings shocks is the minimum wage. A first order effect of a minimum wage would be the reduction of the wage shock variance. However, this reduction in variance would result from the fact that wages now cannot fall below a certain threshold. Extending our model to allow for truncation of wages is beyond the scope of this paper. Nonetheless, an important distinction between progressive taxation and the minimum wage is that progressive taxation also reduces variance and risk from positive hours shocks, which the minimum wage does not. Progressive taxation and minimum wages are equivalent in another important way: they cannot distinguish between shocks that are transitory or permanent. Thus, like progressive taxation, minimum wages are a rather blunt instrument for insurance.

[24]Note that the ratio of the impacts of permanent hours and wage shocks on lifetime earnings equals the square root of the corresponding ratio of contributions to earnings risk reported in Table 6.

V Discussion

In the following discussion we will 1) investigate some potential sources of permanent hours shocks using sub-sample analysis, 2) evaluate alternative model specifications with respect to goodness of fit to determine whether hours shocks are an important feature of the model, and 3) set the parameter of relative risk aversion to calculate partial consumption insurance.

Hours shocks in alternative samples — In order to learn more about the diverse sources of permanent hours shocks, we estimate their standard deviation in alternative samples and, for contrast and convenience, also show the standard deviations of the transitory hours shocks. Column I in Table 7 reports the estimate for the full sample. Column II contains results for a sample of individuals in "blue collar" industries. Individuals in advanced technical sectors, like electrical and mechanical engineering, or skilled service jobs, like legal or medical services, are excluded from the "blue collar" sample.[25] One could expect that the demand for these more routine jobs only allows for very limited variation in hours. However, this does not seem to be the case, as the estimate of the permanent shocks hardly changes. In column III we exclude the years 1981 and 1982, when a global recession hit the US. There is only a modest change to the estimate of the standard deviation of permanent hours shocks, which shows that the results are not driven by this crisis. Finally, in column IV the sample is restricted to individuals who have stayed in their current job for at least 3 years consecutively.[26] This rules out that hours shocks are primarily driven by changes of one's job characteristics. Given that the estimate for the permanent hours shock variance is very close to that of the main sample, we can infer that permanent hours shocks do not merely reflect changes in occupation or job instability. In contrast, the variance of transitory hours shocks in the stayers sample drops sharply, attesting to the transitory nature of the effect of job changes on hours. This change in the magnitude of transitory hours shocks does not appear in any other alternative sample.

The upshot of all of these results is that permanent hours shocks play an important role throughout all samples and are not restricted to very specific adjustments or at-risk groups. The

[25] In particular, individuals in education, sport, legal, health, and other services including service industries, mechanical and electrical engineering, financial institutions, and insurance as well as public administration, social security, private households, volunteering and churches are excluded.

[26] Note that this means that all moments rely only on information from the current job.

fact that hours shocks do not seem to be driven by job changes or possibly unwanted changes in hours of work during crises suggests that they capture very broadly shocks like those due to, e.g., childcare or spousal needs, sickness, and unexpected changes to home production.

Table 7: Hours Shock Standard Deviations in Alternative Samples

		I	II	III	IV
		Main	Blue collar	Exclude years 81-82	Only stayers
$\sigma_{\epsilon,\upsilon}/(\gamma+\tau)$	SD transitory	0.1113	0.1114	0.1140	0.0492
	shocks	(0.0137)	(0.0156)	(0.0124)	(0.0129)
$\sigma_{\zeta,\upsilon}/(\gamma+\tau)$	SD permanent	0.1990	0.2066	0.2064	0.1918
	shocks	(0.0122)	(0.0215)	(0.0163)	(0.0220)
N		46340	32313	40999	29211

Note: Bootstrapped standard errors in parentheses (200 replicates).

Hours shocks and transmission in alternative models — In Table 8 we report the parameters of the hours shock process and the transmission parameter as well as the implied tax-adjusted Marshallian elasticity for the main sample under various restrictions of parameters or alternative assumptions. Further we display a measure of overall fit of these alternative models, namely the value of the distance function $DF(\Theta)$ of the method of moments (see equation (G.27)) as a measure of how well the model fits the data. The estimates of the main model are repeated for comparison in column I.

In column II, the standard deviation of $\ln(\phi_t^\lambda)$ is set to half the value in our main specification. All estimated coefficients except for the standard deviation of permanent hours shocks and the mean of the transmission parameter are virtually unchanged. The standard deviation of permanent hours shocks is slightly larger. The reason is that the variance of the transmission parameter interacts with the variance of hours shocks in explaining the variance of hours growth (equation (G.23) in Online Appendix G). As the model is exactly identified and the variance of permanent hours shocks can freely adjust, the fit is virtually unchanged.[27] In column III, we double the standard deviation of $\ln(\phi_t^\lambda)$ compared to the main specification. Now the standard deviation of

[27]Note that the estimate for the tax-adjusted Marshallian elasticity is unchanged as well. The reason, again, is that the model is exactly identified and μ_ϕ adjusts such that $E[\kappa]$, which results directly from the covariance of hours and wage residuals, is unchanged, see Online Appendix G.

permanent hours shocks is slightly smaller and the mean of the transmission parameter is larger, the latter being a mechanical effect. Again, all other results are virtually unchanged. These exercises demonstrate that the results only depend to a small degree on this calibration.

Table 8: Alternative Models

		I	II	III	IV	V
		Main Model	σ_ϕ halved	σ_ϕ doubled	$\sigma_{\zeta,\upsilon} = 0$	$\sigma_{\epsilon,\upsilon} = 0$
$\theta_\upsilon/(\gamma+\tau)$	persistence	0.1875	0.1875	0.1875	0.1798	
	parameter	(0.0361)	(0.0359)	(0.0361)	(0.0193)	
$\sigma_{\epsilon,\upsilon}/(\gamma+\tau)$	SD transitory	0.1113	0.1114	0.1114	0.1501	
	shocks	(0.0137)	(0.0137)	(0.0137)	(0.0063)	
$\sigma_{\zeta,\upsilon}/(\gamma+\tau)$	SD permanent	0.1990	0.2116	0.1759		0.2782
	shocks	(0.0122)	(0.0161)	(0.0128)		(0.0353)
$E[\phi_t^\lambda]$	transmission	1.8917	1.4316	6.5093	2.4692	1.8898
	parameter	(1.0664)	(0.7081)	(5.0548)	(1.5080)	(1.0656)
$E[\kappa]$	tax-adjusted	-0.0767	-0.0767	-0.0767	-0.1448	-0.0764
	Marshallian elasticity	(0.1382)	(0.1382)	(0.1382)	(0.1535)	(0.1381)
$DF(\Theta)$	distance	1.94×10^{-11}	3.08×10^{-11}	4.1317×10^{-11}	3.82×10^{-05}	4.4474×10^{-05}

Note: Bootstrapped standard errors in parentheses (200 replicates).

In Column IV we set the variance of permanent hours shocks to zero to illustrate the importance of allowing for permanent hours shocks. The estimated variance of transitory hours shocks increases slightly and the estimated mean of the transmission parameter increases to roughly 2.47, doubling the implied Marshallian elasticity. The fit of this model is substantially worse.

For completeness, we set the variance of transitory hours shocks, and thereby also the persistence parameter, to zero in Column V. Now the size of permanent hours shocks increases, but other estimates are virtually unchanged. Again, the fit of the model suffers substantially.

Partial consumption insurance —The parameter ϕ_t^λ is directly related to consumption growth, see equation (13). In our model with endogenous labor supply, permanent wage shocks translate into changes in consumption by $\frac{\phi_t^\lambda(1-\tau)}{\vartheta} \times \frac{1+\gamma}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$. We set $\vartheta = 2$, which is close to the estimates of related papers[28] and calculate the resulting pass-through at mean values of ϕ_t^λ, reported in Table 9. For the full sample we find that, at the mean, a positive permanent wage shock of 1% leads to an increase in consumption by 0.62%.[29] This figure can be compared to studies that use consumption data to obtain similar parameters. Blundell et al. (2016) use PSID data from 1999 to 2009 and find that the Marshallian response of consumption to the male's wage shock is 0.58, when female labor supply is held constant. We obtain a slightly smaller pass-through parameter for the sample of older workers than for the main sample, but find a substantially smaller pass-through for the highly educated, for whom a permanent wage increase by 1% leads to an increase in consumption of just 0.25%. Using a similar data set to ours, PSID data running from 1978 to 1992, Blundell et al. (2008) estimate the pass-through of permanent *income* shocks to consumption, which is given by $(1 - \tau)\phi_t^\lambda/\vartheta$ in our model. They find that college educated individuals are much better insured than the full sample, which concurs with our findings.

Table 9: Pass-through of Permanent Wage Shocks to Consumption

	I	II	III
	$\tau = 0.192$	$\tau = 0$	% reduction
Full sample	0.6179	0.7315	15.53
Age>=40	0.5093	0.6150	17.20
High educ	0.2533	0.3217	21.25
No children <7	0.3904	0.4845	19.41

Note: The pass-through is $\frac{E[\phi_t^\lambda](1-\tau)}{\vartheta} \times \frac{1+\gamma}{\gamma+\tau+(1-\tau)E[\phi_t^\lambda]}$ and we set ϑ=2.

In columns II and III we conduct another tax experiment by setting τ to zero. For the main sample the reduction in pass-through is about 16% in line with the reduction of the impact of permanent shocks on life-time income. For the highly educated the relative reduction is the strongest with about 21%, while the absolute reduction is the strongest for the full sample.

[28]Blundell et al. (2016) estimate a parameter of relative risk aversion of 2.4 and Heathcote et al. (2014) estimate 1.7.

[29]The pass-through is proportional to ϑ. With $\vartheta = 1$ it is 1.236 and with $\vartheta = 3$ it is .4120.

Much of the literature on consumption insurance makes use of moment conditions involving consumption data. We obtain comparable estimates from labor supply and earnings data alone. Similarly, Heathcote et al. (2014) estimate their model with and without moment conditions of consumption. This does not lead to large changes in their estimates. A back-of-the-envelope calculation based on our results for the pass-through parameter to the marginal utility of wealth yields consumption insurance parameters that are broadly comparable to those obtained in previous papers using consumption data. This adds to the notion that much can be learned about consumption insurance from earnings and labor supply data alone.

VI Conclusion

In this paper we have decomposed earnings risk into two natural sources: risk from wages and from hours of work. This decomposition required structural modeling, since hours shocks and labor supply reactions due to wage shocks cannot be distinguished otherwise. Using our life-cycle model of labor supply and consumption we estimate a *sufficient statistic* that captures the impact of shocks on the marginal utility of wealth, i.e. the transmission parameter ϕ_t^λ, which is directly related to consumption insurance. Fist, we find that both wages and hours are subject to permanent shocks. Permanent wage shocks constitute 31% and permanent hours shocks 21% of total earnings risk. Second, permanent wage shocks have a stronger impact on life-time earnings. At the mean, a positive permanent wage shock of one standard-deviation for an individual with annual net labor earnings of 50 000 dollars at age 30 increases life-time earnings by 106 000 dollars, while the effect of a permanent hours shock of one standard-deviation is 87 000 dollars.

Progressive income taxation moderates the impact of a permanent shock on life-time income by 16% at the mean of the transmission parameter. It reduces the contribution of transitory shocks to average earnings growth risk by 45% and the contribution of permanent shocks by 36%. Taxes have a stronger effect on transitory shocks because labor supply responses already reduce the impact of permanent shocks on earnings.

Along the way to these results, we have shown a way to calculate the tax-adjusted Marshallian elasticity of labor supply, which we find to be negative, but small, at -0.08. Further, there is more insurance against permanent wage shocks among the highly educated, for whom we estimate a small positive Marshallian elasticity.

Our investigation of the sources of permanent hours shocks shows that they are a pervasive phenomenon. Further, our alternative model specification confirms that permanent hours shocks considerably improve the fit of the life-cycle model.

Setting the coefficient of relative risk aversion to two, we calculate the pass-through of permanent wage shocks to consumption and find reasonable figures in the same range as those reported in Blundell et al. (2008, 2016). These results are encouraging as they show that comparable estimates of consumption insurance can be obtained using either consumption or labor supply data.

Natural extensions of our framework include modeling family labor supply and the extensive labor supply margin. Further, investigating alternative government insurance mechanisms appears to be a fruitful avenue for future research as progressive income taxation appears to be a fairly blunt insurance instrument.

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Appendix

A Tables and Figures

Table A.1: Tax Progressivity Parameter Estimation

	ln(post-government income)
ln(pre-government income)	0.8080
	(0.0011)
constant	1.9616
	(0.0127)
N	35504

Note: Standard errors in parentheses.

Table A.2: Frisch Labor Supply Equation Estimation

	I Full sample	II Age>=40	III High educ	IV No children <7
Δ ln(wage)	0.3614	0.4020	0.2851	0.3148
	(0.0856)	(0.3778)	(0.0975)	(0.1080)
N	46340	20607	19831	24547
Kleibergen and Paap (2006) F stat	18.4680	1.2408	11.7317	11.6739

Note: Clustered standard errors in parentheses.

Table A.3: Hours Process Parameters and Labor Supply Parameters with Different Frisch Elasticities

		I	II	III	IV	V	VI
Tax-adjusted Frisch elasticity		0.1	0.2	0.3	0.4	0.5	0.6
$\theta_{\upsilon}/(\gamma+\tau)$	persistence	0.0375	0.0852	0.1448	0.2161	0.2981	0.3864
	parameter	(0.0053)	(0.0138)	(0.0272)	(0.045)	(0.0815)	(0.1369)
$\sigma_{\epsilon.\upsilon}/(\gamma+\tau)$	SD transitory	0.1180	0.1145	0.1122	0.1111	0.1113	0.1130
	shocks	(0.0099)	(0.0108)	(0.0120)	(0.0148)	(0.0171)	(0.0190)
$\sigma_{\zeta.\upsilon}/(\gamma+\tau)$	SD permanent	0.1466	0.1667	0.1885	0.2040	0.2089	0.1915
	shocks	(0.0071)	(0.0109)	(0.0123)	(0.0143)	(0.0232)	(0.0997)
$E[\phi_t^{\lambda}]$	transmission	0.0092	0.6981	1.4645	2.1620	2.9034	3.7649
	parameter	(0.0262)	(0.6392)	(0.8841)	(1.2318)	(1.8388)	2.8430
$E[\kappa_t]$	tax-adjusted	0.0990	0.0712	-0.0205	-0.1121	-0.2037	-0.2953
	Marshallian elasticity	(0.0028)	(0.0947)	(0.1217)	(0.1505)	(0.1861)	(0.2253)

Note: Clustered standard errors for $(1-\tau)/(\gamma+\tau)$, bootstrapped standard errors for other coefficients in parentheses (200 replicates).

Table A.4: Hours Process Parameters when Persistence of Transitory Shocks is Zero and When Controlling for Cohort Fixed Effects

		$\theta_\upsilon = 0$	Cohort FEs
$\theta_\upsilon/(\gamma+\tau)$	persistence		0.1964
	parameter		(0.0399)
$\sigma_{\epsilon.\upsilon}/(\gamma+\tau)$	SD transitory	0.0647	0.1118
	shocks	(0.0154)	(0.0142)
$\sigma_{\zeta.\upsilon}/(\gamma+\tau)$	SD permanent	0.2460	0.2009
	shocks	(0.0205)	(0.0126)
$E[\phi_t^\lambda]$	transmission	1.8920	1.9698
	parameter	(1.0670)	(1.0946)
$E[\kappa_t]$	tax-adjusted	-0.0767	-0.0870
	Marshallian elasticity	(0.1383)	(0.1399)

Note: For the cohort FE specification we include cohort fixed effects instead of year fixed effects. Bootstrapped standard errors in parentheses (200 replicates).

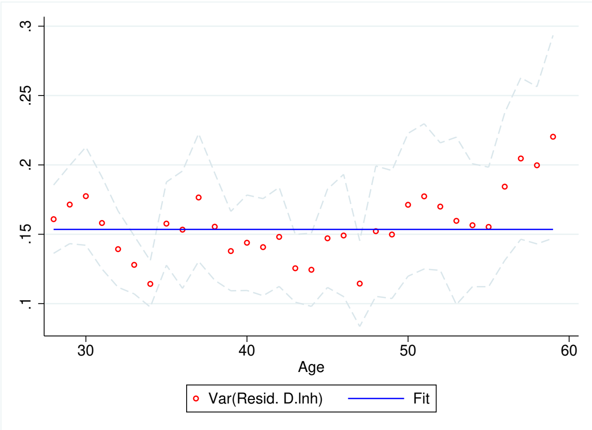
Table A.5: Decomposition of Earnings Risk at Mean

	I	II	III
	$\tau = 0.192$	$\tau = 0$	% reduction
$V\left(\widehat{\Delta \ln y}\|I_{t-1}\right)$	0.0522	0.086	39.28
Contribution of			
trans. wage shocks ($\sigma_{\epsilon,\omega}$)	0.0216	0.0397	45.44
perm. wage shocks ($\sigma_{\zeta,\omega}$)	0.0134	0.0187	28.65
trans. hours shocks ($\sigma_{\epsilon,\upsilon}$)	0.0081	0.0148	45.44
perm. hours shocks ($\sigma_{\zeta,\upsilon}$)	0.0091	0.0128	28.64

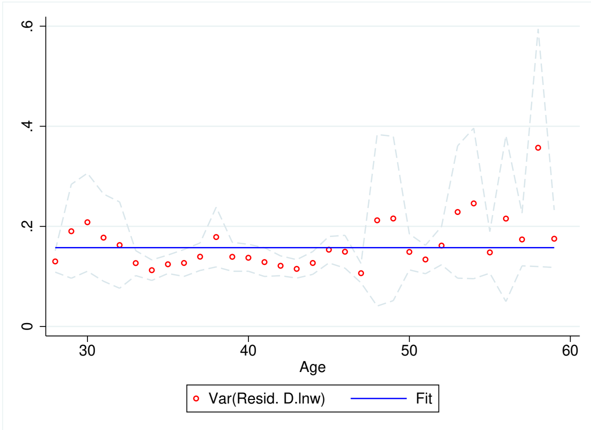
Note: The first line shows total earnings risk given by equation (I.31) with ϕ_t^λ set to the sample mean. Lines 2-5 show the risk when all other shock variances are set to zero. Column II shows risk without progressive taxation. Column III shows the reduction from column II to I.

Figure A.1: Fit of Variance and Covariance Moments over the Life-Cycle After Controlling for Cohort Fixed Effects

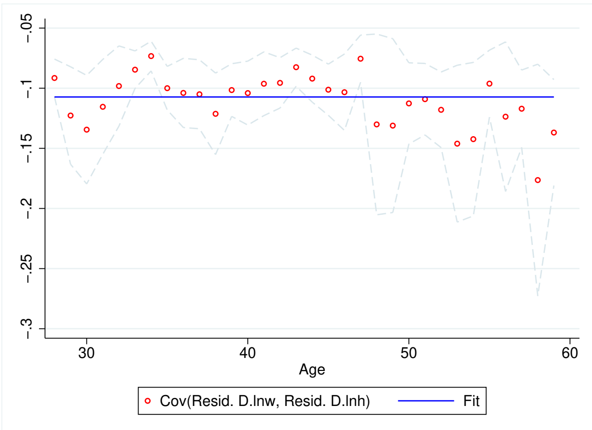
(a) Variance of Hours Residuals



(b) Variance of Wage Residuals



(c) Covariance of Hours and Wage Residuals



Note: Empirical and theoretical variance and covariance moments of residuals obtained from the estimation of equations (4) and (5) for the main sample controlling for cohort fixed effects with bootstrapped 95% confidence interval.

B Implications of Hours Restrictions

If there are hours restrictions, e.g., due to demand side constraints like forced part-time, one can rewrite the model without restrictions in terms of desired as opposed to actual hours of work and add an adjustment term that captures the demand side restrictions. This would introduce another error term in the hours equation, equation (5), namely the difference between actual and desired hours,

$$\Delta \ln h_t = \frac{1}{\gamma + \tau} \left[-\ln(1 + r_{t-1}) - \ln \rho + (1 - \tau) \Delta \ln w_t - \varsigma \Delta \Xi_t + \eta_t + \Delta \upsilon_t \right] + \Delta \mathcal{R}_t, \quad \text{(B.1)}$$

where $\mathcal{R}_t = \ln h_t - \ln h_t^*$ and h_t^* are the desired hours. The estimation of the tax-adjusted Frisch elasticity is valid as long as the IVs are uncorrelated with $\Delta \mathcal{R}_t$. Hence, estimation of the tax-adjusted Frisch elasticity and the wage shock process are unaffected by allowing for restrictions. The residual obtained from Eq. (B.1) additionally contains $\Delta \mathcal{R}_t$. Now, define $\breve{\upsilon} = \upsilon + \mathcal{R}_t$, and assume that $\breve{\upsilon}$ follows a random walk and an MA(1). This leaves identification virtually unchanged as long as the innovations to the restrictions are uncorrelated with wage shocks. Only the interpretation of hours shocks $\breve{\upsilon}$ changes as they capture both taste shocks and restrictions.

If, instead, $\Delta \mathcal{R}_t$ and wage shocks are correlated, the estimate of the transmission parameter is biased and the direction of the bias depends on the sign of the correlation. In principle, both a negative and a positive correlation could occur: A negative correlation may arise when wages rise, due to a jump in productivity, but the employer does not allow hours increases beyond a certain point. A positive correlation may arise if firms impose forced part-time and reduce wages when facing difficulties. If the correlation is positive, we underestimate the transmission parameter and the error may propagate into the estimation of the variance of the hours shocks. Conversely, if it is negative, we overestimate the transmission parameter.

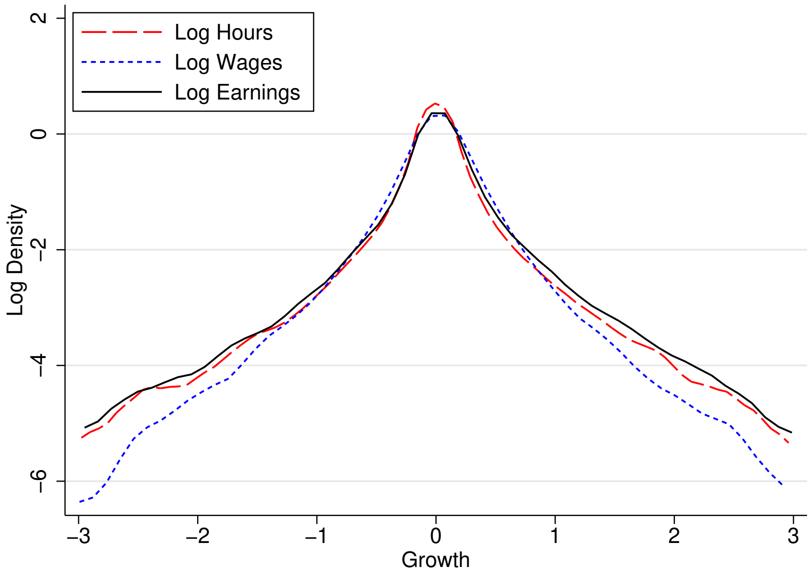
C The Importance of Hours Changes for Women

A relevant limitation of this paper is the restriction of the sample to married males who are the primary earners in the household. While we document sizable hours shocks for this group, hours shocks may play an even more prominent role for women. In Figure C.2 we show the components of log earnings growth as we have done for the main sample in Figure 1. Compared to men, we see that for women hours changes are a more relevant component to earnings growth. Thus, it stands to reason that if we were to include women in the analysis, the magnitude of hours shock variances would be unlikely to decrease.

However, for women not only adjustments along the intensive margin are of importance; especially adjustments along the extensive margin play a major role (Halla et al. 2020). Dealing with adjustments on the extensive margin within our model would complicate the analysis considerably.

Taken together, the evidence supports that hours shocks are an important factor for both women and men and future research should venture to model the shocks for both men and women.

Figure C.2: Components of Annual Earnings Growth of Women



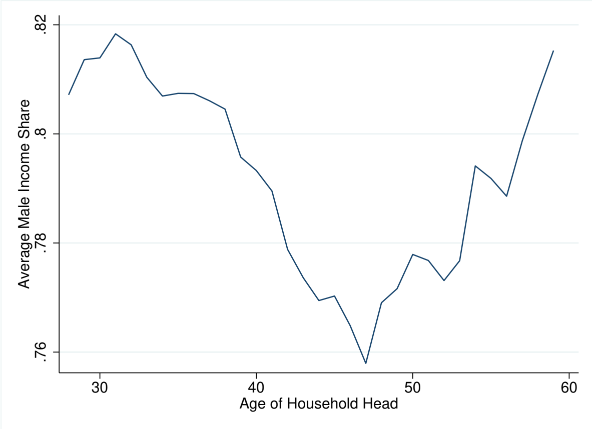
Note: Log densities of first first differences in log earnings, hours, and wages using the sample of married prime age females in the PSID, years 1970-1997, see section III.

D The Share of Male Earnings in Household Earnings

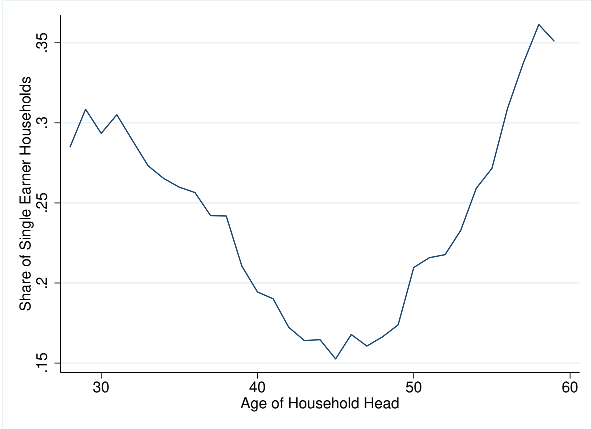
Figure D.3a shows that the average share of male earnings in total household earnings is around 80% in our sample. The trajectory over the life-cycle is driven by the share of single earner households, which is U-shaped (Figure D.3b). These figures are in line with aggregate numbers

Figure D.3: Share of Male Earnings

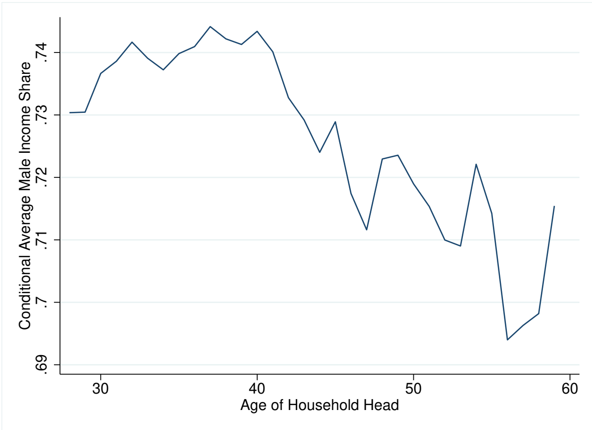
(a) Average Male Income Share



(b) Share of Single Earner Households



(c) Conditional Average Male Income Share



Note: Averages for estimation sample.

of female labor force participation provided by the U.S. department of labor.[30] In our sample period, labor force participation of older women was lower than that of younger women. In contrast, from the year 2000 onward, participation rates are almost the same for women aged 45-54 and those aged 25-44. In our sample, conditional on the woman participating in the labor market, the share of male earnings decreases over the life-cycle (Figure D.3c).

[30]U.S. Bureau of Labor Statistics, Current Population Survey, 1948-2021 annual averages. URL: https://www.dol.gov/agencies/wb/data/lfp/women-by-age, retrieved 2022/09/21.

Online Appendix

E Derivation of the Labor Supply Equation

The residual in the labor supply equation consists of in-period shocks and expectations corrections in the marginal utility of wealth due both to wage and hours shocks.

The first order condition of the consumer's problem w.r.t. h_t is:

$$\frac{\partial \mathcal{L}}{\partial h_t} = E_t \left[\left(-b_t h_t^{\gamma}\right) + \lambda_t \left(\chi \left(1-\tau\right) h_t^{-\tau} w_t^{1-\tau} \right) \right] = 0, \tag{E.1}$$

where $\lambda_t = \frac{\partial u(c_t, h_t, b_t)}{\partial C_t}$ denotes the marginal utility of wealth. The Euler equation of consumption is given by

$$\frac{1}{\rho(1+r_t)} \lambda_t = E_t[\lambda_{t+1}]. \tag{E.2}$$

Expectations are rational, i.e., $\lambda_{t+1} = E_t[\lambda_{t+1}] + \varepsilon_{\lambda_{t+1}}$, where $\varepsilon_{\lambda_{t+1}}$ denotes the mean-zero expectation correction of $E_t[\lambda_{t+1}]$ performed in period $t+1$. Expectation errors are caused by innovations in the hourly wage residual ω_{t+1} and innovations in hours shocks υ_{t+1}, which, as implied by rational expectations, are uncorrelated with $E_t[\lambda_{t+1}]$. Rational expectations imply that $\varepsilon_{\lambda_{t+1}}$ is uncorrelated over time, so that regardless of the autocorrelative structure of the shock terms, $\varepsilon_{\lambda_{t+1}}$ will only be correlated with the innovations of the shock processes.

Resolving the expectation operator in equation (E.1) yields

$$b_t h_t^{\gamma} = \lambda_t \left(\chi \left(1-\tau\right) h_t^{-\tau} w_t^{1-\tau} \right). \tag{E.3}$$

Taking logs of both sides we arrive at the structural labor supply equation

$$\ln h_t = \frac{1}{\gamma+\tau} \left(\ln \lambda_t + \ln \left(1-\tau\right) + \ln \chi + \left(1-\tau\right) \ln w_t - \ln b_t \right). \tag{E.4}$$

To find an estimable form for $\ln h_t$, we take logs of (E.2) and resolve the expectation:

$$\ln \lambda_t = \ln(1+r_t) + \ln \rho + \ln \left(\lambda_{t+1} - \varepsilon_{\lambda_{t+1}} \right)$$

A first order Taylor-expansion of $\ln\left(\lambda_{t+1} - \varepsilon_{\lambda_{t+1}}\right)$ gives $\ln\left(\lambda_{t+1}\right) - \frac{\varepsilon_{\lambda_{t+1}}}{\lambda_{t+1}}$, leading to the expression

$$\ln \lambda_t = \ln(1 + r_t) + \ln \rho + \ln\left(\lambda_{t+1}\right) - \frac{\varepsilon_{\lambda_{t+1}}}{\lambda_{t+1}} + O\Bigg(- \frac{1}{2} \left(\frac{\varepsilon_{\lambda_{t+1}}}{\lambda_{t+1}}\right)^2 \Bigg). \tag{E.5}$$

Accordingly, when we backdate (E.5), we can insert it in (E.4) and remove $\ln \lambda_t$ by first differencing. This yields equation (5).

F Approximation of the Life-Time Budget Constraint

To relate shocks to innovations in the marginal utility of wealth, we need to approximate the life-time budget constraint. The life-time budget constraint at any given point in time t is

$$\sum_{k=0}^{T-t} \frac{c_{t+k}}{(1+r)^k} = \sum_{k=0}^{T-t} \frac{\chi\left(w_{t+k} h_{t+k}\right)^{1-\tau} + (1-\tau_N) N_{t+k}}{(1+r)^k} + a_t. \tag{F.6}$$

A series κ_k can be approximated in the following way up to first order around κ_k^0 (Blundell et al. 2013, 2016),

$$E_I\left[\ln \sum_{k=0}^{T-t} \exp \kappa_k\right] \approx \ln \sum_{k=0}^{T-t} \exp \kappa_k^0 + \sum_{i=0}^{T-t} \frac{\exp \kappa_i^0}{\sum_{k=0}^{T-t} \exp \kappa_k^0} \left(E_I \kappa_i - \kappa_i^0\right), \tag{F.7}$$

where I is an arbitrary information set. We start with the left-hand side of the life-time budget constraint,

$$\begin{aligned} E_I\left[\ln \sum_{k=0}^{T-t} \frac{c_{t+k}}{(1+r)^k}\right] &\approx \ln \sum_{k=0}^{T-t} \exp\left(E_{t-1}\left[\ln c_{t+k} - k \ln(1+r)\right]\right) \\ &+ \sum_{k=0}^{T-t} \pi_{t+k}\left(E_I\left[\ln c_{t+k}\right] - E_{t-1}\left[\ln c_{t+k}\right]\right), \\ \pi_{t+k} &= \frac{\exp\left(E_{t-1}\left[\ln c_{t+k} - k \ln(1+r)\right]\right)}{\sum_{j=0}^{T-t} \exp\left(E_{t-1}\left[\ln c_{t+j} - j \ln(1+r)\right]\right)}. \end{aligned} \tag{F.8}$$

Dating the approximation to E_{t-1} and E_t, we obtain

$$E_{t-1}\left[\ln\sum_{k=0}^{T-t}\frac{c_{t+k}}{(1+r)^k}\right]\approx\ln\sum_{k=0}^{T-t}\exp\left(E_{t-1}\left[\ln c_{t+k}-k\ln(1+r)\right]\right), \tag{F.9}$$

$$E_{t}\left[\ln\sum_{k=0}^{T-t}\frac{c_{t+k}}{(1+r)^k}\right]\approx\ln\sum_{k=0}^{T-t}\exp\left(E_{t-1}\left[\ln c_{t+k}-k\ln(1+r)\right]\right)$$
$$+\sum_{k=0}^{T-t}\pi_{t+k}\left(E_t\left[\ln c_{t+k}\right]-E_{t-1}\left[\ln c_{t+k}\right]\right).$$

The additional term in the t-dated expectation is resolved through the approximated Euler equation (E.5),

$$E_t\left[\ln c_{t+k}\right]-E_{t-1}\left[\ln c_{t+k}\right]\approx-\frac{1}{\vartheta}\eta_t. \tag{F.10}$$

Thus the change in the expectation of life-time consumption after one period is determined by the innovation to the marginal utility of wealth. Since $\sum_{k=0}^{T-t}\pi_{t+k}=1$, it follows that

$$E_{t}\left[\ln\sum_{k=0}^{T-t}\frac{c_{t+k}}{(1+r)^k}\right]-E_{t-1}\left[\ln\sum_{k=0}^{T-t}\frac{c_{t+k}}{(1+r)^k}\right]\approx-\frac{1}{\vartheta}\eta_t \tag{F.11}$$

The right-hand side of the budget constraint is approximated in the same fashion. We define

$$P_1=\sum_{k=0}^{T-t}\exp\left(E_{t-1}\left[\ln\left(\chi(w_{t+k}h_{t+k})^{1-\tau}\right)-k\ln(1+r)\right]\right), \tag{F.12}$$

$$P_2=\exp\left(E_{t-1}\left[\ln a_t\right]\right),$$

$$P_3=\sum_{k=0}^{T-t}\exp\left(E_{t-1}\left[\ln\left((1-\tau_N)N_{t+k}\right)-k\ln(1+r)\right]\right).$$

The expectation at period t of remaining human wealth plus assets is approximated as follows

$$E_t\left[\ln\left(\sum_{k=0}^{T-t}\frac{\chi\left(w_{t+k}h_{t+k}\right)^{1-\tau}+(1-\tau_N)N_{t+k}}{(1+r)^k}+a_t\right)\right]\approx\ln\left(P_1+P_2+P_3\right) \tag{F.13}$$
$$+(1-\tau)\sum_{k=0}^{T-t}\frac{\exp\left(E_{t-1}\left[\ln\left(\chi(w_{t+k}h_{t+k})^{1-\tau}\right)-k\ln(1+r)\right]\right)}{P_1+P_2+P_3}\left(E_t\left[\ln\left(w_{t+k}h_{t+k}\right)\right]-E_{t-1}\left[\ln(w_{t+k}h_{t+k})\right]\right)$$
$$+\frac{P_2}{P_1+P_2+P_3}\left(E_t\left[\ln(a_t)\right]-E_{t-1}\left[\ln(a_t)\right]\right),$$
$$+\sum_{k=0}^{T-t}\frac{\exp\left(E_{t-1}\left[\ln\left((1-\tau_N)N_{t+k}\right)-k\ln(1+r)\right]\right)}{P_1+P_2+P_3}\left(E_t\left[\ln(N_{t+k})\right]-E_{t-1}\left[\ln(N_{t+k})\right]\right)$$

Since a_t is determined in period $t-1$, the last term on the r.h.s., further innovations to non-labor income, is assumed to be negligible, so the last line is approximately zero.

Let

$$\Omega_t = \frac{P_1}{P_1 + P_2 + P_3},$$
$$\alpha_{t+k} = \frac{\exp\left(E_{t-1}\left[\ln\left(\chi(w_{t+k}h_{t+k})^{1-\tau}\right) - k\ln(1+r)\right]\right)}{P_1},$$

then in terms of changes in hours and wages

$$E_t\left[\ln\left(\sum_{k=0}^{T-t}\frac{\chi\,(w_{t+k}h_{t+k})^{1-\tau} + (1-\tau_N)N_{t+k}}{(1+r)^k} + a_t\right)\right] \approx \ln\left(P_1 + P_2 + P_3\right) \tag{F.14}$$
$$+ (1-\tau)\,\Omega_t\sum_{k=0}^{T-t}\alpha_{t+k}\left(E_t\left[\ln\left(w_{t+k}\right)\right] - E_{t-1}\left[\ln(w_{t+k})\right]\right)$$
$$+ (1-\tau)\,\Omega_t\sum_{k=0}^{T-t}\alpha_{t+k}\left(E_t\left[\ln\left(h_{t+k}\right)\right] - E_{t-1}\left[\ln(h_{t+k})\right]\right).$$

Unexpected wage and hours changes consist of the transitory and permanent shocks dated period t,

$$\sum_{k=0}^{T-t}\alpha_{t+k}\left(E_t\left[\ln(w_{t+k})\right] - E_{t-1}\left[\ln(w_{t+k})\right]\right) = \alpha_t\epsilon_t^{\omega} + \alpha_{t+1}\theta^{\omega}\epsilon_t^{\omega} + \sum_{k=0}^{T-t}\alpha_{t+k}\zeta_t^{\omega},$$
$$\sum_{k=0}^{T-t}\alpha_{t+k}E_t\left[\ln\left(h_{t+k}\right)\right] - E_{t-1}\left[\ln(h_{t+k})\right] = \alpha_t\left(\frac{1}{\gamma+\tau}\left(\epsilon_t^{\upsilon} + (1-\tau)\epsilon_t^{\omega}\right)\right)$$
$$+\alpha_{t+1}\left(\frac{1}{\gamma+\tau}\left(\theta^{\upsilon}\epsilon_t^{\upsilon} + (1-\tau)\theta^{\omega}\epsilon_t^{\omega}\right)\right) + \sum_{k=0}^{T-t}\alpha_{t+k}\frac{1}{\gamma+\tau}\left((1-\tau)\zeta_t^{\omega} + \zeta_t^{\upsilon} + \eta_t\right).$$

Since α_t and α_{t+1} are small compared to human wealth, the first and second terms on the right-hand side of both expressions can be neglected. Thus, the expectation innovation on the right-hand side of the life-time budget constraint is

$$
\begin{aligned}
&E_t\left[\ln\left(\sum_{k=0}^{T-t}\frac{\chi\left(w_{t+k}h_{t+k}\right)^{1-\tau}+(1-\tau_N)N_{t+k}}{(1+r)^k}+a_t\right)\right] \\
&-E_{t-1}\left[\ln\left(\sum_{k=0}^{T-t}\frac{\chi\left(w_{t+k}h_{t+k}\right)^{1-\tau}+(1-\tau_N)N_{t+k}}{(1+r)^k}+a_t\right)\right]\approx \\
&(1-\tau)\,\Omega_t\sum_{k=0}^{T-t}\alpha_{t+k}\left(\zeta_t^{\omega}+\left(\frac{1}{\gamma+\tau}\left((1-\tau)\zeta_t^{\omega}+\zeta_t^{\upsilon}+\eta_t\right)\right)\right) \\
&=(1-\tau)\,\Omega_t\left(\zeta_t^{\omega}+\left(\frac{1}{\gamma+\tau}\left((1-\tau)\zeta_t^{\omega}+\zeta_t^{\upsilon}+\eta_t\right)\right)\right),
\end{aligned}
\tag{F.15}
$$

where the last line follows because $\sum_{k=0}^{T-t}\alpha_{t+k}=1$.

Equating (F.10) and (F.15), we find

$$
\eta_t=-\phi_t^{\lambda}(1-\tau)\Bigg(\underbrace{\zeta_t^{\omega}}_{\Delta\ln w_t^{\mathcal{P}}}+\underbrace{\frac{(1-\tau)-(1-\tau)\phi_t^{\lambda}}{\gamma+\tau+(1-\tau)\phi_t^{\lambda}}\zeta_t^{\omega}+\frac{1}{\gamma+\tau+(1-\tau)\phi_t^{\lambda}}\zeta_t^{\upsilon}}_{\Delta\ln h_t^{\mathcal{P}}}\Bigg),
\tag{F.16}
$$

where $\phi_t^{\lambda}=\vartheta\Omega_t$.

G Estimation procedure

G.1 Step 1: Tax Progressivity

To estimate the tax progressivity parameter τ we estimate the following equation by OLS:

$$
\ln(\text{post-government income}_t)=\text{cons}+(1-\tau)\ln(\text{pre-government income}_t)+e_t,
\tag{G.17}
$$

where both post- and pre-government income are taken from the cross-national equivalence file of the PSID. This approach follows Heathcote et al. (2017).

G.2 Step 2: Frisch elasticity, hours residuals, and wage residuals

The augmented empirical labor supply equation containing measurement errors is

$$\Delta \ln \tilde{h}_t = \frac{1}{\gamma+\tau}\left[-\ln(1+r_{t-1}) - \ln\rho + (1-\tau)\Delta\ln\tilde{w}_t - \varsigma\Delta\Xi_t + \eta_t + \Delta\upsilon_t\right] \\ -\frac{1-\tau}{\gamma+\tau}\Delta me_{w,t} + \Delta me_{h,t}. \tag{G.18}$$

The error term of equation (G.18) is correlated with differenced log wages because wage shocks impact the marginal utility of wealth and because of measurement error. To obtain the tax-adjusted Frisch elasticity $(1-\tau)/(\gamma+\tau)$ from equation (G.18) we use human capital related instrumental variables for $\Delta\ln\tilde{w}_t$ following MaCurdy (1981). These instruments predict the expected part of wage growth. Thus, the instruments are uncorrelated with innovations in the marginal utility of wealth and measurement error. Hours residuals $(\eta+\Delta\tilde{\upsilon}_t)/(\gamma+\tau) = (\eta+\Delta\upsilon_t-(1-\tau)\Delta me_{w,t})/(\gamma+\tau)+\Delta me_{h,t}$ are obtained by running IV on differenced log hours using differenced year, child, disability and state dummies as covariates. The instruments for the differenced log wage are interactions of age and years of education, i.e., age, education, education^2, age $\times$ education, age $\times$ education^2, age^2 $\times$ education, and age^2 $\times$ education^2. Wage residuals $\Delta\tilde{\omega}_t = \Delta\omega_t + \Delta me_{w,t}$ are obtained by estimating equation (4) augmented by measurement error, i.e. regressing differenced log wages on the same exogenous regressors as in the hours equation as well as the excluded instruments.

The results of Step 2 are an estimate for $(1-\tau)/(\gamma+\tau)$, which is easily transformed into $1/\gamma$, a matrix of hours residuals, and a matrix of wage residuals. These are used in Steps 3 and 4.

G.3 Step 3: Wage shocks

After recovering $\Delta\tilde{\omega}_t$, all parameters of the autoregressive process, $(\theta, \sigma^2_{\epsilon,\omega}, \sigma^2_{\zeta,\omega})$, are identified through combinations of the autocovariance moments. Label the k-th autocovariance moment by $\Lambda_{\tilde{\omega},k}$:

$$\Lambda_{\tilde{\omega},0} = E\left[(\Delta\tilde{\omega}_t)^2\right] = 2\left(1-\theta_\omega+\theta_\omega^2\right)\sigma^2_{\epsilon,\omega} + \sigma^2_{\zeta,\omega} \\ +2\sigma^2_{me,w} \tag{G.19}$$

$$\Lambda_{\tilde{\omega},1} = E\left[\Delta\tilde{\omega}_t \Delta\tilde{\omega}_{t-1}\right] = -\left(\theta_\omega - 1\right)^2 \sigma^2_{\epsilon,\omega} - \sigma^2_{me,w} \tag{G.20}$$

$$\Lambda_{\tilde{\omega},2} = E\left[\Delta\tilde{\omega}_t \Delta\tilde{\omega}_{t-2}\right] = -\theta_\omega \sigma^2_{\epsilon,\omega} \tag{G.21}$$

Net of $\sigma^2_{me,w}$, dividing $\Lambda_{\tilde{\omega},2}$ by $\Lambda_{\tilde{\omega},1}$ identifies the parameter θ_ω. Successively, the variance of the transitory shock is identified from $\Lambda_{\tilde{\omega},1}$ and the variance of the permanent shock from $\Lambda_{\tilde{\omega},0}$ (see Hryshko 2012).

G.4 Step 3: Hours shocks

The residual obtained from estimating the labor supply equation contains both hours shocks υ_t and the expectation error, η_t. The variance of the residual of the labor supply equation contains both the mean and the variance of $\frac{(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ and the variance of the permanent hours shocks. Since more parameters need to be identified than in the wage case, additional moments are required for estimation. We use the contemporaneous covariance of hours and wage residuals to identify the mean of $1 - \frac{\gamma+\tau}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$. We write $\frac{(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ as $1 - \frac{\gamma+\tau}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ because the mean and variance of $\frac{\gamma+\tau}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ are more easily estimated. To arrive at the theoretical variance moment, substitute equations (8) and (12) into (11) and subsequently (11) into (G.18) to find the following expression for the hours residual

$$\begin{aligned}\frac{\eta + \Delta\tilde{\upsilon}_t}{\gamma+\tau} =& \frac{1}{\gamma+\tau}\Bigg[- \left(1 - (\gamma+\tau)\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}\right)\zeta_t^\upsilon \\ & - (1+\gamma)\left(1 - (\gamma+\tau)\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}\right)\zeta_t^\omega \\ & + \zeta_t^\upsilon + \epsilon_t^\upsilon + (\theta_\upsilon - 1)\epsilon_{t-1}^\upsilon - \theta_\upsilon \epsilon_{t-2}^\upsilon\Bigg] \\ & - \frac{1}{\gamma+\tau}\Delta me_{w,t} + \Delta me_{h,t},\end{aligned} \tag{G.22}$$

where the first and second line on the right hand side equal $\eta_t/(\gamma+\tau)$, i.e. the labor supply reaction due to the impact of shocks on the marginal utility of wealth. These terms give the wealth effect due to the income change caused by permanent shocks to the disutility of work or to the hourly wage, respectively. These income changes include labor supply adjustments. Note that in the case of full insurance ($\phi_t^\lambda = 0$) these terms equal zero. The third line contains immediate, i.e. Frisch, reactions to shocks in the disutility of work. The fourth line contains the terms due to measurement error. The variance can be written as

$$\begin{aligned}\Lambda_{\tilde{v},0} = E\left[\left(\frac{\eta_t + \Delta\tilde{v}_t}{\gamma+\tau}\right)^2\right] &= \frac{1}{(\gamma+\tau)^2}\Big((1+\gamma)^2\left(1 - 2(\gamma+\tau)\mathcal{M}_1 + (\gamma+\tau)^2\mathcal{M}_2\right)\sigma^2_{\zeta,\omega} \\ &+ (\gamma+\tau)^2\mathcal{M}_2\sigma^2_{\zeta,v}\Big) + \frac{1}{(\gamma+\tau)^2}\left(\sigma^2_{\zeta,v} + 2\left(\theta_v^2 - \theta_v + 1\right)\sigma^2_{\epsilon,v}\right) \\ &+ 2\sigma^2_{me,h} + \frac{2(1-\tau)^2\sigma^2_{me,w}}{(\gamma+\tau)^2} - \frac{4(1-\tau)\sigma^2_{me,h,w}}{\gamma+\tau},\end{aligned} \tag{G.23}$$

where $\mathcal{M}_1$ and $\mathcal{M}_2$ denote the first and second non-central moments of $\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$. As no analytical expression for these moments exists, we find them numerically as described in Appendix H. The interpretation of equation (G.23) is analogous to equation (G.22): the first term in parentheses captures the part of the variance that is due to marginal utility of wealth effects, while the second term captures the part of the variance due to direct labor supply reactions to hours shocks. The third line is due to measurement error.

The autocovariance moments of the hours residual $\Lambda_{\tilde{v},1}$ and $\Lambda_{\tilde{v},2}$ are analogous to their wage process counterparts:

$$\begin{aligned}\Lambda_{\tilde{v},1} = E\left[\frac{(\eta_t + \Delta\tilde{v}_t)(\eta_{t-1} + \Delta\tilde{v}_{t-1})}{(\gamma+\tau)^2}\right] &= -\frac{(\theta_v - 1)^2\sigma^2_{\epsilon,v}}{(\gamma+\tau)^2} \\ &- \sigma^2_{me,h} - (1-\tau)^2\frac{\sigma^2_{me,w}}{(\gamma+\tau)^2} + \frac{2(1-\tau)\sigma^2_{me,h,w}}{(\gamma+\tau)^2}\end{aligned} \tag{G.24}$$

$$\Lambda_{\tilde{v},2} = E\left[\frac{(\eta_t + \Delta\tilde{v}_t)(\eta_{t-2} + \Delta\tilde{v}_{t-2})}{(\gamma+\tau)^2}\right] = -\frac{\theta_v\sigma^2_{\epsilon,v}}{(\gamma+\tau)^2} \tag{G.25}$$

To estimate the variance of permanent hours shocks, we need to identify $\mathcal{M}_1$ using the contemporaneous covariance of hours and wage residuals,

$$\Lambda_{\tilde{\omega},\tilde{\upsilon},0} = E\left[\frac{(\eta_t + \Delta\tilde{\upsilon}_t)\,\Delta\tilde{\omega}_t}{(\gamma+\tau)}\right] = -\frac{(\gamma+1)(1-(\gamma+\tau)\mathcal{M}_1)\sigma^2_{\zeta,\omega}}{\gamma+\tau} - \frac{2(1-\tau)\sigma^2_{me,w}}{\gamma+\tau} + 2\sigma^2_{me,h,w}. \tag{G.26}$$

This covariance is larger in absolute value the smaller $\gamma+\tau$ and the smaller $\mathcal{M}_1$, which is due to a larger $E[\phi_t^\lambda]$. When $\gamma+\tau$ goes to infinity, the effect of permanent wage shocks on income is only mechanical and not through labor supply reactions. It is important to stress that, given estimates for $\gamma+\tau$ and $\sigma^2_{\zeta,\omega}$ only equation (G.26) is needed for the estimation of $E[\phi_t^\lambda]$. The estimation of the parameter does not hinge on the identification of hours shocks.

$\mathcal{M}_1$ contains μ_ϕ and $\mathcal{M}_2$ contains both μ_ϕ and σ_ϕ, the mean and standard deviation of the natural logarithm of ϕ_t^λ. To estimate the variance of permanent hours shocks, an estimate of σ_ϕ is needed to make the variance of hours residuals informative. Theoretically, σ_ϕ is identified through the cokurtosis moments of the wage and hours residuals. However, cokurtosis moments are very noisy, hence σ_ϕ can only be estimated to a reasonable degree of reliability when using several million observations.[31] Therefore, we calibrate σ_ϕ to 1.023 based on results in Alan et al. (2018). In that paper, ϕ_t^λ follows a log-normal distribution and is identified through a separate moment condition based on consumption data. Using this calibration, once $\mathcal{M}_1$ is estimated, the mean of ϕ_t^λ, $E[\phi_t^\lambda] = e^{\mu_\phi + \frac{\sigma_\phi^2}{2}}$, can be recovered. In Section V we show the robustness of our results to an alternative value of this parameter. Halving the standard deviation σ_ϕ increases the variance of permanent hours shocks only slightly and the estimate for $E[\phi_t^\lambda]$ is qualitatively the same.

To sum up, the parameters $\theta_\upsilon, \sigma_{\epsilon,\upsilon}, \sigma_{\zeta,\upsilon}$, and $E[\phi_t^\lambda]$ are identified through the moments $\Lambda_{\tilde{\upsilon},0}$, $\Lambda_{\tilde{\upsilon},1}$, $\Lambda_{\tilde{\upsilon},2}$, and $\Lambda_{\tilde{\omega},\tilde{\upsilon},0}$.

G.5 Marshallian elasticity

The term multiplied with $\sigma^2_{\zeta,\omega}$ in equation (G.26) can be rewritten as $E\left[\frac{1-\tau-(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}\right] - \frac{1-\tau}{\gamma+\tau}$, the average tax-adjusted Marshallian minus the tax-adjusted Frisch elasticity of labor supply. Thus,

[31] Simulations evidencing this are available upon request from the authors.

the Marshallian can directly be calculated using the parameter estimates. As long as the model is exactly identified, the Marshallian can be calculated directly from the covariance moment using estimates of γ and τ. The Marshallian elasticity is the uncompensated reaction to a permanent wage shock.[32]

G.6 Estimation

We estimate the parameters of the autoregressive processes and the transition of wage shocks by fitting the theoretical moments $\{\Lambda_{\omega,k}, \Lambda_{\upsilon,k}, \Lambda_{\omega,\upsilon,k}\}$ to those of the data. The vector of parameters, denoted Θ, is estimated using the method of minimum distance and an identity matrix serves as the weighting matrix.[33] The distance function is given by

$$DF(\Theta) = [m(\Theta) - m^d]' I [m(\Theta) - m^d], \tag{G.27}$$

where $m(\Theta)$ indicates theoretical moments and m^d empirical moments. An outline of the entire estimation procedure is detailed in Hryshko (2012). Standard errors are obtained by block bootstrap with 200 replicates.

H Shock Pass-Through on Hours

The moments of the term $\frac{(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ are not as tractable as the rest of the random variables in the variance moment estimation, since we assume $\ln \phi_t^\lambda \sim N(\mu_\phi, \sigma_\phi)$. We can refine the expression to find a more basic expression:

$$\frac{(1-\tau)\phi_t^\lambda}{\gamma+\tau+(1-\tau)\phi_t^\lambda} = 1 - \frac{\gamma+\tau}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$$

The only random term in this expression is $\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$. We can find its distribution by re-expressing its CDF in terms of the underlying normal distribution of $\ln \phi$. Let $\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda} = Z$. Then

[32]See Keane (2011, p.1008).

[33]Altonji and Segal (1996) show that the identity weighting matrix is preferable for the estimation of autocovariance structures using micro data.

$$P\left(Z \leq z\right) = P\left(\frac{1}{\gamma + \tau + (1-\tau)\phi_t^\lambda} \leq z\right) \tag{H.28}$$

$$P\left(\ln \phi_t^\lambda \leq \ln\left(\frac{\frac{1}{z} - (\gamma+\tau)}{1-\tau}\right)\right) = \int_{-\infty}^{\ln\left(\frac{\frac{1}{z}-(\gamma+\tau)}{1-\tau}\right)} \frac{\exp\left(-\frac{(x-\mu_\phi)^2}{2\sigma_\phi^2}\right)}{\sqrt{2\pi\sigma_\phi^2}} dx \tag{H.29}$$

Integrating this CDF, we find the CDF for the random variable Z.

$$F(z) = 1/2\left(1 + \mathrm{Erf}\left(\frac{\ln\left(\frac{\frac{1}{z}-(\gamma+\tau)}{1-\tau}\right) - \mu_\phi}{(2\sigma_\phi^2)^{1/2}}\right)\right)$$

Here Erf$(\cdot)$ is the Gaussian error function. To generate the first and second noncentral moments, we take the derivative to find the PDF of Z.

$$f(z) = \frac{\exp\left(-\frac{\left(\ln\left(\frac{\frac{1}{z}-(\gamma+\tau)}{1-\tau}\right)-\mu_\phi\right)^2}{2\sigma_\phi^2}\right)}{\sqrt{2\pi\sigma_\phi^2}z(z(\gamma+\tau)-1)}$$

The first and second noncentral moments are $\mathcal{M}_1 = \int_0^{1/(\gamma+\tau)} zf(z)dz$ and $\mathcal{M}_2 = \int_0^{1/(\gamma+\tau)} z^2 f(z)dz$. These are calculated via numerical integration, as there is no closed form solution. We implement these formulas in our moment conditions. In estimation we restrict the values of μ_ϕ not to exceed 10, as the moments of $\frac{1}{\gamma+\tau+(1-\tau)\phi_t^\lambda}$ asymptote beyond that point.

I Variance of Stochastic Earnings Growth and Earnings Growth Risk

The formula for the variance of stochastic earnings growth is given by

$$E\left[\left(\widehat{\Delta \ln y}\right)^2\right] = \frac{(1-\tau)^2}{(\gamma+\tau)^2}\Bigg[(\gamma+\tau)^2\mathcal{M}_2\left(\sigma^2_{\zeta,\upsilon} + (\gamma+1)^2\sigma^2_{\zeta,\omega}\right) \\ + 2(\gamma+1)^2((\theta_\omega - 1)\theta_\omega + 1)\sigma^2_{\epsilon,\omega} + 2((\theta_\upsilon - 1)\theta_\upsilon + 1)\sigma^2_{\epsilon,\upsilon}\Bigg], \tag{I.30}$$

where $\mathcal{M}_2$ is obtained numerically using the estimates of the underlying parameters. Note that $\mathcal{M}_2$ depends on the mean and the variance of the transmission parameter ϕ^λ_t, which are known to individuals. Additionally, the realization of transitory components of wage and hours growth are partially known in advance, see equation (7). Therefore this overall variance is not a measure of risk. The relevant measure of risk removes the shocks realized before time t.

Denote by I_{t-1} the agent's information set at $t-1$. At that point in time the agent knows ϕ^λ_t and the realization of shocks in $t-1$. Thus, $E\left[\widehat{\Delta \ln y_t}|I_{t-1}\right]$ includes the transitory components from the previous two periods. The resulting equation for earnings risk conditional on the information set in $t-1$ is

$$E\left[\left(\widehat{\Delta \ln y_t} - E\left[\widehat{\Delta \ln y_t}|I_{t-1}\right]\right)^2\Big|I_{t-1}\right] = (1-\tau)^2\left(\frac{\sigma^2_{\epsilon,\upsilon} + (\gamma+1)^2\sigma^2_{\epsilon,\omega}}{(\gamma+\tau)^2} + \frac{\sigma^2_{\zeta,\upsilon} + (\gamma+1)^2\sigma^2_{\zeta,\omega}}{(\gamma+\tau+(1-\tau)\phi^\lambda_t)^2}\right). \tag{I.31}$$