Insurance Cyclicality

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Abstract

This paper investigates how households smooth consumption against idiosyncratic wage shocks in recessions and expansions. Labour market uncertainty amplifies during recessions, captured through the cross-sectional dispersion of wages. I focus on the relative contribution of two insurance mechanisms to wage changes, namely, adjustments in labour supply and assets, during periods of high and low uncertainty. I exploit variation in expenditure, hours worked and wages over the business cycle to wage shocks, and apply it to US household panel data. I document a new empirical fact – the contribution of labour supply to consumption smoothing increases during labour market downturns. Households with low liquid wealth show the strongest asymmetric labour supply response between recessions and expansions. To jointly explain these empirical facts, I develop an incomplete market life-cycle model with multiple asset-types (liquid and illiquid) and an aggregate state that affects wage dispersion. The model shows that the key mechanism is the shift in portfolio composition towards liquid assets during high uncertainty periods.

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1 Introduction

Do households smooth consumption differently between recessions and expansions? This paper studies the extent and channels of household consumption smoothing against idiosyncratic wage shocks during labour market upturns and downturns. Many studies argue that the cross-sectional idiosyncratic income or wage dispersion increases during economic downturns (Nakajima and Smirnyagin 2019 and Storesletten et al. 2004).[1] Yet, we know little about how households respond to *ex-post* wage shocks in presence of *ex-ante* wage uncertainty which varies over the business cycle. This paper documents that the extent of consumption smoothing does not vary between recessions and expansions. But, I show that labour supply adjustments for insurance gain importance in periods of high labour market uncertainty. These empirical findings can help to differentiate between alternative models of consumer behaviour (incomplete asset markets models relative to complete asset markets models with limited commitment), and policy evaluation where individual marginal propensities to consume play a key role.[2]

In the first part of this paper, I document little known differences in the consumption smoothing behaviour of households between economic downturns and upturns. I characterize the response of consumption and hours to wage shocks using the predictions of a broad-class of life-cycle models. I assume that consumers experience transitory and permanent wage shocks every period whose variances can change over the business cycle. The elasticity of hours and consumption to wage changes are referred as "transmission coefficients" in the consumption inequality literature. The degree of consumption smoothing can be inferred using the consumption transmission coefficient. I capture the relative contribution of labour supply and savings against the wage shocks using these transmission coefficients.

I use the Panel Study of Income Dynamics (PSID) to estimate three sets of coeffi-

[1] Busch and Ludwig (2020), Nakajima and Smirnyagin (2019) and Storesletten et al. (2004) show that the idiosyncratic permanent income and wage dispersion increases during bad times. On the other hand, Busch et al. (2018) and Guvenen et al. (2014) argue that the variance of idiosyncratic income risk does not change over the business cycle. This study provides evidence favouring the former with varying methodologies and datasets used across the studies being one possible reason of different conclusions across the studies. I discuss this further in Section 4.1.

[2] For example, Broer et al. (2020) shows that consumption insurance is not cyclical in the Krusell and Smith, Jr. (1998) economy with incomplete markets, unlike the complete market economies with limited commitment in Krueger and Perri (2006). Consumption insurance changes as borrowing constraints react endogenously to macroeconomic fluctuations in the limited commitment models.

cients for downturns and upturns: (1) variances of permanent and transitory shocks, (2) pass-through coefficients of temporary and permanent wage shocks to consumption and labour supply, and (3) sources of consumption smoothing.[3] The second-order cross-sectional moments of wage, hours and consumption help to estimate the above mentioned coefficients through a GMM approach. The changes in the cross-sectional wage dispersion between economic downturns and upturns highlight that the permanent wage variance increases in recessions, consistent with the findings of Nakajima and Smirnyagin (2019).

I show that the role of labour supply for insurance against permanent wage shocks increases in economic downturns. The relative contribution of savings to consumption smoothing falls during bad times. However, households smooth consumption against wage shocks equally well in both recessions and expansions. These findings remain robust after including additional channels of insurance like progressive taxation and spousal labour supply. The asymmetric nature of insurance mechanisms between good and bad times is the key contribution of this paper.

I further show that households with low asset liquidity at the beginning of the year demonstrate sharp differences in labour supply response to a wage shock in a recession than expansion. Noise in the asset data does not drive this empirical result. I show that similar results arise when substituting observed asset data with median values over age and education groups.

In the second part of the paper, I formalize the link between asset liquidity and asymmetric consumption smoothing mechanisms through a decision-theoretic incomplete market life cycle model with two asset-types (illiquid and liquid). Illiquid assets (e.g. housing or stocks) pay a higher return than liquid assets (like cash and checking account); but the trading of illiquid holdings is costly (e.g. transaction cost of selling a house). People form expectations about the future state of the world given the current state of the economy using a Markov process. They decide on individual labour supply, consumption, allocation between liquid and illiquid assets and whether to deposit into or withdraw from the illiquid asset in the current period.

[3]Panel Study of Income Dynamics (PSID) is a longitudinal study of households starting from 1967. PSID's long panel is essential for statistical inference since I want to include many recession episodes. Consumer Expenditure Survey (CES), which began in 1980, has information on consumption but no information on hours worked or wages. Thus, CES data cannot be used to identify the relevant coefficients of interest.

The model helps to highlight the role of portfolio allocation towards liquid assets in explaining the empirical fact. A large negative wage shock can push an individual to become borrowing constrained. Higher wage uncertainty during recessions increases the probability of a large negative wage shock. In response to the higher *ex-ante risk* during recessions, individuals accumulate more precautionary savings in the form of liquid rather than illiquid holdings because illiquid assets are costly to transact. This portfolio rebalancing leads to a sharp fall in financial wealth of people. The wealth effect on labour supply against a permanent wage shock rises leading to the role of labour supply for consumption smoothing increasing during bad times.

I also show the multiple asset-type formulation plays a vital role in generating the patterns consistent with the data. In a single asset-type model, households accumulate more savings as uncertainty rises due to precautionary motives. The rise in asset holdings increases wealth holdings and reduces the wealth effect on labour supply against a permanent wage shock. Thus, the role of labour supply for insurance against a permanent wage shock falls during recessions in a single asset-type model, inconsistent with the empirical result.

The empirical findings of this paper bear significant implications for policy.[4] I empirically find that the the marginal propensity consume to a permanent income shock rises from 11.5% in expansions to 19% in recessions. Moreover, portfolio rebalancing plays a key role through wealth effects in shaping consumption and labour supply adjustments to wage shocks. Thus, it is possible that the transmission of fiscal and monetary policy into household consumption can be quite different depending on the business cycle phase.

Relation to literature: This paper is related to four strands of the literature in macroeconomics and labour economics. First and foremost, it contributes to the literature that studies individuals' response to unpredictable income changes. There are two approaches used in this literature. The first approach focusses on exploiting exogenous changes in income such as a tax rebate (Johnson et al. 2006) or government transfers (Agarwal and Qian 2014 and Baker et al. 2020). The second approach imposes more structure on the data. The seminal study by Blundell et al. (2008) separately identi-

[4] Kaplan et al. (2014) argue that, "Identifying the determinants of how consumers respond to stimulus payments helps in choosing policy options and in assessing whether the same fiscal instrument can be expected to be more or less effective under different macroeconomic conditions."

fies the transmission of permanent and transitory income shocks into consumption. Blundell et al. (2016) (henceforth referred to as "BPS") develops the state-of-the-art semi-structural approach to decompose consumption smoothing into three channels: (1) government taxes and transfers, (2) own labour supply and (3) spousal labour supply. The focus of this paper is on households' response to a wage change in recessions and expansions which has not been studied yet.[5]

In this study, I take the second approach and contribute to the literature in multiple dimensions. First, I compute both the degree and channels of consumption smoothing in recessions and expansions which are novel empirical facts. Second, I complement the methodology of BPS in estimating the transmission coefficients without using asset data. I show that this leads to small and statistically insignificant differences in the estimated transmission coefficients between the two approaches. This paper's methodology can be applied to datasets where either do not contain asset data or asset data is noisy unlike BPS. But, I cannot recover the underlying utility preference parameters which BPS can.

Second, this paper contributes to the literature in macroeconomics concerned with estimating the nature of idiosyncratic income risk over the business cycle, and its consequences on consumption smoothing. The seminal study by Storesletten et al. (2004) presents evidence that the variance of male permanent income is countercyclical in the United States. The subsequent literature focusses on two aspects. First, on estimating the higher order moments of idiosyncratic income shocks over the business cycle using new data and/or methodology (Busch et al. 2018, De Nardi et al. 2019, Guvenen et al. 2014, and Nakajima and Smirnyagin 2019, to name a few). Second, compute the effect on consumption smoothing after incorporating properties of higher order income risk over the business cycle (Busch and Ludwig 2020).

This study complements the literature by contributing to both these aspects. I affirm the finding in the literature using an alternative methodology that the variance of permanent wage changes increases during economic downturns. I show that the increased variance also exists among currently employed individuals and so, government unemployment benefits provide limited insurance against higher-order income

[5] Broer (2020) and Gross et al. (2020) assess the degree of consumption smoothing against changes in income or credit limit during recessions and expansions. This study studies exogenous shocks to wages rather than income (which includes hours) or credit limit.

risk over the business cycle. Additionally, this paper complements the argument of Busch and Ludwig (2020) that the role of assets for insurance falls during recessions. However, I also show that the contribution of hours for consumption smoothing increases during recessions that can partially compensate for the fall in the role of assets.

Third, I contribute to the literature that deals with both the empirical estimation and impact of uncertainty on macroeconomic outcomes (see Bloom 2014 for an extensive survey of this literature). Flodén (2006) show that consumers can increase current labour supply when future idiosyncratic wage uncertainty increases, and Basu and Bundick (2017) highlights the impact of such behaviour at the household level on macroeconomic outcomes. Bayer et al. (2019) argue that consumers reallocate their asset portfolio as the variance of idiosyncratic productivity shocks increases. This study presents a novel link between labour supply elasticity and uncertainty, both empirically and theoretically. It shows how the portfolio reallocation channel during recessions can also lead to differences in the manner of consumption smoothing.

Fourth, I contribute to the literature on macroeconomics and labour economics about the implications of wealth effects on labour supply. Cesarini et al. (2017), and Kimball and Shapiro (2008) find evidence of modest to large wealth effects on labour supply.[6] Yet, the use of GHH preferences (Greenwood et al. 1988) which generate no wealth effects on labour supply is ubiquitous in macroeconomics because of its theoretical simplicity (like, Aguiar and Gopinath 2007 and Mendoza 1991). I find that wealth effects vary significantly between recessions and expansions. Galí et al. (2011) and Cantore et al. (2022) show how the magnitude of the wealth effect has important implications for the transmission of monetary policy.

The rest of the paper proceeds as follows: Section 2 describes the empirical specification that we take to the data. Section 3 describes the data, identification assumptions, and estimation strategy utilized to estimate the coefficients of interest. Section 4 describes the main empirical findings, and robustness checks. Section 5 and 6 examines how a multiple assets-type model can rationalize the empirical findings. Section 7 concludes and discusses potential avenues for future research.

[6] Keane (2011), and Pencavel (1986) survey this literature extensively.

2 Empirical Specification

I present a framework to study the degree and channels of consumption smoothing against wage shocks based on the established consumption inequality literature (Blundell et al. (2008)). The representation of consumption and labour supply against wage shocks follows the predictions of a broad class of life-cycle models.

2.1 Wage Process

Real wage is a function of both permanent and transitory component.[7] Wages deviates from their deterministic path due to innovations in the permanent (e.g. promotion/demotion) or transitory element (such as, bonus). A permanent shock causes an irreversible change in the market value of that individual's skills, whereas a transitory shock is short-lived and mean-reverting. The permanent component follows a unit root process. The wage process is written as:

$$\log W_{i,t} = x'_{i,t}\beta + F_{i,t} + u_{i,t} \tag{1}$$

$$F_{i,t} = F_{i,t-1} + v_{i,t} = F_{i,0} + \sum_{s=1}^{t} v_{i,s} \tag{2}$$

where, $x_{i,t}$ are observed characteristics of household i at time t. $u_{i,t}$ and $v_{i,t}$ are temporary and permanent shocks to wages with $F_{i,0}$ being the initial condition in wages. This is a popular method to model the wage process since it fits the individual life-cycle wage profile quite well (Abowd and Card (1989) and Meghir and Pistaferri (2004)).[8] It also implies that the growth in residual log wages is a sum of the change in the transitory components and the permanent wage shock.

$$\Delta w_{i,t} = \Delta u_{i,t} + v_{i,t} \tag{3}$$

[7] During estimation, I construct two-year rather than one-year difference due to data limitations. This implies that if temporary shocks follow a MA(1) or MA(2) process then $Cov(\Delta^2 w_{i,t}, \Delta^2 w_{i,t+3})$ or $Cov(\Delta^2 w_{i,t}, \Delta^2 w_{i,t+4})$ should be significantly different from zero. But, I cannot reject the null hypothesis of zero autocovariance in all periods as shown in Appendix Table 6.

[8] Guvenen (2007), and Haider (2001) argue in favour of heterogeneous income profile with some persistence in income. Hryshko (2012) finds that such a wage model is rejected in the PSID data whereas the permanent-transitory model is not.

where $\Delta w_{i,t} = \Delta \ln W_{i,t} - \Delta x'_{i,t}\beta$ and Δ is the first-difference operator. The properties of the error structure can be summarised as follows:

$$\mathbb{E}(u_{i,t}) = \mathbb{E}(v_{i,t}) = 0$$

$$\mathbb{E}(v_{i,t}v_{i,t+r}) = \begin{cases} \sigma^2_{v,s(t)} & \text{if } r = 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{E}(u_{i,t}u_{i,t+r}) = \begin{cases} \sigma^2_{u,s(t)} & \text{if } r = 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{E}(u_{i,t}v_{i,t+r}) = 0 \; \forall r$$

The expected value of the shocks is zero. The variances of the permanent and transitory shocks are denoted by $\sigma^2_{v,s(t)}$ and $\sigma^2_{u,s(t)}$ respectively. $s(t)$ refers to the aggregate state at time t. The transition probabilities between the aggregate states are known to the agent. The change in the variance of shocks implies fluctuations in uncertainty.[9] Transitory and permanent shocks are uncorrelated from each other. Agents can perfectly distinguish between transitory and permanent shocks.[10]

2.2 Relation of Consumption and Hours against wage shocks

Using the approach of BPS, the change in hours and consumption in response to a permanent and growth in transitory wage shocks is described in equation 4. BPS derive an analytical relationship between consumption and hours against wage shocks in a two earner household with access to assets.[11] Section 5 describes a multiple asset-type economy with a single earner household that can also generate the same relationship

[9]Guvenen et al. (2014) and Busch et al. (2018) argue that the income process is more negatively skewed during recessions than expansions. Skewness is zero in my wage process by assumption. Higher order terms will be included in the error term of the empirical setup.

[10]Druedahl and Jørgensen (2017) show that households can distinguish to a high degree between transitory and permanent income shocks in a consumption-savings model where households have to infer their income process from actual market income realizations and a noisy private signal.

[11]BPS derive this relationship by linearizing the first order conditions, the Euler equation and the intertemporal budget constraint. These transmission coefficients depend on the underlying preference parameters and share of human wealth in total human and financial wealth. For more details refer to Appendix 1 in their study.

as shown below:

$$\begin{pmatrix} \Delta c_{i,t}^{s(t)} \\ \Delta h_{i,t}^{s(t)} \end{pmatrix} = \begin{pmatrix} \kappa_{c,u}^{s(t)} & \kappa_{c,v}^{s(t)} \\ \kappa_{h,u}^{s(t)} & \kappa_{h,v}^{s(t)} \end{pmatrix} \begin{pmatrix} \Delta u_{i,t} \\ v_{i,t} \end{pmatrix} \tag{4}$$

$\kappa_{x,m}$ measures the transmission of shock m into the variable x. $\kappa_{c,v}^{s(t)}$ denotes the pass-through of a permanent shock into consumption. $\kappa_{c,v}^{s(t)}$ equal to 0.1 means that a 100% fall in permanent wage reduces consumption by 10%. $\kappa_{c,v}^{s(t)} = \kappa_{c,u}^{s(t)} = 0$ implies complete consumption insurance as predicted by the complete market hypothesis. On the other hand, $\kappa_{c,v}^{s(t)} = \kappa_{c,u}^{s(t)} = 1$ reflects a one-to-one impact of the wage shocks into consumption. Thus, the degree of consumption smoothing increases as the transmission coefficient of consumption falls.

The transmission coefficient of hours against a transitory shock ($\kappa_{h,u}^{s(t)}$) can be interpreted as the Frisch elasticity of labour supply if transitory shocks carry little or no wealth effects. On the other hand, permanent shocks do create wealth effects. The hours transmission coefficient with respect to a permanent shock ($\kappa_{h,v}^{s(t)}$) can then be interpreted as a Marshallian labour supply elasticity. The sign of $\kappa_{h,v}^{s(t)}$ highlights whether labour hours are used as consumption smoothing device against permanent wage shocks. A negative sign implies that the agent works more hours in response to a negative permanent wage shock and so, hours are used as a consumption smoothing channel.

An important thing to note is that $\kappa_{c,v}^{s(t)}$ and $\kappa_{h,v}^{s(t)}$ are connected. A more negative coefficient of $\kappa_{h,v}^{s(t)}$ means that hours are used more to smooth consumption which would imply a lower $\kappa_{c,v}^{s(t)}$ (more consumption smoothing), ceteris paribus. In other words, a more muted Marshallian labour supply elasticity implies a higher degree of consumption smoothing, ceteris paribus. Thus, these coefficients illustrate the manner through which households' smooth consumption.

2.3 Decomposing Consumption Smoothing

To decompose the sources of consumption smoothing, I arrange the per-period budget constraint such that, consumption is equal to the income minus net asset position (M).

$$C = wh - M \tag{5}$$

After log-linearising equation 5, and taking the derivative of the change in variables against permanent shock, I get:

$$\kappa^{s(t)}_{c,v_1} \approx 1 + \kappa^{s(t)}_{h_1,v_1} - \frac{\partial \Delta (M/Y)}{\partial v_1} \quad (\because \text{Using eq 3 and 4}) \tag{6}$$

Equation 6 confirms the intuition as stated above that a smaller $\kappa^{s(t)}_{h,v}$ implies a reduced $\kappa^{s(t)}_{c,v}$. Dividing equation 6 with $(1 - \kappa_{c,v})$ helps to compute the relative contribution of the two channels of consumption smoothing.

$$1 \approx \underbrace{\frac{-\kappa^{s(t)}_{h,v}}{1 - \kappa^{s(t)}_{c,v}}}_{\text{Labour Supply}} + \underbrace{\frac{1}{1 - \kappa^{s(t)}_{c,v}} \frac{\partial \Delta (M/Y)}{\partial v_1}}_{\text{Savings and borrowing}} \tag{7}$$

The first term in Equation 7 shows the role of labour supply in consumption smoothing. The second term is the relative contribution of savings and borrowing. The residual channel can be interpreted as the self-insurance through assets because the model comprises of only two sources of insurance. In models that include progressive taxation and spousal labour supply as channels to smooth consumption, the residual can be further decomposed to reveal their relative contribution.[12] Section 4.3 contains more details about the decomposition of consumption smoothing with these additional channels and illustrates their role in the data.

The relative contribution of the channels of consumption smoothing can be recovered only after estimating the transmission coefficients. These coefficients could be calculated using a OLS regression if the shocks were observable. Section 3 describes the identification strategy employed to estimate the parameters of interest since these shocks are not observable in the data.

[12] There are other channels such as extensive margin of spousal labour supply (Attanasio et al. (2008)) and loan default which I do not consider (Livshits et al. (2007)). The current empirical setup cannot deal with any extensive margin channel of consumption smoothing. Moreover, Wu and Krueger (2019) show that the intensive spousal margin has a significantly higher role in consumption smoothing than the extensive margin.

3 Data, Identification and Estimation Strategy

The sets of coefficients to estimate are: (1) variances of the transitory and permanent shocks, (2) consumption and hours elasticities to the shocks, and (3) consumption smoothing channels. Panel data on wages and hours, and consumption is required to estimate the parameters of interest. First, I discuss about the dataset that can meet this criteria. Then, the identification and estimation strategy employed is examined.

3.1 Data

The only dataset in the US that satisfies the data requirements is the Panel Study of Income Dynamics (PSID). The PSID was conducted annually from 1968-1997 and then biennially from 1999 onwards. PSID contains data on individual annual earnings and hours worked. Hourly wage is obtained by dividing annual earnings by annual hours worked.[13]

PSID collected information only on food consumption and rent until 1997. From 1999 onwards, they started collecting detailed data on consumption of services such as child care, education, health expenses, transportation, utilities, and home insurance. Durables and services account for a large share of total household consumption (78% in the NIPA series for year 2016). The imputation procedure of Attanasio and Pistaferri (2014) allows the recovery of the consumption of services before 1999 by using data from 1999 onwards. Their method relies on the intuition that the total money spent on durables depends on the relative prices of the various consumption categories, taste and preferences shifters (demographic and socio-economic variables), and total expenditure. This methodology is quite popular in the literature, examples include Gallipoli et al. (2020), and Gorbachev (2016). Appendix D.2 provides more details on the imputation procedure.

I restrict the analysis to the non-SEO (Survey of Economic Opportunity), non-Latino and non-immigrant sample of the PSID, and the years 1977-2016. The selection on years is forced since the information regarding job mobility and spousal earnings and hours became available only since 1977. Household earnings and hours are restricted to males in the baseline analysis. The sample selection used in this paper fol-

[13] Figure 14 shows that my computed wage lines up well with the reported wage for individuals that report to receive hourly wage on their main job.

lows BPS quite closely. But it can be summarized as follows: drop households where males report zero annual hours and age is above 57 years or below 25 years. Wages, income, and consumption observations that display extreme jumps are dropped. More details on the sample selection process are discussed in Appendix D.1.

3.1.1 Classifying recessions in data

The most commonly used classification system of business cycles is the NBER business cycle dates. Following Guvenen et al. (2014) recessions are labelled using the trough to peak of the national unemployment rate. When the trough of the unemployment rate occurs in the first six months of the year, then that year is included as a recession year. A year is labelled an expansion if the peak of the unemployment rate occurs in the first half of the year; otherwise, it is a recession. Following Guvenen et al. (2014), the separate recessions in the early 1980's are combined together as a single recession phase. 2010 is classified as a recession because the unemployment rate in that year was still higher than the peak unemployment rate of most other recessions. Overall, the years 1979-1982, 1990-1992, 2002, and 2008-2010 are classified as recessions.

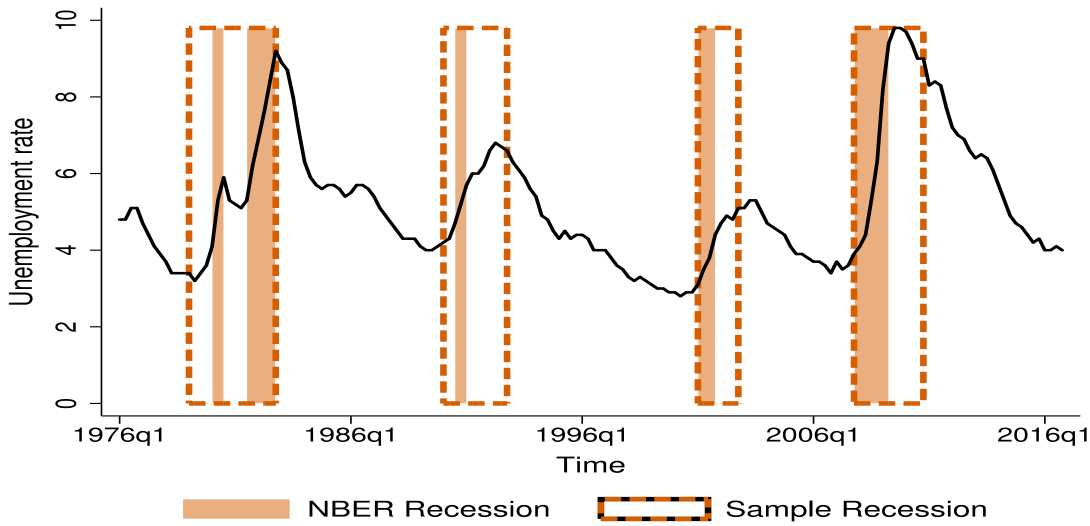

Figure 1: Male unemployment rate in the age group of 25-54

Figure 1 presents the national unemployment rate of men (aged 25-54) from the first quarter of 1976 upto the fourth quarter of 2016. NBER recessions are denoted using solid colours. The classification of recessions applied in this study is shown as dashed blocks. Two things stand out from figure 1. First, NBER recessions usually last around one year. Secondly, this paper's labelled recessions include NBER recession dates. 34% of the person-year observations in the sample are recessions and 66% are expansions. Figure 15 exhibits that the GDP per capita growth rate is negative or close to zero in those years labelled as recessions (except for 1979). Thus, economic conditions were worse in the years classified as recessions.

3.1.2 Descriptive statistics

Table 1: Descriptive Statistics

	Recession	Expansion
Panel A: Averages		
Consumption ($)	31528	32780
Labour earnings		
Earnings ($)	59924	62293
Hours worked	2216	2271
Panel B: Standard deviation		
$\Delta^2 \log$ (Wages)	0.321	0.315
$\Delta^2 \log$ (Earnings)	0.338	0.336
$\Delta^2 \log$ (Consumption)	0.259	0.259
Observations	10760	20998

Note: Variables expressed in dollars are deflated by the CPI index (base year is 2006). All variables are annual apart from wages that are per hour.

Panel A in Table 1 displays the sample averages and standard deviation of the total consumption, and labour market outcomes. Consumption falls by 3.8%, from $32780 in expansions to $31528 during recessions. The fall in earnings in recessions is higher than that of hours. Thus, both hours and wages must be falling during economic downturns. Panel B shows the standard deviation of the log wages, and earnings and household consumption. Real wages have slightly higher volatility in recessions than expansions but this is not true for earnings. Grigsby et al. (2021) highlight the presence of nominal wage rigidity in the US. Appendix Figure 16 shows that the highest density of wage growth is around 0 but there still exists substantial variation away from 0 as well.

3.2 Identification

The cross-sectional moments of wages, consumption and hours are used estimate the elasticities and variances. Identification involves two steps. First, I estimate the variance of transitory and permanent shocks by using the cross-sectional variance and covariance of wage growth. Second, estimate the elasticities of hours and consumption by using the cross-sectional covariance of wage growth and consumption and hours growth. Some of the identification assumptions are standard in the consumption inequality literature. But some additional assumptions are needed to estimate the coefficients for recessions and expansions.

3.2.1 Identification of wage parameters

To identify the variance of transitory and permanent shocks, I use the covariance of current wage growth with future wage growth, and variance of current wage growth. Unfortunately, the PSID became a biennial survey from 1999 onwards which implies that one can only define variables of two-year difference.

$$\text{Cov}\left(\Delta^2 w_{i,t}^{s(t)}, \Delta^2 w_{i,t+2}^{s(t+2)}\right) = -\sigma^2_{u,s(t)} \tag{8}$$

$$\text{Var}\left(\Delta^2 w_{i,t}^{s(t)}\right) = \sigma^2_{u,s(t)} + \sigma^2_{u,s(t-2)} + \sigma^2_{v,s(t)} + \sigma^2_{v,s(t-1)} \tag{9}$$

Equation 8 estimates the variance of transitory shocks for recessions (expansions) when at time t a recessions (expansions) occurs irrespective of the aggregate state at time $t+2$. Equation 9 helps to identify the variance of the permanent shock for recessions when $s(t) = s(t-1) = s(t-2)$ are recessions. Thus, a recession or expansion episode has to last for 3 periods in order to identify the respective permanent shock variance. This is the key assumption to estimate the parameters over the business cycle, and it also affects how I define recessions and expansions in the data.

3.2.2 Identification of consumption and hours elasticities

Equations 10, and 11 helps us identify transmission coefficients with respect to transitory shocks. Equations 12 and 13 identify transmission coefficients with respect to permanent shocks when $s(t) = s(t-1) = s(t-2)$, and given the coefficients against transitory shocks.[14]

$$\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\, \Delta^2 w_{i,t+2}^{s(t+2)}\right) = -\kappa_{c,u}^{s(t)} \sigma_{u,s(t)}^2 \tag{10}$$

$$\text{Cov}\left(\Delta^2 h_{i,t}^{s(t)},\, \Delta^2 w_{i,t+2}^{s(t+2)}\right) = -\kappa_{h,u}^{s(t)} \sigma_{u,s(t)}^2 \tag{11}$$

$$\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\, \Delta^2 w_{i,t}^{s(t)}\right) = 2\kappa_{c,u}^{s(t)} \sigma_{u,s(t)}^2 + 2\kappa_{c,v}^{s(t)} \sigma_{v,s(t)}^2 \tag{12}$$

$$\text{Cov}\left(\Delta^2 h_{i,t}^{s(t)},\, \Delta^2 w_{i,t}^{s(t)}\right) = 2\kappa_{h,u}^{s(t)} \sigma_{u,s(t)}^2 + 2\kappa_{h,v}^{s(t)} \sigma_{v,s(t)}^2 \tag{13}$$

Two sets of orthogonality conditions must hold relating the consumption and hours allocation to the shocks for the identification strategy to hold:

$$\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\, v_{i,t+1}\right) = \text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\, u_{i,t+1}\right) = 0 \tag{14}$$

$$\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\, v_{i,t-2}\right) = \text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\, u_{i,t-3}\right) = 0 \tag{15}$$

Equations 14 and 15 are assumed to hold for relating hours to wage shocks as well. Equation 14 is known as the "No Advance Information" about future shocks in the consumption inequality literature. Equation 15 is thought as "Short History Dependence" of past shocks.[15] Blundell et al. (2008) assume the same set of orthogonality conditions while estimating the transmission coefficient of temporary and permanent shocks into consumption.

BPS argue that a zero covariance of future wage growth and current consumption growth indicates that current household consumption is not responding to future changes in wage. This should indicate that households do not have advance information. I cannot reject the null hypothesis of zero correlation in the data.[16] Kaplan and Violante (2010) argue that the assumption of short history dependence causes a negligible downward bias in the transmission coefficient of consumption in an economy where households face the natural borrowing constraint.

[14] Please refer to Appendix C.2.3 where I discuss the over-identifying restrictions

[15] See Arellano et al. (2017) and Commault (2017) as examples where the short history dependence assumption is relaxed by allowing for effect of past income shocks on current consumption growth

[16] This test works better when there is a short run anticipation of future shocks like promotion next year. But if the wage process involves heterogeneous growth component that are known to an individual at time 0 (as in Baker (1997), Guvenen (2007), and Lillard and Weiss (1979)) then Kaplan and Violante (2010) show that the bias in the transmission coefficients increases with the amount of information the individual has at time 0.

3.3 Estimation Strategy

I employ a multi-step empirical strategy where, in the first step, predictable changes in consumption, earnings, and wages are accounted for by regressing two year growth of variables on observable characteristics. Following BPS, I utilize earnings instead of hours during estimation.[17] Predictable changes in consumption, wages and income These characteristics in the wage regression contain dummies for year, year of birth, education, race, state, and interaction of education or race with year. The controls in the consumption and income regression include those used in the wage regression and dummies for employment status interacted with year, level and change in family size, number of kids, other income recipients in the household and whether the couple supports anyone outside their family.

The cross-sectional moments are constructed using the residuals from the above regressions. Measurement error in wages, consumption and earnings are taken into account using a bounds approach. Estimates from Bound et al. (1994) are used to assign the variances of wage and income that can be attributed to error.[18] The estimation process proceeds in two steps. First, the variances of the shocks by age-groups are computed (25-33, 34-39, 40-45, 46-51, and 52-57). Second, the transmission coefficients are recovered using the moment conditions involving consumption, earnings, and wage growth. The Generalized Method of Moments (GMM) with an Equally Weighted Minimum Distance is used in both cases.[19] Standard errors for the transmission coefficients are derived using Panel Bootstrap, and robust standard errors for the variances are clustered at the household level.

4 Empirical Results

The empirical results are discussed in this section. First, I show how uncertainty changes over the business cycle. The transmission coefficients into consumption and hours and subsequently the channels of insurance are analysed.

[17] Transmission coefficient in hours is equal to the transmission coefficients in earnings minus 1 as $\Delta^2 y_{i,t} = \Delta^2 h_{i,t} + \Delta^2 w_{i,t}$.

[18] Appendix C.1 contains more details on how I deal with measurement error.

[19] Altonji and Segal (1996) show that the Equally Weighted Minimum Distance outperforms the Optimally Weighted Minimum Distance in small samples due to the correlation between sampling errors in the weighting matrix and sampling errors in the second order moments.

4.1 Wage parameters

Figure 2 displays the estimates of the variances of transitory and permanent wage shocks in recessions and expansions. The solid lines denote the 90% confidence interval around each estimate. The stars indicate the p-value of the null hypothesis of the recessions and expansions coefficient being equal. The transitory shock variance increases from 0.008 in recessions to 0.011 in expansions, but this difference is insignificant. The permanent wage shock variance decreases from 0.032 in recession to 0.02 in expansion. The estimates and the difference between them are all statistically significant.

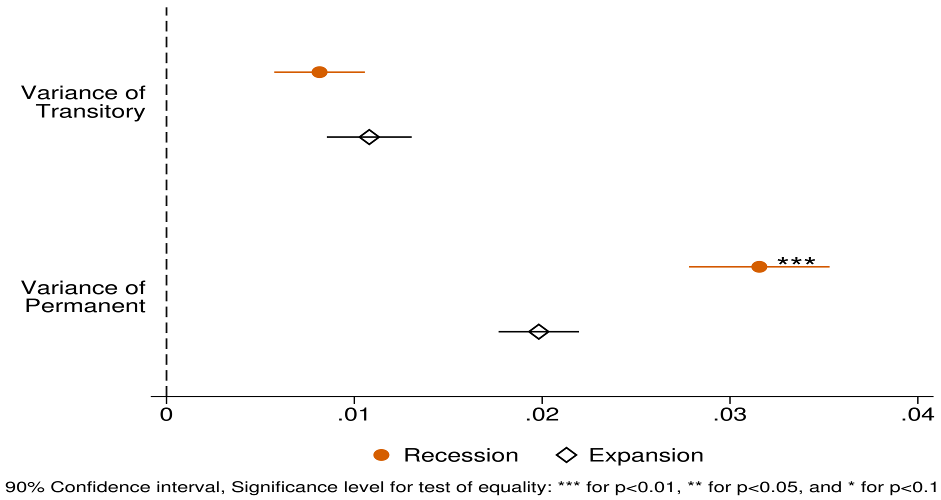

Figure 2: Transitory and permanent shock variances

Nakajima and Smirnyagin (2019) finds that the ratio of the permanent wage's standard deviation in recession to expansion is 1.5, similar to my estimate of 1.26.[20] Thus, wage uncertainty or the cross-sectional dispersion in permanent wage shock, does increase during bad economic conditions. Tables 8, 9, and 10 show that this increase in the variance of permanent wage exists among various age-groups, occupations and industries respectively.

Busch et al. (2018) and Guvenen et al. (2014) do not find evidence of countercyclicality in permanent wage. Nakajima and Smirnyagin (2019) argues that some of these differences can be attributed to a narrower definition of labour income adopted in Gu-

[20]Nakajima and Smirnyagin (2019) follows the same parametric framework as Storesletten et al. (2004), which is different from this study. Their methodology relies on the following intuition: cohorts that have experienced more recessions will have a higher variance of persistent wage.

venen et al. (2014). Guvenen et al. (2014) excludes individuals whose income does not exceed half of an hourly minimum wage multiplied by 520 hours (roughly $1,300 in 2005). Moreover, a smaller variance of temporary shocks in recessions can also explain the dichotomy between these studies given that the variance in the growth of wages does not change much over the business cycle. Table 1 shows the the variance in the growth of wages or earnings does not change much between downturns and upturns. If the variance of temporary shocks is smaller in recessions, which we find, then a larger residual variance of wages is attributed to permanent shocks. On the other hand, Busch et al. (2018) and Guvenen et al. (2014) assume in their estimation strategy that the variance of temporary shocks does not change over the business cycle which subsequently leads to the conclusions that the variance of permanent shocks does not vary between good and bad times.

Low et al. (2010) argue that accounting for job mobility in the wage process reduces the variance of permanent shocks. I modify the wage process to account for wage differentials accruing to employer changes, following Low et al. (2010). This includes both voluntary and involuntary job changes since I cannot separate them in the data. Job mobility is endogenous to wages, so the Inverse-Mills ratio from the Heckman-correction of job mobility is included while computing the wage growth residuals. Mobility is instrumented using households' unearned income and interaction of holding mortgage or not dummy with year.

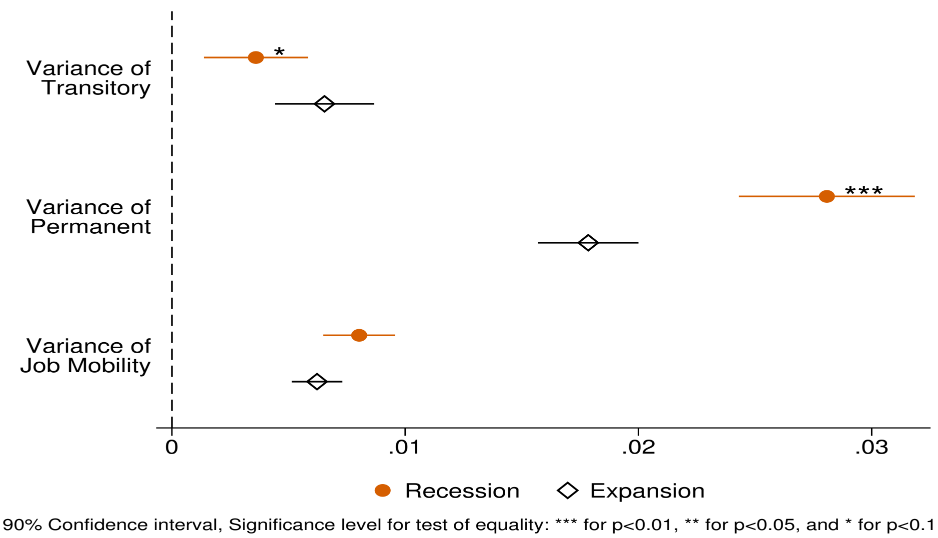

Figure 3: Wage parameters accounting for job mobility

Figure 3 exhibits that the variance of permanent wage is still higher in recessions than expansions, even after accounting for job mobility. The job mobility variance is also higher during recessions than expansions, but this difference is statistically insignificant from zero. Thus, this shows that the rise in wage uncertainty is present in among individuals who have not changed their employer. This result can explain why studies in the income risk literature find that the government benefits play a limited role in insuring against business cycle risk. Nakajima and Smirnyagin (2019) and Busch and Ludwig (2020) display that the variance and negative skewness of both the post- and pre-government household permanent income increase during bad times. This paper's finding implies that increasing unemployment benefits will not fully close this gap as employed individuals contribute to this cyclicality as well.

4.2 Transmission Coefficients and Consumption Smoothing Channels

Figure 4 highlights the transmission coefficients into consumption and hours against transitory and permanent wage shocks in recessions and expansions. The transmission into consumption against a transitory shock is -0.175 in recessions and -0.26 in expansions. This difference is statistically insignificant from zero. A negative coefficient can be interpreted as consumption and leisure being complements to each other (Wu and Krueger (2019)). Hours rise (leisure falls) in response to a positive temporary wage shock because of substitution effects. The marginal utility of consumption falls with a rise in hours if consumption and leisure are complements, so agents optimally reduce their consumption.

The pass-through of a permanent wage shock into household consumption is 0.29 and 0.31 in bad and good times respectively. BPS estimate this coefficient as 0.33. Heathcote et al. (2014) find the effect of a permanent income shock into consumption is approximately 0.4. Moreover, the difference between the recession and expansion estimate is small and insignificant, which implies that households can smooth consumption equally well in recessions and expansions. To the best of my knowledge, this is the first study that has systematically quantified the degree of consumption smoothing in recessions and expansions.[21]

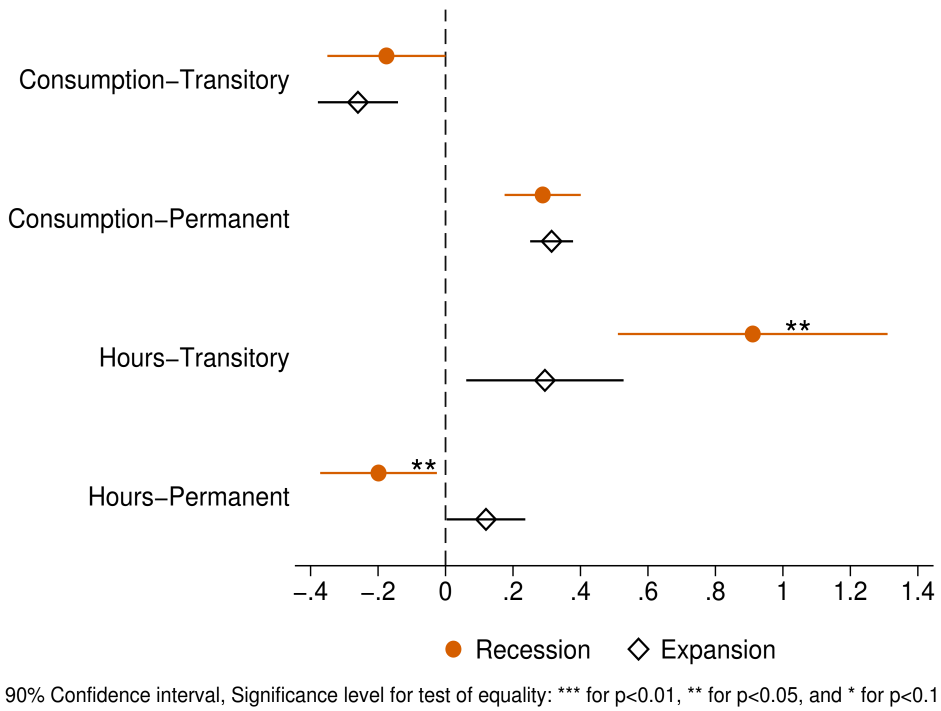

Figure 4: Transmission coefficients against transitory and permanent wage shocks

The transmission coefficient of a transitory wage shock into hours is 0.295 and 0.91 in expansions and recessions respectively. Keane (2011) finds that the median and mean value of Frisch labour supply from a meta-analysis of many studies to be 0.31 and 0.85 respectively. Thus, my estimates are around the range of estimates in the literature. The transmission coefficient into hours against a permanent wage shock is -0.2 and 0.12 in recessions and expansions respectively. These differences are large and statistically significant. They imply that hours increase more in response to a fall in permanent wage in recessions than expansions. The expansion estimate is insignificantly different from zero, so the focus on the difference between the coefficients should be only in terms of magnitude and not size. Keane (2011) compute the mean Marshallian labour supply elasticity to be 0.06.

The difference between the hours elasticity permanent wage shocks in good versus bad times implies that wealth effects on labour supply are stronger during economic

[21] Blundell et al. (2008) argue in favour of a similar conclusion. They cannot reject the null hypothesis of the consumption transmission coefficient is equal between 1979-1984 and 1985-1992. They argue that the former period mostly comprise recessions and the latter period contains mostly expansions. But, there is significant overlap of recessions and expansions in both these periods, as shown in Figure 1, to say convincingly that consumption insurance is acyclical.

downturns than upturns. Cantore et al. (2022) find evidence of strong income effects on labour supply among the poorer employed individuals who increase their hours worked in response to an increase in the interest rate. Auclert and Rognlie (2017) show that New Keynesian models with GHH preferences, which lead to zero wealth effects on labour supply, generate unrealistically large fiscal and monetary multipliers. The estimates in this paper suggest that optimal tax policies in recessions versus expansions can be significantly different if wealth effects on labour supply are considered or ignored. Thus, researchers should exercise caution when utilizing GHH preferences in macroeconomics models.

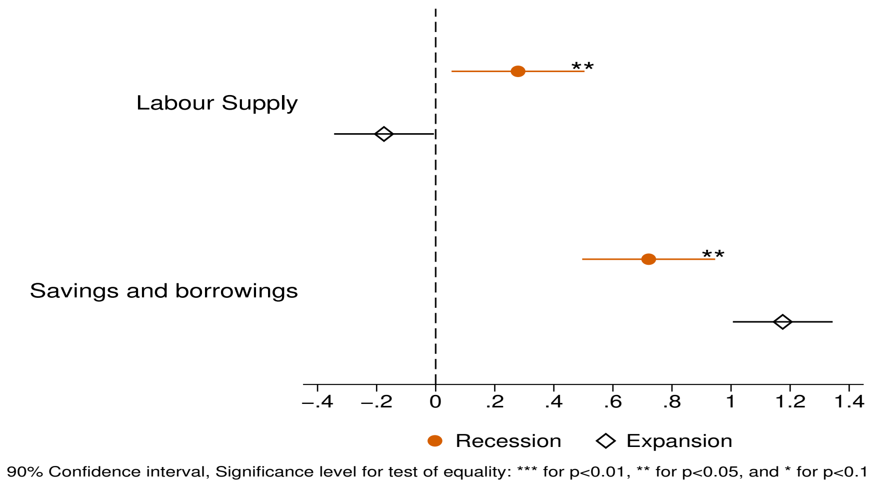

Figure 5: Decomposing consumption smoothing against a permanent wage shock

What are the implications on the channels of consumption smoothing of the fluctuations in labour supply elasticities between good and bad times? Given, that consumption against transitory shocks is perfectly smoothed, I focus on the channels of consumption smoothing against permanent shocks. Figure 5 shows that the relative contribution of labour supply to consumption smoothing increases from -17.5% in expansions to 28% in recessions. These differences are statistically significant. The contribution of savings and borrowing falls from 117.5% in expansions to 72% in recessions. Mechanically, these effects are driven entirely due to the change in the coefficients of labour supply against the permanent shocks ($\kappa_{h,v}^{s(t))}$) as seen from equation 7. The coefficient of consumption against a permanent wage shock ($\kappa_{c,v}^{s(t))}$) is not different in recessions and expansions. Intuitively, wealth effects on labour supply become stronger during economic downturns that lead to the increase in the relative contribution of labour supply to consumption smoothing. In practise, people might be finding reemployment in lower-skill occupations (Huckfeldt 2022) or resorting to the gig economy to smooth wage shocks (Koustas 2018).

I also show that this asymmetric nature of consumption smoothing is prevalent across the income distribution. I split households into below and above median recent earnings, using average earnings 4 and 6 years before an expansion/recession episode. Figure 6 shows the relative importance of the two instruments to smooth consumption for below and above median pre-episode income in recessions and expansions. The increase in labour supply as a consumption smoothing device during recessions exists for both groups.

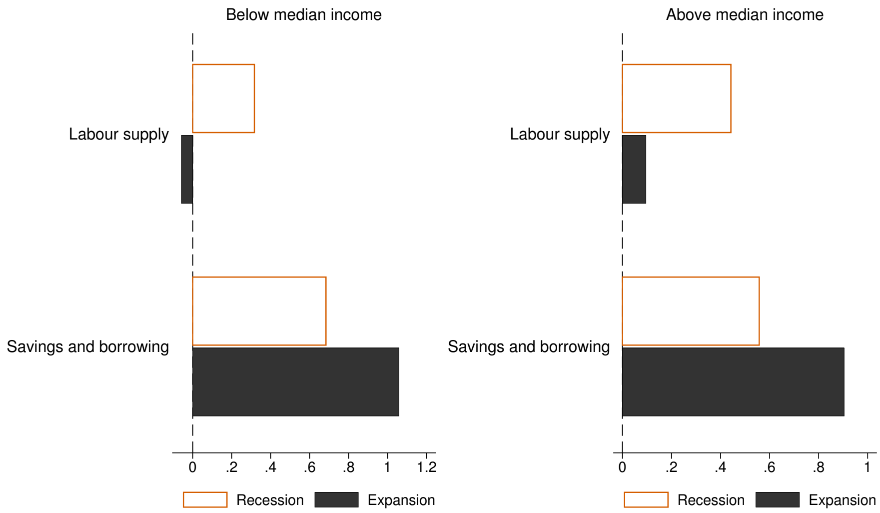

Figure 6: Decomposing consumption smoothing between below and above pre-episode individual income

An alternate way to understand the degree of consumption smoothing is to compute the Marginal Propensity to Consume out of permanent shocks (MPCP). The transmission coefficient of consumption to the permanent wage shock provides the Marginal Propensity to Consume out of permanent wage shocks. On the other hand, the Marginal Propensity to Consume out of permanent income which is the main coefficient of interest in macro models, (Carroll 2009), is given by:

$$MPCP_t^v = \frac{\kappa_{c,v}}{1+\kappa_{h,v}} \left(\frac{\overline{C_{i,t}}}{Y_{i,t}} \right)$$

This captures the aggregate marginal propensity to consume given that all individuals have the same transmission coefficient to permanent wage shocks. [22]

The annual MPCP is 11.5% and 18.9% in expansions and recessions respectively. As the role of savings in consumption smoothing falls during recessions, the pass-through of a permanent wage shock into consumption after accounting for the endogenous labour supply responses increases during recessions.

4.3 Additional Channels of Consumption Smoothing

The empirical exercise above included labour supply and savings, the two tools available to an individual to insure consumption. But there are additional channels that households use to smooth consumption, namely, government taxes and transfers and spousal labour supply. In this subsection, I discuss whether my empirical findings change when these additional channels are considered.

4.3.1 Government Taxes and Transfers

I incorporate the role of government taxes and transfers through progressive taxation. In the presence of progressive taxation, an individual pays a lower tax rate when experiencing a negative wage shock, thus achieving some insurance. I follow the same formulation as Heathcote et al. (2017), given by:

$$Y^{AT} = (1 - \chi)\, Y^{1-\tau} \tag{16}$$

where, Y is the before-tax income, Y^{AT} is the after-tax income, τ is the marginal tax rate and χ affects the level of taxes. This function approximates the average tax rate quite well, as seen in the Appendix Figure 21.

This formulation does not change the structure relating consumption and hours to shocks in Equation 4. But it affects two things: firstly, the interpretation of transmission coefficients, and secondly, the decomposition of consumption smoothing. The transmission coefficients must now be interpreted as the effect of the wage shock and progressive taxation combined. When there is a positive temporary wage shock then hours increase as Frisch labour supply elasticity is positive. But since tax rate increases

[22] The Appendix Section C.3 provides more details.

as well, the after-tax increase in wage is smaller. So, hours also increase less relative to when progressive taxation is absent. The transmission coefficients into hours and consumption must be interpreted as capturing this final effect. The decomposition of consumption smoothing also changes into:

$$1 \approx \underbrace{\frac{\tau}{1-\kappa_{c,v}^{s(t)}}}_{\text{Tax}} + \underbrace{\frac{-(1-\tau)\,\kappa_{h,v}^{s(t)}}{1-\kappa_{c,v}^{s(t)}}}_{\text{Labour Supply}} + \underbrace{\frac{1}{1-\kappa_{c,v}^{s(t)}}\frac{\partial \Delta\,(M/Y)}{\partial v_1}}_{\text{Savings and borrowing}} \tag{17}$$

The left panel of Figure 7 shows that government taxes and transfers contribute 25% and 23% to consumption smoothing during recessions and expansions respectively. Heathcote et al. (2014) estimates that public insurance accounts for 30 percent of total consumption smoothing and BPS estimate the role of taxes and transfers to be 20 percent. My estimates lie in the middle of their estimates. The difference in the estimates is not significantly different from zero. The right panel clarifies this finding, the marginal tax rates do rise during recessions, but this increase is relatively small. This small increase in the marginal tax rates is consistent with the findings of Heathcote et al. (2020), they use data from the Congressional Budget Office rather than survey data. This is in spite of unemployment benefits being included in the estimation of the marginal tax rates.[23] More importantly, the role of labour supply is 38pp higher in recessions than expansions and is significantly different from zero. Thus, the key take-away from this exercise is – incorporating taxes and transfers does not change the conclusion of the main empirical findings of this article.

4.3.2 Spousal Labour Supply

Spousal labour supply or the added-worker effect is another channel that households' use to smooth consumption. Halla et al. (2020), Lundberg (1985), and Stephens (2002) show the importance of this strategy when the male earner loses their job involuntarily. BPS and Haan and Prowse (2015) find that the spousal labour supply contributes significantly in response to a wage shock. Including the secondary earner (also referred as "spouse") can also have additional effects. It might affect the first earner's response to their own wage shock depending on the degree of complementarity in the leisure

[23] Appendix D.3 contains more details on how I computed the progressivity of the US tax system

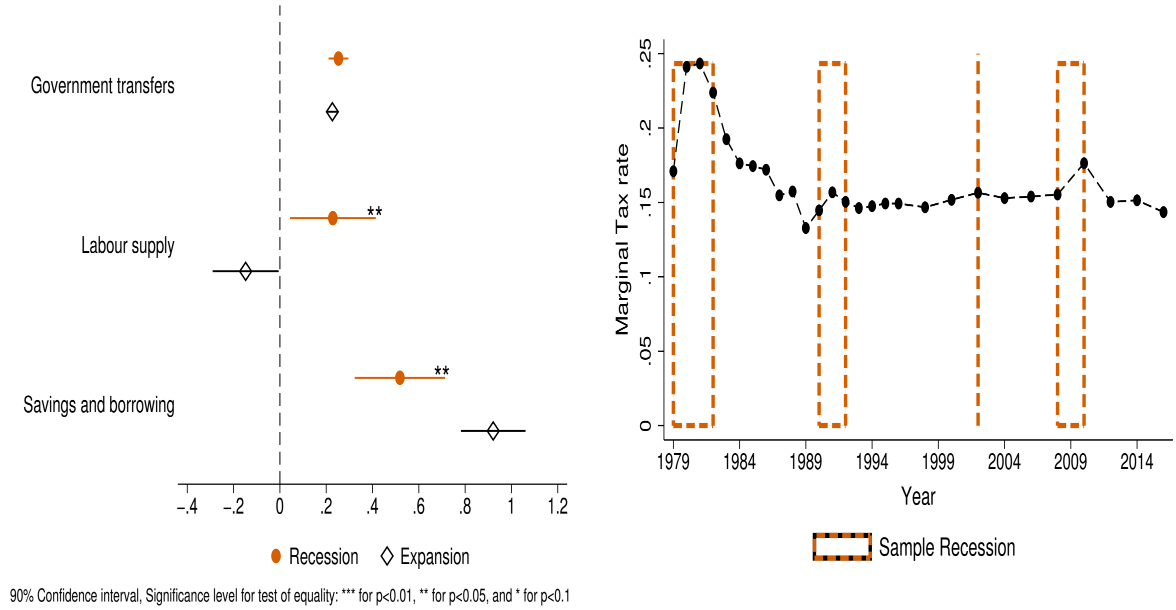

Figure 7: The left panel shows the sources of consumption smoothing against a permanent wage shock. The right panel shows the time series of the marginal tax rates.

or bargaining power between the two earners. It is also possible that it leaves the first earner's response unaffected and so only affects only savings. I extend the baseline empirical set-up to include the spouse's hours worked (intensive margin) and wage shocks.[24] The decomposition of consumption smoothing against a permanent wage shock to the first earner is given by:

$$1 \approx \underbrace{\frac{\tau s}{s-\kappa_{c,v_1}^{s(t)}}}_{\text{Tax}} - \underbrace{\frac{(1-\tau)\, s\kappa_{h_1,v_1}^{s(t)}}{s-\kappa_{c,v_1}^{s(t)}}}_{\text{Own Labour Supply}} - \underbrace{\frac{(1-\tau)\,(1-s)\,\kappa_{h_2,v_1}^{s(t)}}{s-\kappa_{c,v_1}^{s(t)}}}_{\text{Spousal Labour Supply}} + \underbrace{\frac{1}{1-\kappa_{c,v}^{s(t)}}\frac{\partial\Delta\,(M/Y)}{\partial v_1}}_{\text{Savings and borrowing}} \tag{18}$$

where s denotes the share of first earner's human wealth (present discounted value of lifetime income) in family human wealth, v_1 is the first earner's permanent wage shock, $\kappa_{h_2,v_1}^{s(t)}$ is the elasticity of spousal hours against a first earner permanent wage shock. $\kappa_{h_2,v_1}^{s(t)} < 0$ implies that the second earner works more in response to a negative permanent wage shock to the first earner.

Figure 8 highlights the sources of consumption smoothing against a head permanent wage shock. Spousal labour supply provides 10% and 18% consumption insurance in expansion and recession respectively. These differences are not significant

[24]Refer to Appendix E for more details.

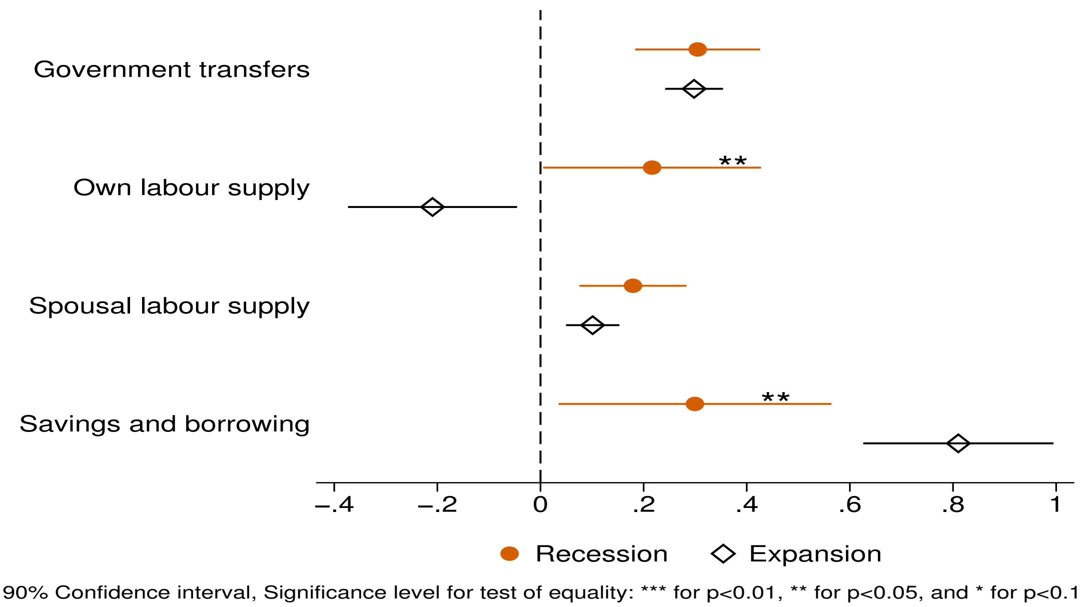

Figure 8: Decomposing consumption smoothing against a shock to the first earner permanent wage

though. Own labour supply accounts for -21% and 22% in expansion and recession respectively and these differences are significant. Spousal labour supply not being used more during recessions than expansions, might be due to the first earner being concerned about the loss in bargaining power. Therefore, they insure themselves more rather than relying on spousal labour supply (Pan (2017)). Government transfers account for 30% in both recession and expansion.[25] The relative contribution of savings falls from 81% in expansions to 30% in recessions, and this difference is statistically significant from zero. Thus, own labour supply is used more by the first earner in recessions to smooth consumption and households' use savings less.

Comparison of methodology with BPS : BPS uses a semi-structural model to estimate the transmission coefficients where the share of financial wealth to total wealth (financial plus human) links the Frisch and Marshallian elasticities. They rely on asset data to estimate the utility preferences and the model implied transmission coefficients. On the other hand, my methodology does not impose any relation between the coefficients, and does not use asset data. This suggests that my estimates are severely biased because these coefficients are not explicitly linked in my estimation, unlike BPS. In order to address these concerns, I apply the methodology in this paper (without business

[25]The spousal labour supply estimates suggest that taxes do not displacing spousal labour supply when the first earner experience a wage shock, as in Cullen and Gruber (2000).

cycle extension) on the same sample as BPS.

Table 7 in the Appendix highlights the transmission coefficients computed by each methodology. Most of the coefficients are close or are within the confidence interval of the estimate by the other methodology and vice-versa, except for transmission of the first earner hours against the spouse's temporary wage shock. This suggests that the approach undertaken in this study works well compared to their methods, as long as the object of interest are the transmission coefficients. This paper's methodology cannot recover the underlying preference parameters, unlike BPS.

4.4 Robustness checks

In this subsection, I explore two candidate explanations of this paper's findings. One focusses on how wealth effects on labour supply might increase due to a fall in the interest rates, whereas the other investigates whether the nature of employer-employee relationships might explain the findings.

4.4.1 Fall in interest rates

One rationalization of the empirical fact is that the monetary authority reduces the interest rate to boost economic activity during high uncertainty periods. This reduces an individual's wealth (wealth that an individual holds at the start of a period) and strengthens the wealth effect on labour supply. I account for changes in the interest rate in two ways. First is to include year fixed effects in the regression to compute residuals. This can account for aggregate changes that affect all households; however, they cannot capture the heterogeneous effects among consumers. Second, I compare households' consumption smoothing channels with and without a mortgage to determine whether changes in interest rates can shed light on the findings. The logic relies on Wong (2019)'s arguments that the transmission of monetary policy into consumption is driven by homeowners who refinance or acquire new housing loans. Moreover, Beraja et al. (2019) argue that regional differences in monetary policy are driven by housing equity through its influence on mortgage refinancing.

Figure 9 displays the consumers' insurance channels for those who hold a mortgage on their main house and those who did not. The baseline recessions and expansions estimate for labour supply are 28% and -17.5% respectively, which means a

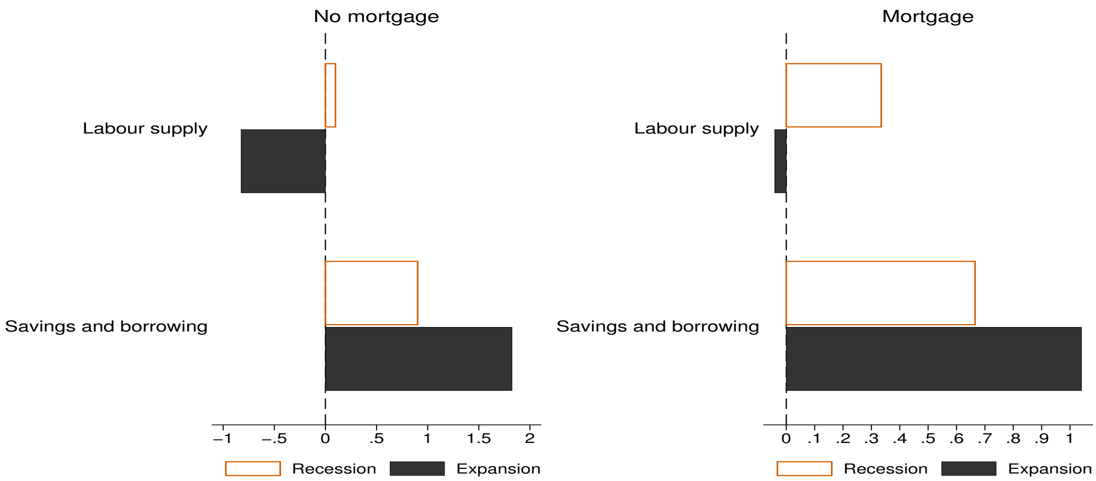

Figure 9: Decomposing consumption smoothing between mortgage and no-mortgage holders

difference of 45.5pp. This difference is 38pp for households with a mortgage and 92pp for households without a mortgage between recessions and expansions. Households without a mortgage have a higher difference, but account for only 30% of the sample. Thus, interest rate shocks cannot fully account for the data patterns.

4.4.2 Performance Pay versus Fixed Wage Contracts

Bloom et al. (2018) shows that adjustment costs in labour hiring are needed to generate reductions in output when idiosyncratic uncertainty increases. When an employer-employee relationship requires an investment, it is costly to break such relationships and form new ones. Lemieux et al. (2012) argues that when employer-employee relationships require investment and employers can better measure their workers' productivity in performance-pay contracts then it is optimal for employers to choose performance-pay contracts over fixed-pay contracts. Moreover, they find empirically that workers in performance pay wage contracts experience a wage cut but no significant change in hours worked with the employer during recessions. On the other hand, workers with fixed wage contracts face a reduction in hours with no significant change in wages during recessions. To shed more light on how differential wage contracts can influence my empirical observations, I separately estimate the transmission coefficients and consumption smoothing channels for individuals with performance

Figure 10: Decomposing consumption smoothing between individuals with performance pay or fixed wage contracts

pay contracts and fixed-pay contracts.[26]

Figure 10 shows the consumption smoothing channels with performance pay and fixed pay contracts. The difference in the baseline estimates for the contribution of hours to consumption smoothing is 45.5pp. The difference between recession and expansion is 67pp for households with fixed wage contracts and 21pp for performance pay contracts. Thus, hours are used more to smooth consumption during recessions, irrespective of the contractual arrangements between firms and workers.

4.4.3 Additional Robustness checks

Table 2 shows the contribution of labour supply to consumption smoothing against permanent wage shock in recessions and expansions and the p-value of the test of equality of the two coefficients for different specifications. The role of savings is not shown for brevity. For each new specification, I re-estimate the transmission coefficients and the sources of consumption smoothing.

Autor et al. (2015) and Moretti (2011) argue that aggregate shocks affect each local labour market differently due to factors such as industry composition and productivity. To capture differences in the local labour market, I classify recessions in each division using its unemployment rate. The differences in the trough and peak of the

[26] I follow Lemieux et al. (2009) in categorizing individuals between performance pay and fixed wage contracts.

unemployment rate across these divisions clearly stands out in the figure 17 in the Appendix. The unemployment rate increased in the West South Central and Mountain divisions during 1985 in sharp contrast to the other divisions.[27] I find that the role of labour supply increases further during recessions than the baseline estimates when using the local unemployment rate to classify recessions. The standard errors on the coefficients also fall compared to the baseline. Thus, the spatial variation in economic conditions strengthens the results, and provides support in favour of the identification strategy employed in this paper.

Table 2: Additional Robustness Results

Role of labour supply	Recession	Expansion	p-value
Baseline	0.279**	-0.175*	0.016
	(0.137)	(0.103)	
Local Unemployment	0.315***	-0.176*	0.003
	(0.118)	(0.092)	
Only currently employed	0.326***	-0.019	0.022
	(0.111)	(0.091)	
Consumption excluding rent	0.284**	-0.151	0.017
	(0.137)	(0.093)	
Friends and Family	0.335***	-0.088	0.012
	(0.114)	(0.115)	

Note: Parentheses include standard errors computed using panel bootstrap. The p-value is the level of significance of the test of equality of coefficients.

The model and the empirical specifications did not include the extensive margin of employment, but the data sample includes individuals who have experienced unemployment spells during the year. This can be problematic since the incidence of unemployment increases sharply during recessions. To address this concern, I focus on individuals that are currently employed and have not changed their employer within

[27] West South Central division contains the states of Arkansas, Louisiana, Oklahoma and Texas. Mountain division includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming.

the past two years. The role of labour supply among this group is 33% and -2% during recessions and expansions respectively. This difference is statistically significant from zero, and slightly smaller than the baseline difference.

Chetty and Szeidl (2007) argues that the presence of consumption commitments (like rent) can lead to a higher wealth elasticity of labour supply. The estimation strategy includes over-identifying restrictions between consumption and hours, and consumption includes rent. Thus, it is possible that the labour supply elasticity could be smaller during economic downturns than upturns because of such commitments. However, the baseline results are almost unchanged when comparing those obtained after excluding rent from the consumption measure. Thus, I argue that the presence of consumption commitments does not justify the empirical observations.

Friends and relatives might be another source of insurance, which is included in the residual channel. One way to account for this channel is to incorporate it into a life-cycle model and use its structure to isolate it, similar to equation 7. This is outside the scope of this paper. Instead, I re-estimate the channels by focusing on individuals living in the same state as they were born. These individuals are likely to have a strong connections to their family networks. The role of labour supply is still higher during bad than good times, and the difference is statistically significant from zero after isolating who are likely to utilize their family networks to smooth consumption.[28]

Summary of Empirical Results: I have shown so far, that uncertainty does shoot up during recessions, reflected in the rise of the variance of permanent wage shocks. The implications of the rising uncertainty are: (1) it does not affect the degree of consumption smoothing in recessions and expansions and (2) the relative contribution of labour hours to insurance against permanent wage shocks is larger during recessions than expansions. The contribution of savings falls in recessions. This reallocation in the sources of consumption smoothing occurs during recessions is robust to including government transfers and spousal labour supply as extra instruments of consumption smoothing. The fall in interest rates and the prevalence of different wage contracts among workers cannot fully resolve this empirical finding.

[28]This is not a surprising result in the context of United States as Attanasio et al. (2015) also argue that the extended family networks do not provide insurance against idiosyncratic shocks. This might not be true in the context of developing countries (Banerjee and Duflo (2007)).

4.5 Role of Liquid Assets in explaining empirical fact

Baker (2017) highlights that liquidity is an important determinant to highlight the heterogeneity in consumption responses to income shock. I investigate whether low liquidity individuals behave differently to wage shocks than high liquid wealth individuals. PSID started collecting data on the various asset categories starting from 1999. I follow Bayer et al. (2019) in defining liquid assets as consisting of saving, checking, money market and call accounts, certificate of deposits, and government bonds. Liquid debt comprises of credit card debt. I split individuals into below-median and above-median liquid wealth group based on the amount of liquid wealth at the beginning of a period.

Figure 11 shows that the asymmetry in insurance between recessions and expansions is driven by households with below-median liquid wealth. Above-median liquid wealth households in fact show a lower role of labour supply in bad relative to good times. To alleviate concerns that since I am working with a smaller sample as asset data was collected only from 1999 and that wealth is typically quite noisy, I replace observed household liquid wealth with median liquid wealth over age and education categories for the entire sample. I show in Appendix Figure 18 that I get very similar results using median measures of liquid wealth than actual values to construct the two categories.

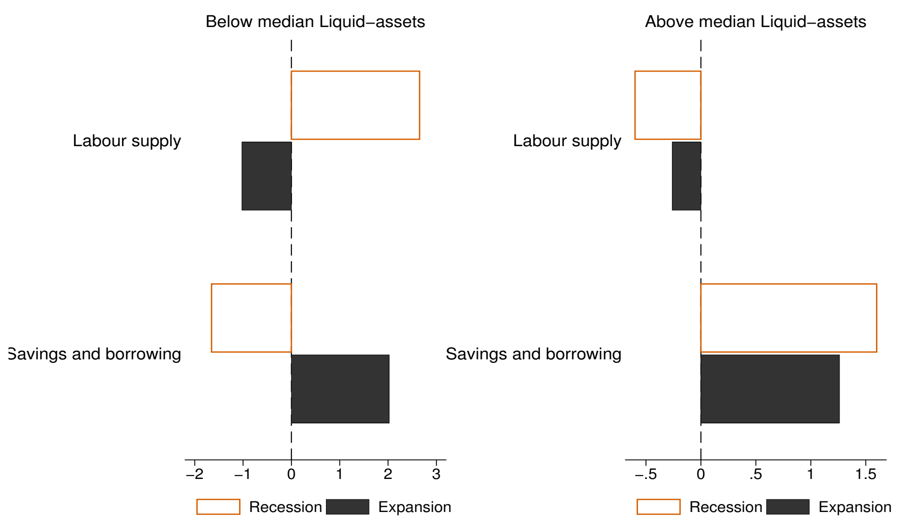

Figure 11: Decomposing consumption smoothing between below-median and above-median liquid wealth

The mechanism that I propose to show the importance of liquid wealth in driving this asymmetry over the business cycle is that since consumers accumulate more liquid than illiquid assets as uncertainty rises, it creates an indirect effect on labour supply. The portfolio reallocation strengthens the wealth effects on labour supply against a permanent wage shock leading to the increasing contribution of labour supply to insurance. I formalize this indirect effect using an incomplete assets market model in the subsequent section.

5 Life-Cycle Model

To shed light on the role of liquid assets in explaining the empirical facts, I propose a standard incomplete market life-cycle model augmented in two dimensions. First, is to allow for two portfolio choices (liquid and illiquid assets) in the spirit of Kaplan et al. (2014). Second, incorporate an aggregate state with a Markov process that affects uncertainty. The model is otherwise standard, comprising endogenous consumption, labour supply, and asset allocations given an aggregate state and idiosyncratic wage process. I abstract from the equilibrium determination of labour and asset prices as effects on labour supply elasticities cannot be transparently isolated in a general equilibrium model.

Time is discrete and frequency is annual. Agents start working at age 25 (first period), retire at age 61 (36^{th} period) and die at age 80 (55^{th} period). Individuals are trying to maximize expected utility which is additively separable across periods. The function they are maximizing is:

$$\mathbb{E}_0 \sum_{t=0}^{T} \beta^t u\left(C_t, L_t\right) \tag{19}$$

where β is the time discount factor, C_t, and L_t are consumption and leisure respectively. The per-period utility is a CES function comprising of leisure and consumption.

$$u\left(C_t, L_t\right) = \frac{\left\{\theta C_t^{\gamma} + (1-\theta)\, L_t^{\gamma}\right\}^{\frac{1-\sigma}{\gamma}} - 1}{1-\sigma}$$

where, $\gamma < 0$ governs the degree of substitution between consumption and leisure, θ determines the share between consumption and leisure, and σ is the degree of risk aversion. The felicity formulation is motivated by the empirical fact that a positive transitory wage shock leads to a fall in consumption. Wu and Krueger (2019) show that a CES utility function in consumption and hours can account for this finding, whereas a separable function cannot.[29]

The individuals face an exogenous wage process which comprises of a deterministic trend, transitory shock, and the log of a permanent shock. The variance of the transitory shock is invariant over the business cycle in the model, in support of the findings in Figure 2. The permanent wage shocks follow a log-normal distribution to ensure that the average wage does not change over the business cycle. If permanent wages follow a normal distribution then because of Jensen's inequality, the average wage will be higher in a recession than expansion.[30]

$$\begin{aligned} log\ W_{i,t} &= \alpha_1 t + \alpha_2 t^2 + F_{i,t} + u_{i,t},\ u_{i,t} \sim \mathrm{N}\left(0, \sigma_u^2\right) && (20) \\ F_{i,t} &= F_{i,t-1} + v_{i,t},\ v_{i,t} \sim \left(\frac{-\sigma^2_{v,s(t)}}{2}, \sigma^2_{v,s(t)}\right) && (21) \end{aligned}$$

Households enjoy utility from consumption in their retirement that is given by:

$$u\left(C_t\right) = \frac{C_t^{1-\sigma}}{1-\sigma}$$

Individuals receive a fixed pension that is a function of average lifetime gross income. This function is used to assess pension benefits in the US. I approximate an individual's average lifetime gross income by specifying that it is equal to 75% of their last working period permanent wage level. Low (2005) apply the same approach to approximate an agent's average lifetime gross earnings. Pension benefits are equal to 90% of average earnings upto the first bend point, 32% from the first to second and 15% after that. The bend points are set at 0.18 and 1.10 times the cross-sectional aver-

[29]The intuition is that when consumption and leisure are complements then marginal utility of consumption decreases as labour hours increase. A temporary increase in wages induces labour hours to increase because of the substitution effect. The complementarity causes the marginal utility of consumption to fall and as a result optimizing agents reduce consumption.

[30]While performing the empirical exercises, I include year fixed effects in the pre-estimation stage to control for the deviation in average wages in recessions versus expansions.

age past earnings.[31]

Asset Structure: Households cannot trade fully state contingent Arrow securities, but they can hold risk-free liquid (A), and illquid assets (D). I follow Kaplan and Violante (2014) in defining illiquid assets as earning a higher interest rate than liquid assets, but the trading of illiquid assets is subject to an adjustment cost. Illiquid assets can be thought of as either housing or stocks. The gross return of the illiquid assets is R_d and they cannot be short sold, so $D_{t+1} \geq 0$. The adjustment cost of the illiquid assets is given by:

$$\phi\left(D_t, D_{t+1}\right) = \frac{\psi}{2}\left(\frac{D_{t+1} - D_t}{D_t}\right)^2 D_t + \kappa \mathbb{1}_{D_t \neq D_{t+1}}$$

It is a combination of a fixed cost and a convex cost dependent on the current and future asset holdings. The convex cost crucially affects the relative price of illiquid to liquid asset when households are deciding their portfolio allocation problem. κ is a fixed cost which is paid whenever agents want to adjust their illiquid asset. It helps to create an inaction region such that some households might choose to not change their illiquid asset holdings every period.

Liquid assets can be thought as cash or chequeing account holdings that pay a much lower return than the illiquid asset, but can be traded without any additional cost. The gross return of the liquid asset is given by:

$$R = \begin{cases} R_a & \text{if } A_t \geq 0 \\ \bar{R} & \text{if } A_t < 0 \end{cases}$$

There is an intermediation cost $(\bar{R})$ that households pay if they want to borrow. This assumption ensures there is a mass of agent with zero liquid assets. Moreover, I assume that $\bar{R} > R_d > R_a$ so that agents cannot borrow in liquid asset to buy illiquid assets. Households' face an exogenous borrowing constraint such that $-A_{t+1} \leq \underline{A}$.

Value Function and First-order conditions while working: The value function of a

[31]Computing the actual average lifetime gross income involves adding another state variable to the problem that significantly increases the computational complexity.

household in the working phase of their life-cycle is:

$$\mathrm{V}(A,D,u,F,s(t),t) = \max\left\{V^{NA}(A,D,u,F,s(t),t), V^{A}(A,D,u,F,s(t),t)\right\}$$

where V^A and V^{NA} are the value functions conditional on adjusting or not adjusting the illiquid asset respectively. There are six state variables: the liquid and illiquid accounts, transitory shock, permanent wage level, aggregate state and time (or age).

A household who is not adjusting their illiquid asset position decides on consumption, labour supply and liquid assets. The value function of such a household is:

$$\begin{aligned}
V^{NA}(A,D,u,F,s(t),t) &= \max_{C,L,A'} u(C,L) + \beta \mathbb{E}_t \mathrm{V}\left(A',D',u',F',s(t+1),t+1\right) \\
\text{s.t. } C + A' &= \tau W (T-L) + G + RA + (R_d - 1) D \\
\text{s.t.} \quad & D' = D \\
\text{s.t.} \quad & A' \geq -\underline{\mathrm{A}}
\end{aligned}$$

Households pay a proportional tax (τ) on their income and receive a lump-sum government subsidy and constant spousal income (G). T is total time available every period. $RA + (R_d - 1) D$ is asset income. Individuals spend their total income to buy consumption good and liquid assets. When agent wants to deposit/withdraw from their illiquid account, their value function is:

$$\begin{aligned}
V^{A}(A,D,u,F,s(t),t) &= \max_{C,L,A',D'} u(C,L) + \beta \mathbb{E}_t \mathrm{V}\left(A',D',u',F',s(t+1),t+1\right) \\
\text{s.t. } C + A' + D' &= \tau W (T-L) + G + RA + R_d D - \phi\left(D,D'\right) \\
\text{s.t.} \quad & D' \geq 0 \\
\text{s.t.} \quad & A' \geq -\underline{\mathrm{A}}
\end{aligned}$$

The first-order conditions for the working individual are:

$$u_C(C,L) = \lambda_t \tag{22}$$

$$u_L(C,L) = \lambda_t \tau W \tag{23}$$

$$\beta R \mathbb{E}_t \frac{\partial \mathrm{V}(A',D',u',F',s(t+1),t+1)}{\partial A'} = \lambda_t \tag{24}$$

$$\beta R_d \mathbb{E}_t \frac{\partial \mathrm{V}(A',D',u',F',s(t+1),t+1)}{\partial D'} = \lambda_t \left(1 + \psi\left(\frac{D'-D}{D}\right)\right) \tag{25}$$

Equations 22, 23, 24, and 25 give the First-order conditions with respect to consumption, leisure, liquid asset and illiquid asset respectively, and λ_t is the Lagrange multiplier of the budget constraint. Equation 25 applies only when the household wants to adjust their illiquid asset position. The presence of a non-convex adjustment cost generates kinks in the value function which makes the first order conditions necessary but not sufficient for an optimal solution.[32]

5.1 Response in recession versus expansion

Figure 12 shows the percentage change in consumption, hours and asset allocations when the aggregate state changes to recession compared to expansion at age 15. The aggregate state realization is an expansion from age 16 and onwards. Higher cross-sectional idiosyncratic uncertainty implies a higher probability of a large negative wage shock that can lead to agents' becoming borrowing constraint. Households increase their precautionary savings to avoid such an outcome. They choose to hold more liquid relative to illiquid assets because illiquid assets are better suited to increase the level of consumption in the long-run as they earn a higher return than liquid assets. But, the presence of adjustment costs in illiquid asset trading, makes them ill-suited for short-run consumption smoothing. The stock of liquid asset doubles, whereas the stock of illiquid asset falls by 4% in recessions relative to expansions. Thus, individuals reallocate their portfolio towards liquid compared to illiquid assets in recessions relative to expansions, also highlighted by Bayer et al. (2019). Individuals also reduce consumption to increase their amount of savings, though total hours worked do not change in the current period.

[32] Details on the numerical solution are explained in Appendix F.1.

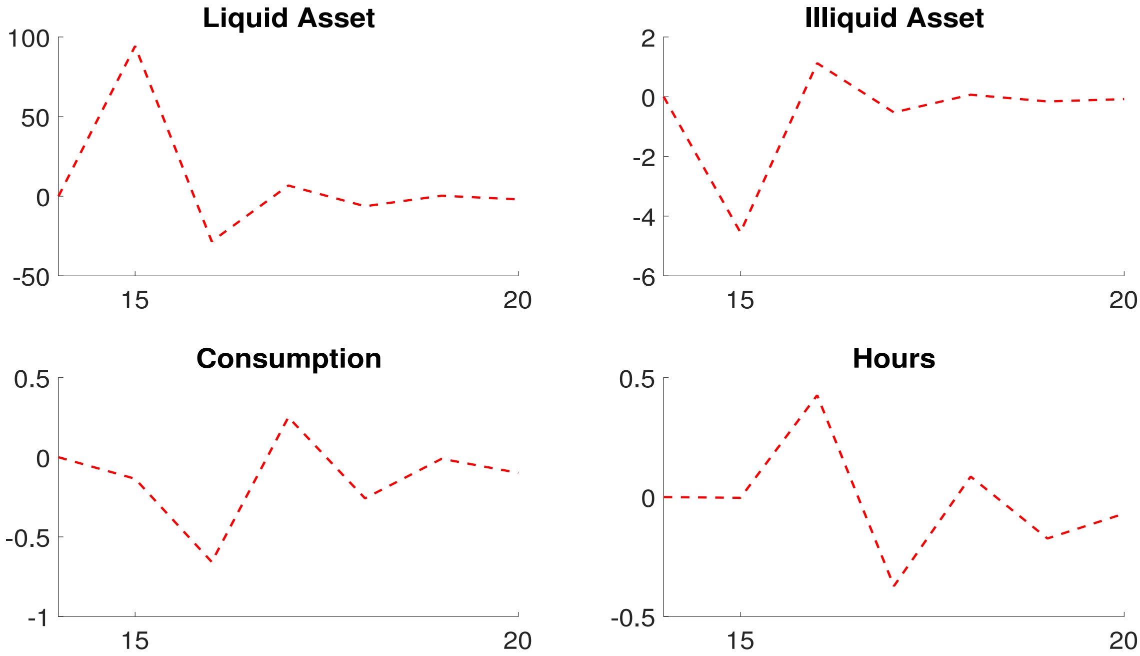

Figure 12: Shows the percentage deviation in the choice of consumption, hours, illiquid assets and liquid holdings in recession versus expansion. Table 3 shows the calibrated parameters used to simulate these responses, except for the rates of return on the assets which are constant over the business cycle.

6 Model Results

Table 3 displays the calibrated model parameters. All of the wage process parameters are calculated from the data. To compute α_1 and α_2 in equation 20, log wage is regressed on age, age squared, education dummies and 5 year cohort dummies. The sum of cohort dummy coefficients are constrained to be zero to avoid confounding age and cohort effects. The variance of the permanent wage level at time 0 ($\sigma^2_{0,w}$) in the model is equal to the cross-sectional variance at age 24 of the residuals from the above regression. The estimated wage parameters are similar to those in Blundell et al. (2018).

I define liquid wealth as sum of cash, saving and checking accounts, certificate of deposits, and government bonds minus credit card debt. Illiquid wealth comprises of real estate wealth net of mortgages, business assets, pension, stocks and other non financial assets. Illiquid debt contains mortgage debt, other real estate debt and installment debt. The real returns on liquid and illiquid assets are computed as an average of the aggregate returns over the various subcategories of assets and liabilities with their corresponding portfolio shares in the Survey of Consumer Finances used as weights. The time period considered is 1983-2016. Real returns change over the business cycle, given the significant changes in asset prices. The returns on illiquid assets are 4.5% and 0.5% in expansion and recession respectively. The returns on liquid assets are 0.5% and -0.3% in expansion and recession respectively. This corresponds to a difference of 4pp and 0.8pp between the returns on illiquid and liquid holdings. Kaplan et al. (2014) estimate a difference of 3.77pp between the average risk-adjusted after-tax real returns on liquid and illiquid assets over 1960-2009.

The convex adjustment cost of illiquid assets is 5%, which is the fee charged by realtors in the United States. The fixed cost parameter is set at 0.08. Conditional on adjusting, the total adjustment cost paid in the model is 7.6% of the stock of illiquid assets, or 3.1% of household income during working life. If adjustment costs can be interpreted as spending on financial services, it amounts to slightly more than 3% of annual income. The values for the net return on borrowing and risk aversion are from Bayer et al. (2019) that most closely resembles the current model.

The preference parameters θ and β were calibrated to target the average annual pre-tax male income ($61630) and the ratio of average working life illiquid asset to average working-life post-tax household earnings (2.31) during expansions. The degree of substitutional between consumption and leisure (γ) is set at -1.5 which is smaller than that of a Cobb-Douglas utility function ($\gamma = 0$). The aggregate state is governed by a two-state Markov process. The transition matrix is calibrated by targeting the average duration of a recession and expansion of 3 and 5 years respectively. Average length of a business cycle is 8 years in the US, and 3 years is the length of a recession that I have imposed in the data. The transition probabilities are given by:

$$\mathbb{P} = \begin{bmatrix} 0.8 & 0.2 \\ 0.33 & 0.67 \end{bmatrix}$$

where $\text{P}\left(\text{Expansion}_t|\text{Expansion}_{t-1}\right) = 0.8$ and $\text{P}\left(\text{Recession}_t|\text{Recession}_{t-1}\right) = 0.67$.

Table 3: Calibrated Model Parameters

	Description	Value Rec	Value Exp	Target/Source
Wage Process:				
σ_v^2	Variance of permanent shocks	0.032	0.02	Data
σ_u^2	Variance of temporary shocks	0.01		Data
α_1	Coefficient on age	0.07		Data
α_2	Coefficient on age squared	-0.0007		Data
$\sigma_{0,w}^2$	Variance of log wage at time 0	0.195		Data
Tax and Other Income:				
τ	Proportional tax rate	21%		Data
G	Subsidy and Spousal Income	1.01		Post-tax household income
Asset Returns and Borrowing:				
$R_d - 1$	Real net return on illiquid asset	0.33%	4.5%	Survey of Consumer Finances
$R_a - 1$	Real net return on liquid savings	-0.3%	0.5%	Survey of Consumer Finances
$\bar{R} - 1$	Net return on liquid borrowing	16%		Bayer et al. (2019)
$\underline{A}$	Borrowing Limit	-0.53		Quarter of annual income
Adjustment Cost:				
κ	Fixed Cost	0.08		
ψ	Convex component	5%		Zillow
Preferences:				
β	Discount factor	0.90		Illiquid wealth to income ratio
σ	Risk aversion	4		Bayer et al. (2019)
θ	Share between C and L	0.92		Average Annual Income
γ	Substitution between C and L	-1.5		

Note: “Rec" and “Exp" denotes Recessions and Expansions respectively.

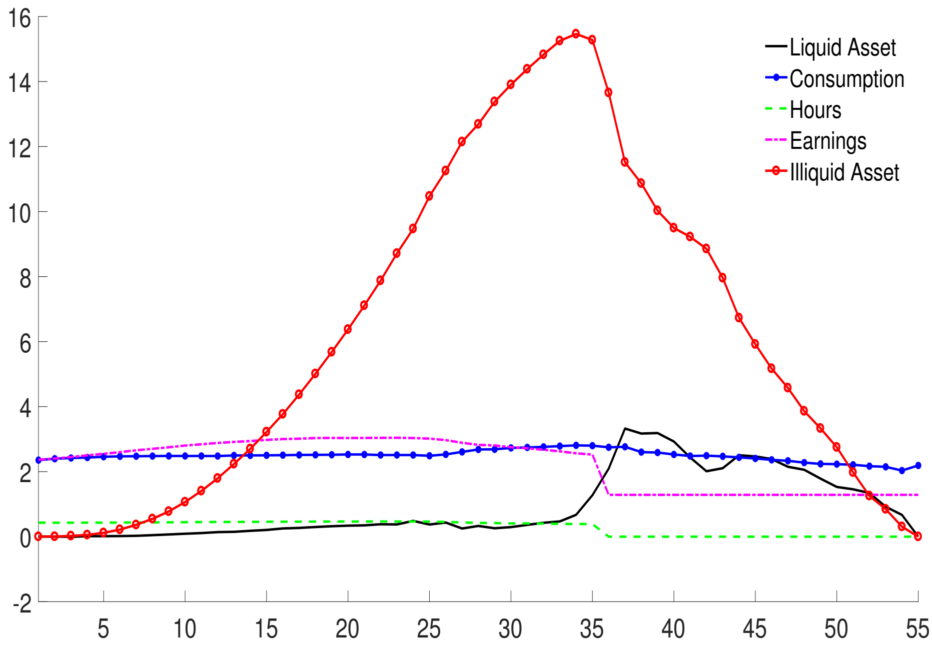

Figure 13: Average post-tax income, hours worked, consumption, illiquid assets and liquid stock over the life-cycle.

Life-Cycle Profiles

Figure 13 shows the life-cycle choices of consumption, post-tax earnings, hours worked, and illiquid and liquid asset holdings. Households deposit into the illiquid asset during working life and withdraw from it during retirement. Moreover, liquid asset positions are kept at low levels during early and middle working life. Households start saving in liquid assets close to retirement and use the combination of their pension benefits, selling illiquid assets and liquid savings to ensure their consumption level does not fall in retirement.

6.1 Elasticities of consumption and hours in recession and expansion

Table 4 shows the role of labour supply in consumption smoothing in recessions and expansions implied by the model.[33] The effect of a permanent wage shock on con-

[33]The expansion coefficient is generated by simulating an expansion for all periods and averaging over the life-cycle. I average over the working life until age 57 to be consistent with the empirical exercise. Recession value is computed by simulating a recession at each age with all other periods being expansion.

sumption ($\kappa_{c,v}^{s(t)}$) is 43.7% and 45.5% during expansions and recessions respectively, with the difference being quite small. One reason is that the demand for insurance by households and the financial conditions are exogenous. Borrowing constraints do not change over the business cycle in this model. As Broer (2020) shows that incomplete markets model display the same marginal propensity to consume in recessions and expansions unlike complete markets model with limited commitment. In such models, when households demand more insurance then borrowing constraints endogenously become less binding and so, the degree of consumption smoothing can be different in recessions and expansions. Another reason is that I allow for multiple channels of insurance. When agents demand more insurance then they can increase the role of labour supply to insure against wage shocks, keeping the role of savings unchanged.

Table 4: Model Consumption Smoothing Channels

	Recession	Expansion
Consumption to permanent shock ($\kappa_{c,v}$)	45.5%	43.7%
Channels of Consumption Smoothing		
Labour supply	17.2%	10.1%
Savings and borrowing	82.8%	89.9%

Table 4 highlights that the relative contribution of labour supply in consumption smoothing increases from 10.1% in expansions to 17.2% in recessions. The role of savings falls from 90% to 83%. The increase in uncertainty leads to a portfolio reallocation towards liquid assets relative to illiquid assets as shown in Figure 12. Since households start holding more of a lower return asset in recessions than expansions, their value of financial wealth falls. This strengthens the wealth effect on labour supply and leads to a fall in the coefficient of hours to a permanent wage shock ($\kappa_{h,v}^{s(t)}$). Thus, the role of labour supply to insurance increases as uncertainty rises in recessions.

6.1.1 Role of multiple asset-types and changes in interest rates

To demonstrate the importance of the multiple asset-types and the fall in the rates of returns over the business cycle, I perform two experiments. First, I highlight the role of labour supply to insurance in a single asset-type economy, but allow for the interest rates to fall in recessions. Second, I compute the contribution of labour supply to insurance with the rates of return not changing with the aggregate state.

Table 5: Role of labour supply across models

Role of labour supply	Recession	Expansion	Difference
Two Asset-types Model (Baseline)	17.22%	10.13%	7.09pp
Single Asset-type Model	14.73%	13.81%	0.92pp
Single Asset-type Model (Returns constant)	10.88 %	10.93%	-0.05pp

Note: $\beta = 0.93$, and $\theta = 0.918$ in single asset-type model with change in real net return on net worth of 4.1% and 0.23% in expansion and recession respectively. $\beta = 0.929$, and $\theta = 0.92$ in one-asset model with real net return on net worth of 4.1% in recession and expansion. The rest of the calibration parameters are the same across all model calibrations.

Table 5 displays the contribution of labour supply to insurance is 13.81% and 14.73% during expansions and recessions respectively in the single asset-type model. This is an increase of 0.92pp in the role of labour supply during bad times compared to the 7.09pp in the multiple asset-types model. Moreover, this small increase in the one asset-type model is entirely driven by the fall in the rates of return in recessions. When the interest rates are unchanged over the business cycle, the role of labour supply falls during recessions. An increase in uncertainty leads to households buying more assets due to the precautionary saving motive even in the single asset-type economy. But, this increases their value of financial wealth, thereby dampening the wealth effects on labour supply. Thus, the single asset-type model cannot reconcile the empirical findings. Moreover, the main reason for the increase in the wealth effects on labour during recessions is due to the indirect effect of portfolio reallocation towards a lower paying asset rather than the fall in the asset returns in recessions.

7 Conclusion

Does the degree and channels of households' consumption smoothing change in recessions versus expansions? This is the research question that this study tries to answer. An increase in cross-sectional uncertainty during recessions is the main aspect that characterizes a business cycle. Using the implications of a life-cycle model, I capture the degree of consumption smoothing and the relative contribution of two channels of consumption smoothing: (1) labour supply and (2) savings. I exploit changes in hours and consumption to wage changes within each phase of the business cycle and apply it to the Panel Study of Income Dynamics from 1977-2016. I show that the degree of consumption smoothing against a permanent wage shock is 70% in both recessions and expansions. But, the relative contribution of hours to insurance against a permanent wage shock increases significantly in recessions. The novel empirical fact and methodology are the key contributions of this paper.

I also document that the increase in the contribution of labour supply to consumption smoothing arises among the low liquid wealth households. This mechanism is formalized through a incomplete markets life-cycle model with multiple asset-types and aggregate state that affects uncertainty. When uncertainty increases, agents want to hold more liquid relative to illiquid asset that reduces their financial wealth as liquid asset pay a lower return. This reduces their financial wealth and increases the wealth effect on labour supply to a permanent wage shock. Thus, the coefficient of hours to a permanent wage shock becomes muted and the role of hours to insurance increases during recessions due to portfolio reallocation towards liquid assets.

The original empirical findings of this study point towards re-thinking about the welfare costs of business cycles. Storesletten et al. (2001) argued that the welfare costs of business cycles are significantly higher than those predicted by Lucas (1987) after incorporating the increase in the cross-sectional wage dispersion during bad times. Households desire to hold more savings and consume less leads to a sharper fall in output. This channel can be amplified in a two-asset model with labour supply. My paper shows that agents will supply more labour in response to a negative wage shock during recessions than expansions. This might lead to a further increase in holding liquid assets (unproductive) and holding less of illiquid assets (productive), and amplify the welfare costs of a recession. Future research can shed more light on the issue discussed here.

References

Abowd, J. M. and D. Card (1989). On the Covariance Structure of Earnings and Hours Changes. *Econometrica 57*(2), 411–445.

Agarwal, S. and W. Qian (2014, dec). Consumption and debt response to unanticipated income shocks: Evidence from a natural experiment in Singapore? *American Economic Review 104*(12), 3841–3884.

Aguiar, M. and G. Gopinath (2007). Emerging Market Business Cycles: The Cycle Is the Trend. *Journal of Political Economy 115*(1), 69–102.

Altonji, J. G. and L. M. Segal (1996). Small-Sample Bias in GMM Estimation of Covariance Structures. *Journal of Business and Economic Statistics 14*(3), 353–366.

Arellano, M., R. Blundell, and S. Bonhomme (2017). Earnings and Consumption Dynamics: A nonlinear Panel Data Framework. *Econometrica 85*(3), 693–734.

Attanasio, O., P. Levell, H. Low, and V. Sánchez-Marcos (2018). Aggregating Elasticities: Intensive and Extensive Margins of Women's Labor Supply. *Econometrica 86*(6), 2049–2082.

Attanasio, O., H. Low, and V. Sanchez-Marcos (2008). Explaining Changes in Female Labor Supply in a Life-Cycle Model. *American Economic Review 98*(4), 1517–1552.

Attanasio, O., C. Meghir, and C. Mommaerts (2015). Insurance in extended family networks. *NBER Working Paper 21059*.

Attanasio, O. and L. Pistaferri (2014). Consumption Inequality over the Last Half Century: Some Evidence Using the New PSID Consumption Measure. *American Economic Review: Papers & Proceedings 104*(5), 122–126.

Auclert, A. and M. Rognlie (2017). A note on multipliers in NK models with GHH preferences. *Manuscript*.

Autor, D. H., D. Dorn, and G. H. Hanson (2015, may). Untangling Trade and Technology: Evidence from Local Labour Markets. *Economic Journal 125*(584), 621–646.

Baker, M. (1997). Growth-Rate Heterogeneity and the Covariance Structure of Life-Cycle Earnings. *Journal of Labor Economics 15*(2), 338–375.

Baker, S. R. (2017). Debt and the Response to Household Income Shocks: Validation and Application of Linked Financial Account Data. *Journal of Political Economy*.

Baker, S. R., R. Farrokhnia, S. Meyer, M. Pagel, and C. Yannelis (2020). How Does Household Spending Respond To an Epidemic? Consumption During the 2020 COVID-19 Pandemic. *NBER Working Paper No. 26866*.

Banerjee, A. V. and E. Duflo (2007). The Economic Lives of the Poor. *Journal of Economic Perspectives 21*(1), 141–167.

Basu, S. and B. Bundick (2017). Uncertainty Shocks in a Model of Effective Demand. *Econometrica 85*(3), 937–958.

Bayer, C., R. Luetticke, L. Pham-Dao, and V. Tjaden (2019). Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk. *Econometrica 87*(1), 255–290.

Beraja, M., A. Fuster, E. Hurst, and J. Vavra (2019). Regional Heterogeneity and the Refinancing Channel of Monetary Policy. *The Quarterly Journal of Economics 134*(1), 109–183.

Bloom, N. (2014). Fluctuations in Uncertainty. *Journal of Economic Perspectives 28*(2), 153–176.

Bloom, N., M. Floetotto, N. Jaimovich, I. Saporta-Eksten, and S. J. Terry (2018). Really Uncertain Business Cycles. *Econometrica 86*(3), 1031–1065.

Blundell, R., L. Pistaferri, and I. Preston (2008). Consumption Inequality and Partial Insurance. *American Economic Review 98*(5), 1887–1921.

Blundell, R., L. Pistaferri, and I. Saporta-Eksten (2016). Consumption Inequality and Family Labor Supply. *American Economic Review 106*(2), 387–435.

Blundell, R., L. Pistaferri, and I. Saporta-Eksten (2018, oct). Children, time allocation, and consumption insurance. *Journal of Political Economy 126*, S73–S115.

Bound, J., C. Brown, G. J. Duncan, and W. L. Rodgers (1994). Evidence on the Validity of Cross-Sectional and Longitudinal Labor Market Data. *Journal of Labor Economics 12*(3), 345–368.

Broer, T. (2020). Consumption insurance over the business cycle. *Working Paper*.

Broer, T., N.-J. Harbo Hansen, P. Krusell, and E. Öberg (2020, mar). The New Keynesian Transmission Mechanism: A Heterogeneous-Agent Perspective. *The Review of Economic Studies 87*(1), 77–101.

Busch, C., D. Domeij, F. Guvenen, and R. Madera (2018). Asymmetric Business-Cycle Risk and Social Insurance. *NBER Working Paper 24569*.

Busch, C. and A. Ludwig (2020). Higher-Order Income Risk over the Business Cycle: A Parametric Approach. *Working Paper*.

Cantore, C., F. Ferroni, H. Mumtaz, and A. Theophilopoulou (2022). A tail of labor supply and a tale of monetary policy A tail of labor supply and a tale of monetary policy . *Federal Reserve Bank of Chicago WP 2022-30*.

Carroll, C. D. (2006). The method of endogenous gridpoints for solving dynamic stochastic optimization problems. *Economics Letters 91*(3), 312–320.

Carroll, C. D. (2009, sep). Precautionary saving and the marginal propensity to consume out of permanent income. *Journal of Monetary Economics 56*(6), 780–790.

Cesarini, D., E. Lindqvist, M. J. Notowidigdo, and R. Östling (2017). The effect of wealth on individual and household labor supply: Evidence from Swedish lotteries. *American Economic Review 107*(12), 3917–3946.

Chetty, R. and A. Szeidl (2007). Consumption Commitments and Risk Preferences. *The Quarterly Journal of Economics 122*(2), 831–877.

Commault, J. (2017). How Does Consumption Respond to a Transitory Income Shock? Reconciling Natural Experiments and Structural Estimations. *Working Paper*.

Cullen, J. B. and J. Gruber (2000). Does Unemployment Insurance Crowd out Spousal Labor Supply? *Journal of Labor Economics 18*(3), 546–572.

De Nardi, M., G. Fella, M. G. Knoef, G. Paz-pardo, and R. V. Ooijen (2019). Family and Government Insurance: Wage, Earnings, and Income Risks in the Netherlands and the U.S. *NBER Working Paper 25832*.

Druedahl, J. and T. H. Jørgensen (2017). Can Consumers Distinguish Persistent from Transitory Income Shocks? *The B.E. Journal of Macroeconomics (Advances) 17*(1), 1–16.

Evers, M., R. De Mooij, and D. Van Vuuren (2008). The Wage Elasticity of Labour Supply: A Synthesis of Empirical Estimates. *De Economist 156*, 25–43.

Fella, G. (2014). A generalized endogenous grid method for non-smooth and non-concave problems. *Review of Economic Dynamics 17*(2), 329–344.

Flavin, M. and T. Yamashita (2002). Owner-Occupied Housing and the Composition of the Household Portfolio. *American Economic Review 92*(1), 345–362.

Flodén, M. (2006). Labour Supply and Saving Under Uncertainty. *The Economic Journal 116*(513), 721–737.

Galí, J., F. Smets, and R. Wouters (2011). Unemployment in an Estimated New Keynesian Model. In D. Acemoglu and M. Woodford (Eds.), *NBER Macroeconomics Annual 2011, Volume 26*, Chapter 6, pp. 329–360. University of Chicago Press.

Gallipoli, G., H. Low, and A. Mitra (2020). Consumption and Income Inequality across Generations. *Working Paper*.

Gorbachev, O. (2016). Has the Increased Attachment of Women to the Labor Market Changed a Family's Ability to Smooth Income Shocks? *American Economic Review: Papers & Proceedings 106*(5), 247–251.

Greenwood, J., Z. Hercowitz, and G. W. Huffman (1988). Investment, Capacity Utilization, and the Real Business Cycle. *American Economic Review 78*(3), 402–417.

Grigsby, J., E. Hurst, and A. Yildirmaz (2021). Aggregate Nominal Wage Adjustments: New Evidence from Administrative Payroll Data. *American Economic Review 111*(2), 428–71.

Gross, T., M. J. Notowidigdo, and J. Wang (2020). The marginal propensity to consume over the business cycle. *American Economic Journal: Macroeconomics 12*(2), 351–384.

Guvenen, F. (2007). Learning Your Earning: Are Labor Income Shocks Really Very Persistent? *American Economic Review 97*(3), 687–712.

Guvenen, F., S. Ozkan, and J. Song (2014). The Nature of Countercyclical Income Risk. *Journal of Political Economy 122*(3), 621–660.

Haan, P. and V. L. Prowse (2015). Optimal Social Assistance and Unemployment Insurance in a Life-Cycle Model of Family Labor Supply and Savings. *IZA DP No. 8980*.

Haider, S. J. (2001). Earnings instability and earnings inequality of males in the United States: 1967-1991. *Journal of Labor Economics 19*(4), 799–836.

Halla, M., J. Schmieder, and A. Weber (2020). Job Displacement, Family Dynamics, and Household Labor Supply. *American Economic Journal: Applied Economics 12*(4), 253–87.

Heathcote, J., K. Storesletten, and G. L. Violante (2014). Consumption and Labor Supply with Partial Insurance: An Analytical Framework. *American Economic Review 104*(7), 2075–2126.

Heathcote, J., K. Storesletten, and G. L. Violante (2017). Optimal Tax Progressivity: An Analytical Framework. *Quarterly Journal of Economics 132*(4), 1693–1754.

Heathcote, J., K. Storesletten, and G. L. Violante (2020). How Should Tax Progressivity Respond to Rising Income Inequality? *NBER Working Paper No. 28006*.

Hryshko, D. (2012). Labor income profiles are not heterogeneous: Evidence from income growth rates. *Quantitative Economics 3*(2), 177–209.

Huckfeldt, C. (2022). Understanding the Scarring Effect of Recessions. *American Economic Review 112*(4), 1273–1310.

Johnson, D. S., J. A. Parker, and N. S. Souleles (2006). Household expenditure and the income tax rebates of 2001. *American Economic Review 96*(5), 1589–1610.

Kaplan, G. and G. L. Violante (2010). How Much Consumption Insurance Beyond Self-Insurance? *American Economic Journal: Macroeconomics 2*(4), 53–87.

Kaplan, G. and G. L. Violante (2014). A Model of the Consumption Response to Fiscal Stimulus Payments. *Econometrica 82*(4), 1199–1239.

Kaplan, G., G. L. Violante, and J. Weidner (2014). The Wealthy Hand-to-Mouth. *Brookings Papers on Economic Activity*.

Keane, M. P. (2011). Labor Supply and Taxes: A Survey. *Journal of Economic Literature 49*(4), 961–1075.

Kimball, M. and M. Shapiro (2008, jul). Labor Supply: Are the Income and Substitution Effects Both Large or Both Small? *NBER Working Paper 14208*.

Koustas, D. K. (2018). Consumption Insurance and Multiple Jobs: Evidence from Rideshare Drivers. *Working Paper*.

Krueger, D. and F. Perri (2006). Does Income Inequality Lead to Consumption Inequality? Evidence and Theory. *Review of Economic Studies 73*(1), 163–193.

Krusell, P. and A. Smith, Jr. (1998, oct). Income and Wealth Heterogeneity in the Macroeconomy. *Journal of Political Economy 106*(5), 867–896.

Lemieux, T., W. B. Macleod, and D. Parent (2009). Performance Pay and Wage Inequality. *Quarterly Journal of Economics 124*(1), 1–49.

Lemieux, T., W. B. Macleod, and D. Parent (2012). Contract Form, Wage Flexibility, and Employment. *American Economic Review: Papers & Proceedings 102*(3), 526–531.

Lillard, L. A. and Y. Weiss (1979). Components of Variation in Panel Earnings Data: American Scientists 1960-70. *Econometrica 47*(2), 437–454.

Livshits, I., J. MaCgee, and M. Tertilt (2007). Consumer bankruptcy: A fresh start. *American Economic Review 97*(1), 402–418.

Low, H., C. Meghir, and L. Pistaferri (2010). Wage Risk and Employment Risk over the Life Cycle. *American Economic Review 100*(4), 1432–1467.

Low, H. W. (2005). Self-insurance in a life-cycle model of labour supply and savings. *Review of Economic Dynamics 8*(4), 945–975.

Lucas, R. E. (1987). *Models of business cycles*. Oxford: Basil Blackwell.

Lundberg, S. (1985). The Added Worker Effect. *Journal of Labor Economics 3*(1), 11–37.

Meghir, C. and L. Pistaferri (2004). Income Variance Dynamics and Heterogeneity. *Econometrica 72*(1), 1–32.

Mendoza, E. G. (1991). Real Business Cycles in a Small Open Economy. *The American Economic Review 81*(4), 797–818.

Moretti, E. (2011). Local labor markets. In D. Card and O. Ashenfelter (Eds.), *Handbook of Labor Economics*, Volume 4, Part B, pp. 1237–1313. Elsevier.

Nakajima, M. and V. Smirnyagin (2019). Cyclical Labor Income Risk. *Working Paper*.

OECD. What are Equivalence Scales?

Pan, J. (2017). *Essays on Household Consumption and Labor Supply*. Ph. D. thesis, University of British Columbia.

Pencavel, J. (1986). Labor supply of men: A survey. In O. Ashenfelter and Layard. Richard (Eds.), *Handbook of Labor Economics*, Volume 1, pp. 3–102. Elsevier.

Stephens, M. (2002). Worker Displacement and the Added Worker Effect. *Journal of Labor Economics 20*(3), 504—-537.

Storesletten, K., C. I. Telmer, and A. Yaron (2001). The welfare cost of business cycles revisited: Finite lives and cyclical variation in idiosyncratic risk. *European Economic Review 45*(7), 1311–1339.

Storesletten, K., C. I. Telmer, and A. Yaron (2004). Cyclical Dynamics in Idiosyncratic Labor Market Risk. *Journal of Political Economy 112*(3), 695–717.

Wong, A. (2019). Refinancing and The Transmission of Monetary Policy to Consumption. *Working Paper*.

Wu, C. and D. Krueger (2019). Consumption Insurance Against Wage Risk: Family Labor Supply and Optimal Progressive Income Taxation. *NBER Working Paper 26466*.

Appendix

A Figures

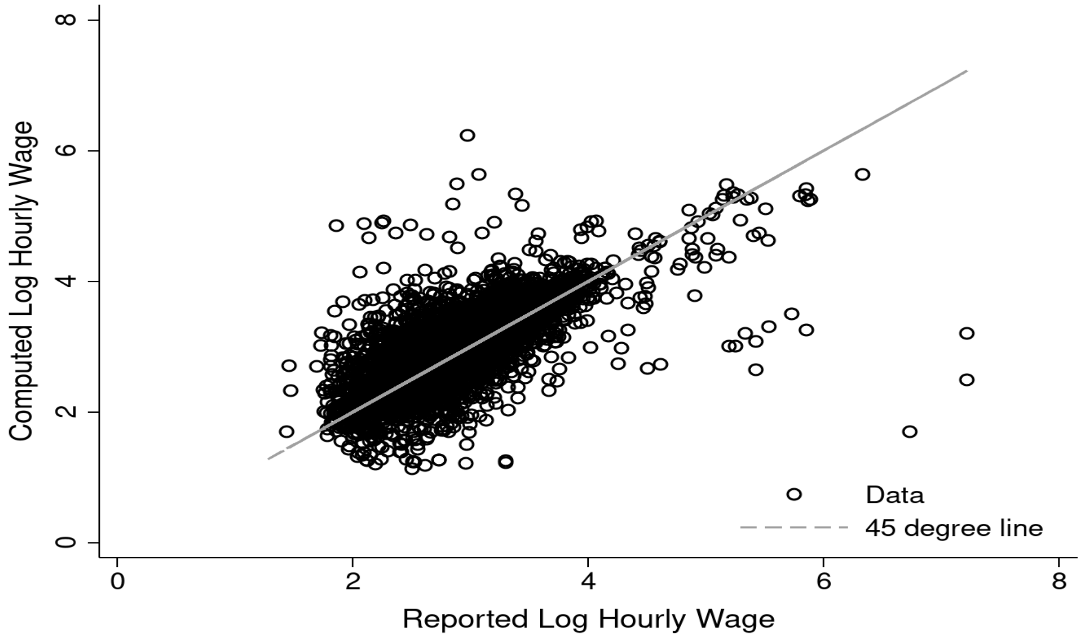

Figure 14: Comparing Computed Wage versus Reported Wage for individuals that receive hourly wage on main job

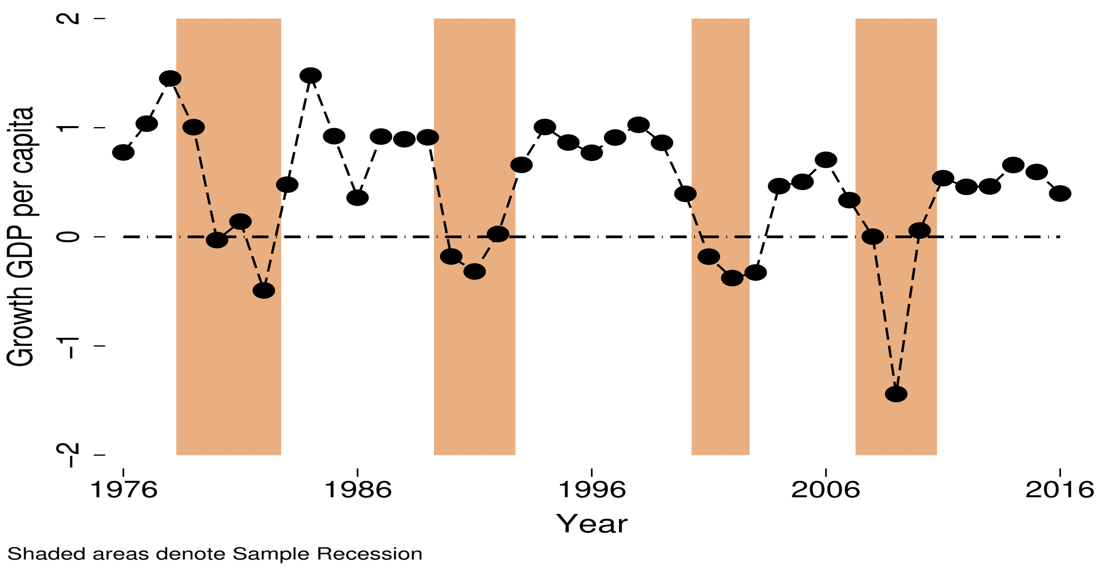

Figure 15: Growth rate of GDP per capita

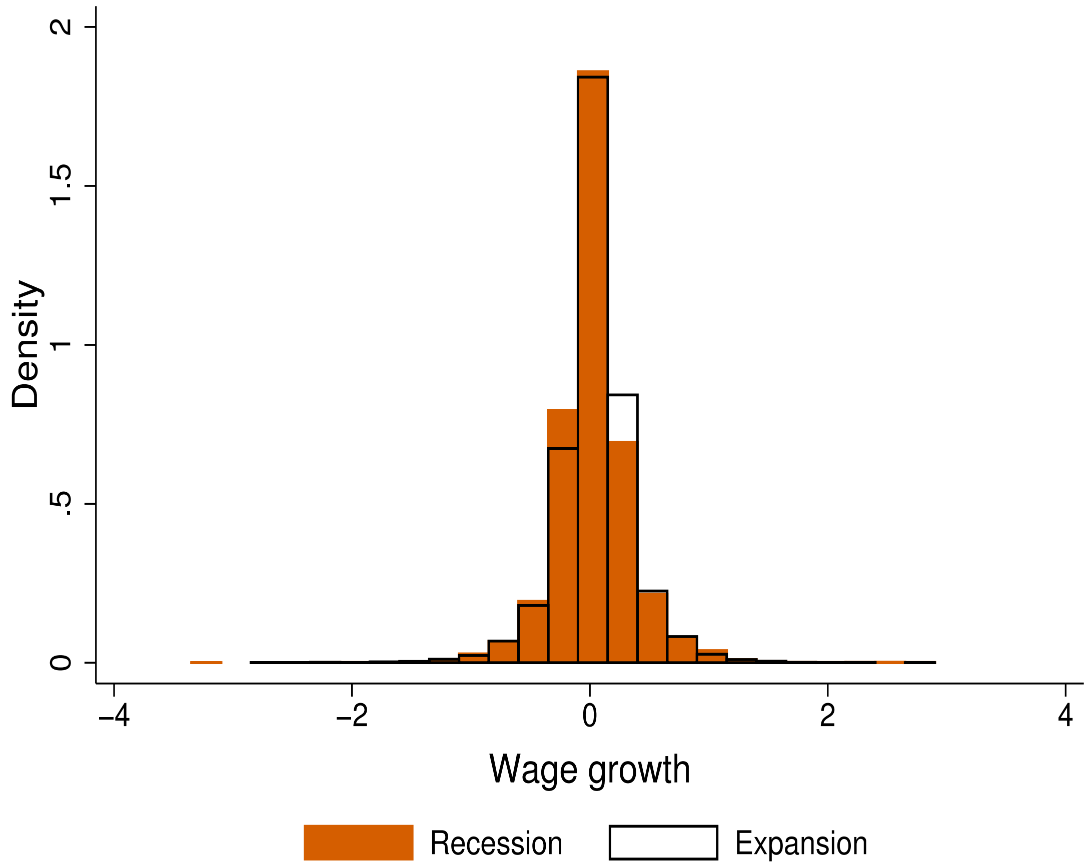

Figure 16: Wage Growth

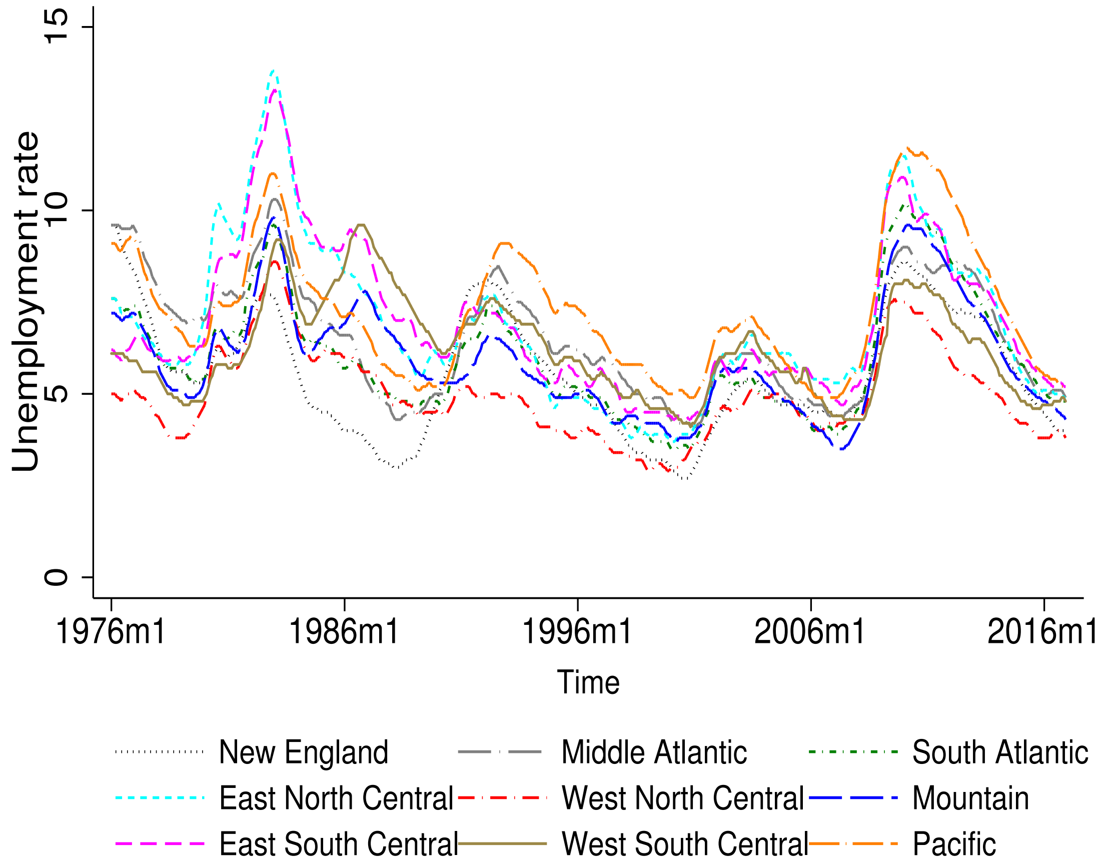

Figure 17: Unemployment rate across US divisions

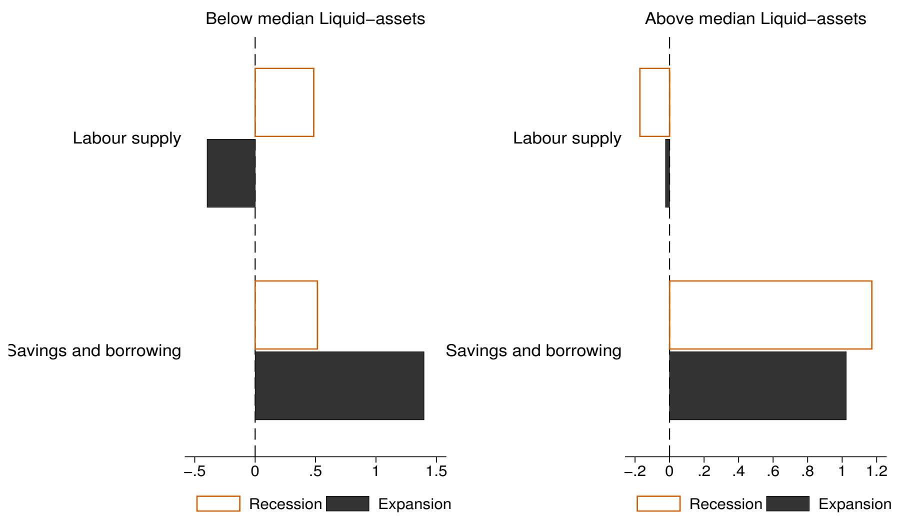

Figure 18: Decomposing consumption smoothing between below-median and above-median liquid wealth. Actual wealth is replaced by median liquid wealth over age and education cells.

B Tables

Table 6: Test of Hypothesis of Zero Autocovariances

Coefficient	First Earner			Spouse		
Order of Autocovariance	2	3	4	2	3	4
Chi-square	805	18.7	30.2	605	21	21.5
Degrees of freedom	27	16	24	27	16	24
P-value	0	.285	.177	0	.177	.607

In this table we present tests for zero autocovariance of order 2–4. We provide the test statistic for the hypothesis that the respective autocovariance is zero in all time periods, the degrees of freedom of the test, which is determined by the number of time periods for which we can estimate the autocovariance, and the asymptotic p-value for the hypothesis that the autocovariances are zero. PSID became biennial from 1998 so, third order autocovariances are defined only upto 1996.

Table 7: Comparing estimates between BPS and this paper

Coefficient	BPS	Replication
Consumption to first earner wage transitory shock	-0.14**	-0.22
	(0.07)	(0.27)
Consumption to spouse wage transitory shock	-0.04	-0.07
	(0.07)	(0.56)
Consumption to first earner wage permanent shock	0.32***	0.36**
	(0.05)	(0.18)
Consumption to spouse wage permanent shock	0.19***	0.16
	(0.03)	(0.24)
First earner hours to first earner wage transitory shock	0.58***	0.45
	(0.16)	(0.43)
First earner hours to spouse wage transitory shock	0.11**	0.66
	(0.06)	(0.88)
First earner hours to first earner wage permanent shock	-0.08	0.07
	(0.08)	(0.07)
First earner hours to spouse wage permanent shock	-0.22***	-0.42**
	(0.04)	(0.19)
Spouse hours to first earner wage transitory shock	0.17**	0.19
	(0.11)	(0.55)
Spouse hours to spouse wage transitory shock	0.88***	1.01
	(0.23)	(0.72)
Spouse hours to first earner wage permanent shock	-0.75***	-0.73**
	(0.14)	(0.27)
Spouse hours to spouse wage permanent shock	0.42***	0.46***
	(0.08)	(0.11)

Note: Column 1 shows BPS estimates from Table 5, column 1. Column 2 shows coefficients from my methodology. Parentheses include the standard errors, calculated using 500 bootstrap replications. *** indicates p<0.01, ** indicates p<0.05, and * indicates p<0.1.

Table 8: Wage Parameters across Age-groups

	25-33		34-39		40-45		46-51		52-57	
	Rec	Exp	Rec	Exp	Rec	Exp	Rec	Exp	Rec	Exp
Variance of transitory	0.010***	0.012***	0.006*	0.008***	0.006**	0.009***	0.000	0.011***	0.003	0.009**
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
P-value	0.494		0.427		0.396		0.018		0.359	
Variance of permanent	0.039***	0.023***	0.025***	0.014***	0.021***	0.015***	0.017**	0.024***	0.009**	0.023***
	(0.004)	(0.003)	(0.004)	(0.002)	(0.006)	(0.002)	(0.007)	(0.004)	(0.004)	(0.004)
P-value	0.004		0.049		0.374		0.459		0.041	

Note: Parentheses include GMM standard errors, clustered at household level. *** indicates $p<0.01$, ** indicates $p<0.05$ * indicates $p<0.1$. The third row for every coefficient shows the p-values of the test of equality between recession and expansion estimate.

Table 9: Wage Parameters across Occupation and Task Content

	Managers		Professional		Service		Sales and Office		Production		Construction	
	Rec	Exp	Rec	Exp	Rec	Exp	Rec	Exp	Rec	Exp	Rec	Exp
Variance of transitory	0.009***	0.012***	-0.002	0.008**	0.022***	0.016***	0.005	0.012***	0.008**	0.006**	0.024***	0.017***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.007)	(0.005)	(0.003)	(0.004)	(0.003)	(0.002)	(0.004)	(0.004)
P-value	0.502		0.010		0.464		0.150		0.685		0.206	
Variance of permanent	0.014**	0.012***	0.035***	0.027***	0.051***	0.026***	0.035***	0.027***	0.021***	0.016***	0.046***	0.017***
	(0.005)	(0.003)	(0.004)	(0.003)	(0.010)	(0.007)	(0.007)	(0.005)	(0.005)	(0.002)	(0.006)	(0.003)
P-value	0.762		0.142		0.046		0.378		0.426		0.000	

Note: Parentheses include GMM standard errors, clustered at household level. *** indicates p<0.01, ** indicates p<0.05 * indicates p<0.1. The third row for every coefficient shows the p-values of the test of equality between recession and expansion estimate.

Table 10: Wage Parameters across Industries

	Agriculture		Manufacturing		Service	
	Rec	Exp	Rec	Exp	Rec	Exp
Variance of transitory	0.001	0.035***	0.006**	0.011***	0.011***	0.010***
	(0.008)	(0.012)	(0.002)	(0.002)	(0.002)	(0.002)
P-value	0.008		0.084		0.843	
Variance of permanent	0.054***	0.011	0.028***	0.011***	0.033***	0.025***
	(0.014)	(0.011)	(0.004)	(0.002)	(0.003)	(0.002)
P-value	0.034		0.001		0.036	

Note: "Rec" and "Exp" denotes Recessions and Expansions respectively. Parentheses include GMM standard errors, clustered at household level. *** indicates p<0.01, ** indicates p<0.05, and * indicates p<0.1. The third row for every coefficient shows the p-values of the test of equality between recession and expansion estimate.

C Identification and Moment Conditions

PSID is available at annual frequency for some years and biennial frequency for some years, so I construct two year differences in variables. Given equations 1 and 2, I can express two-year growth of wages as:

$$\Delta^2 w_{i,t} = u_{i,t} - u_{i,t-2} + v_{i,t} + v_{i,t-1} = \Delta^2 u_t + v_t + v_{t-1} \tag{26}$$

In the next subsections I describe how I deal with measurement error and describe how I identify the variances of permanent and temporary shocks, transmission coefficients into consumption and earnings and the over-identifying conditions when estimating the transmission coefficients.

C.1 Measurement error

Survey data on earnings and consumption are subject to measurement errors. Moreover, my measure of wages suffers from "division bias" as I divide income by hours to derive them. I rewrite the equations in consumption, wage and earnings growth to allow for measurement error as follows:

$$\begin{pmatrix} \Delta w_{i,t}^2 \\ \Delta c_{i,t}^2 \\ \Delta y_{i,t}^2 \end{pmatrix} \approx \begin{pmatrix} 1 & 1 \\ \kappa_{c,u} & \kappa_{c,v} \\ \kappa_{y,u} & \kappa_{y,v} \end{pmatrix} \begin{pmatrix} \Delta^2 u_{i,t} \\ v_{i,t} + v_{i,t-1} \end{pmatrix} + \begin{pmatrix} \Delta^2 \varepsilon_{i,t}^w \\ \Delta^2 \varepsilon_{i,t}^c \\ \Delta^2 \varepsilon_{i,t}^y \end{pmatrix}$$

where $\varepsilon_{i,t}^w$, $\varepsilon_{i,t}^c$ and $\varepsilon_{i,t}^y$ are measurement errors in log wages, log consumption and log earnings respectively of household i at time t.

I allow measurement error between earnings and wages to be correlated since log wages is equal to log earnings minus log hours. This implies that,

$$var\left(\varepsilon^w\right) = var\left(\varepsilon^y\right) + var\left(\varepsilon^h\right) - 2cov\left(\varepsilon^y, \varepsilon^h\right)$$

Then,

$$cov\left(\varepsilon^y, \varepsilon^w\right) = cov\left(\varepsilon^y, \left(\varepsilon^y - \varepsilon^h\right)\right) = var\left(\varepsilon^y\right) - \frac{1}{2}\left(var\left(\varepsilon^y\right) + var\left(\varepsilon^h\right) - var\left(\varepsilon^w\right)\right)$$

Both classical measurement error and transitory shocks enters the wage process linearly. Thus, I cannot separately identify variance of transitory shocks from variance of measurement error unless I have more equations. I instead use estimates from Bound et al. (1994) to set a *priori* amount of wage and earnings variability that can be attributed to measurement error. Measurement error in wages and earnings is assigned in the following ways: $var\left(\varepsilon^{y}\right) = 0.03 * var(y)$ and $var\left(\varepsilon^{w}\right) = 0.07 * var(w)$ and in recessions and expansions. Bound et al. (1994) estimate measurement error in earnings to be around 3% - 4% and in wages to be in the range of 7% - 16%. I have to assume measurement error in wages to be in the lower bound of their estimates as otherwise variance of transitory shocks is negative. Moreover, I account for extreme consecutive jumps in earnings, wages and consumption (described in Appendix D.1) which reduces the variance of transitory shocks. In other words, my sample selection accounts for some of the measurement error and so, I select lower values of variance of measurement error in wages and earnings. $var\left(\varepsilon^{h}\right) = 0.28 * var(h)$. The variances of measurement error are non-stationary so they do not change over the business cycle.

Following Blundell et al. (2016) measurement error in consumption is equal to the covariance between present and future consumption. This implies that measurement error fully explain the covariance between current and future consumption and transitory shocks do affect this covariance. Clearly, this is an upper bound on the amount of measurement error in consumption.

C.2 Moment conditions and Over-identifying Restrictions

When I describe the moment conditions I write them such that . As stated before, I need a recession/expansion phase to continue for three consecutive periods for identification.

C.2.1 Wage Variance and Covariance

$$-\text{Cov}\left(\Delta^2 w_{i,t}^{s(t)}, \Delta^2 w_{i,t+2}^{s(t+2)}\right) = \sigma^2_{u,s(t)} + var\left(\varepsilon^{w}\right) \quad (27)$$

$$\text{Var}\left(\Delta^2 w_{i,t}^{s(t)}\right) = 2\sigma^2_{u,s(t)} + 2\sigma^2_{v,s(t)} + 2var\left(\varepsilon^{w}\right) \quad (28)$$

C.2.2 Transmission Coefficient Identifying Equations

$$-\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\ \Delta^2 w_{i,t+2}^{s(t+2)}\right) = \kappa_{c,u}^{s(t)} \sigma_{u,s(t)}^2 \tag{29}$$

$$-\text{Cov}\left(\Delta^2 y_{i,t}^{s(t)},\ \Delta^2 w_{i,t+2}^{s(t+2)}\right) = \kappa_{y,u}^{s(t)} \sigma_{u,s(t)}^2 + cov\left(\varepsilon^y, \varepsilon^w\right) \tag{30}$$

$$\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\ \Delta^2 w_{i,t}^{s(t)}\right) = 2\kappa_{c,u}^{s(t)} \sigma_{u,s(t)}^2 + 2\kappa_{c,v}^{s(t)} \sigma_{v,s(t)}^2 \tag{31}$$

$$\text{Cov}\left(\Delta^2 y_{i,t}^{s(t)},\ \Delta^2 w_{i,t}^{s(t)}\right) = 2\kappa_{y,u}^{s(t)} \sigma_{u,s(t)}^2 + 2\kappa_{y,v}^{s(t)} \sigma_{v,s(t)}^2 + 2cov\left(\varepsilon^y, \varepsilon^w\right) \tag{32}$$

I identify $\kappa_{c,u}^{s(t)}$, and $\kappa_{y,u}^{s(t)}$ from equations 29, and 30. $\kappa_{c,v}^{s(t)}$, and $\kappa_{y,v}^{s(t)}$ are identified from 31, and 32.

C.2.3 Over-identifying Moments

During estimation of the transmission coefficients, apart from equations 29, 30, 31, and 32 , I also use the following additional 8 moments:

$$\begin{aligned}
\text{Var}\left(\Delta^2 c_{i,t}\right) &= 2var\left(\varepsilon^c\right) + 2\left(\kappa_{c,v}^{s(t)}\right)^2 \sigma_v^2 \\
\text{Var}\left(\Delta^2 y_{i,t}\right) &= 2\left(\kappa_{y,u}^{s(t)}\right)^2 \sigma_u^2 + 2\left(\kappa_{y,v}^{s(t)}\right)^2 \sigma_v^2 + 2var\left(\varepsilon^y\right) \\
-\text{Cov}\left(\Delta^2 y_{i,t}^{s(t)},\ \Delta^2 y_{i,t+2}^{s(t+2)}\right) &= \left(\kappa_{y,u}^{s(t)}\right)^2 \sigma_u^2 + var\left(\varepsilon^y\right) \\
\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\ \Delta^2 y_{i,t}^{s(t)}\right) &= 2\kappa_{c,u}^{s(t)} \kappa_{y,u}^{s(t)} \sigma_{u,s(t)}^2 + 2\kappa_{c,v}^{s(t)} \kappa_{y,v}^{s(t)} \sigma_{v,s(t)}^2 \\
-\text{Cov}\left(\Delta^2 w_{i,t}^{s(t)},\ \Delta^2 c_{i,t+2}^{s(t+2)}\right) &= \kappa_{c,u}^{s(t)} \sigma_{u,s(t)}^2 \\
-\text{Cov}\left(\Delta^2 c_{i,t}^{s(t)},\ \Delta^2 y_{i,t+2}^{s(t+2)}\right) &= \kappa_{c,u}^{s(t)} \kappa_{y,u}^{s(t)} \sigma_{u,s(t)}^2 \\
-\text{Cov}\left(\Delta^2 y_{i,t}^{s(t)},\ \Delta^2 c_{i,t+2}^{s(t+2)}\right) &= \kappa_{c,u}^{s(t)} \kappa_{y,u}^{s(t)} \sigma_{u,s(t)}^2 \\
-\text{Cov}\left(\Delta^2 w_{i,t}^{s(t)},\ \Delta^2 y_{i,t+2}^{s(t+2)}\right) &= \kappa_{y,u}^{s(t)} \sigma_{u,s(t)}^2 + cov\left(\varepsilon^y, \varepsilon^w\right)
\end{aligned}$$

C.3 Marginal Propensity to Consume

The individual Marginal propensity to consume out of permanent income is defined as:

$$MPC_{i,t}^v = \frac{\partial C_{i,t}/\partial v_{i,t}}{\partial Y_{i,t}/\partial v_{i,t}}$$

Given the representation of log consumption in equation 4, we can write $\partial C_{i,t}/\partial v_{i,t}$ as:

$$\begin{aligned}\frac{\partial C_{i,t}}{\partial v_{i,t}} &= \frac{\partial \ln C_{i,t}}{\partial v_{i,t}} * C_{i,t} \\ &= \kappa_{c,v} * C_{i,t}\end{aligned} \tag{33}$$

Given the representation of log hours in equation 4, we can write $\partial Y_{i,t}/\partial v_{i,t}$ as:

$$\begin{aligned}\frac{\partial Y_{i,t}}{\partial v_{i,t}} &= \frac{\partial \ln Y_{i,t}}{\partial v_{i,t}} * Y_{i,t} \\ &= Y_{i,t}\left(\frac{\partial \ln w_{i,t}}{\partial v_{i,t}} + \frac{\partial \ln h_{i,t}}{\partial v_{i,t}}\right) \\ &= Y_{i,t}\left(1+\kappa_{h,v}\right)\end{aligned} \tag{34}$$

Combining equations 33 and 34, we get:

$$MPC^{v}_{i,t} = \frac{\kappa_{c,v}}{1+\kappa_{h,v}}\frac{C_{i,t}}{Y_{i,t}}$$

Thus, the aggregate marginal propensity to consume is:

$$MPC^{v}_{t} = \frac{\kappa_{c,v}}{1+\kappa_{h,v}}\left(\overline{\frac{C_{i,t}}{Y_{i,t}}}\right)$$

D Data

This section describes the sample selection criterion, how I imputed the consumption series and estimated the US tax system progressivity.

D.1 Sample Selection

The sample selection follows Blundell et al. (2016). I focus on the non-SEO, non-Latino and non-immigrant sample of the PSID between the years 1977-2016. Since, I are concerned with labour supply of a household so I drop unmarried households and households with less than four years of data.[34] I drop households where the head's age is below 25 or above 57. Strong labour market attachments usually begin from around 25 until 57 where head's start to retire. my methodology developed does not account for the extensive margin decision of the head. Thus, I drop households who either report zero hours of work or zero earnings or transfers twice greater than household earnings. This includes head who are either long-term unemployed or retired or faced disability which caused long term unemployment. I drop household where either of the earner are self-employed. This is because the concept a wage is difficult to define and job mobility is not pertinent to this group.

I also drop heads with missing information on education, state of residence or age. I drop households with wealth holdings greater than $ twenty million or more, taxes greater than twice or transfers greater than twice the size of household earnings. I drop households whose hourly wage is less than half of the federal minimum wage. Whenever there is a change in the family composition, because of a change in the head of the household, then I drop that year of the change. The family re-enters as a new family unit in the next year following the change.

I drop observations for earnings, and wages of head and spouse and household consumption which show extreme consecutive jumps. Extreme consecutive jumps are defined as an extremely negative (positive) change from t-2 to t and then extremely positive (negative) change from t to t+2. I compute the product of lagged and today's growth and drop observations in the top 0.5 percentile to correct for extreme jumps.

[34] Recessions may have an effect on household formation as divorce may be more likely during recessions. Currently I control for that by only keeping households who are continuously available for at least four years.

D.2 Consumption Imputation

I follow Attanasio and Pistaferri (2014) to impute total consumption but differ in two dimensions: firstly, I exclude rent while defining net consumption and secondly, I include log total income in the regression otherwise the regression specification implicitly assumes homothetic preferences. To impute the natural logarithm of net consumption, I use the following approximated demand system that relates food consumption to consumption of services:

$$ln\left(D_{i,t}\right) = p_t'\phi + Z_{i,t}'\omega + h\left(F_{i,t};\theta\right) + u_{i,t}$$

where D is consumption net of food expenditure and rent, p includes the relative prices, Z are the socio-economic controls, F is total food expenditure including rent, h(:) is a third degree polynomial function , and u is the error term. Food expenditure is excluded to avoid endogeneity issues in the regression.

This equation is estimated over 1999-2017 biennial waves. Net consumption measure D_t is the sum of annual expenditures on child care, school expenses(tuition plus other school expenses), health expenses (insurance plus out-of-pocket), expenditure on travel (car insurance and repairs, gasoline, parking, bus fares, taxi fares, other transportation expenses) and utility expenditure (electricity, heating, water and other miscellaneous items). Expenditure on some categories such as clothing, home furnishing are available only from 2005 which I do not include so as to maintain a consistent measure. Relative prices (the overall CPI and the CPIs for food at home, food away from home, and rent) are included as controls since changes in them induce a reallocation of total expenditure among different categories. The socio-economic and demographic controls includes total family income and dummies for age, education, marital status, race, state of residence, employment status, self-employment, home-owner, disability, family size, and the number of children in the household. F is total food expenditure (sum of food at home, food away from home, and food stamps).

Imputed total consumption is defined as the sum of F, rent and exponential of the predicted values of the regression. Rent is defined as the actual annual rent for renters and otherwise 6% of the self-reported house value for the home-owners (Flavin and Yamashita (2002)). This measure is then converted into real, adult-equivalent terms by dividing it by the Consumer Price Index and the OECD adult-equivalence scale. The equivalence scale is defined as 1 plus 0.7 times one less than the number of adults in the household and 0.5 times the number of kids (OECD).

To judge how well the imputation procedure has performed, I can look at two measures. The first is the goodness of fit (R^2) which is 34% for the above regression. I think the better measure is to compare the standard deviation of the imputed and actual consumption data. my main empirical exercise deals with the second order moments of consumption rather than the first order. By construction, expectation of the imputed and actual consumption is equal but variances are not. Figure 19, Panel A compares the standard deviation of the actual and imputed consumption, each series normalised (with respect to year 1998). The standard deviation of the imputed series seems to have a good fit with the actual consumption series with both series demonstrating similar time series profiles. Panel B shows the standard deviation of the total, food and imputed consumption and total family earnings. It shows that indeed consumption inequality as defined by the standard deviation of consumption has steadily increased and so has household earnings inequality.

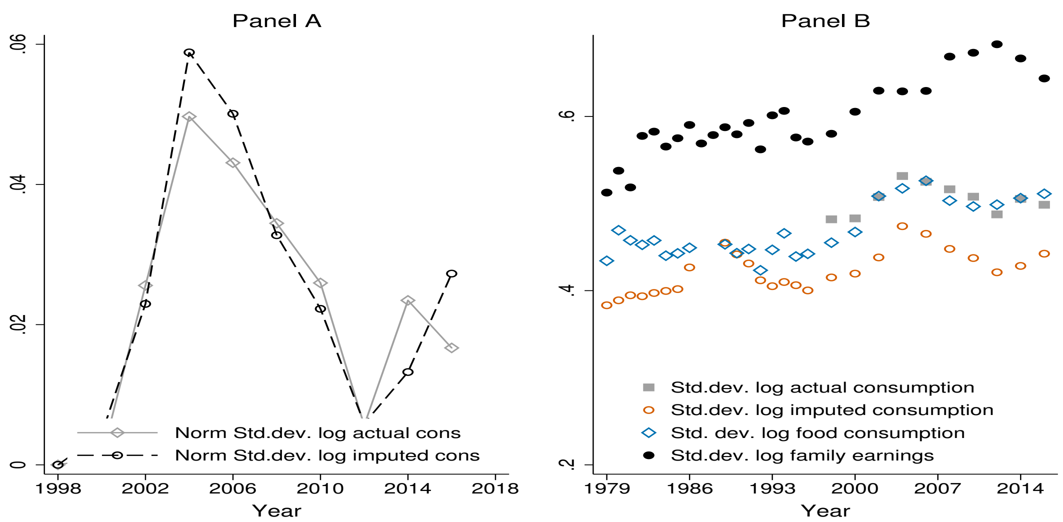

Figure 19: Comparing Imputed consumption with actual consumption in Panel A, standard deviation of food, imputed and actual consumption and family earnings in Panel B

D.3 Tax progressivity

PSID contains information on federal taxes for each household only until 1992. Instead, I used NBER's taxsim program to estimate federal taxes for all years of the sample. Figure 20 shows that the taxes computed using TAXSIM program compare quite well to PSID's estimates.

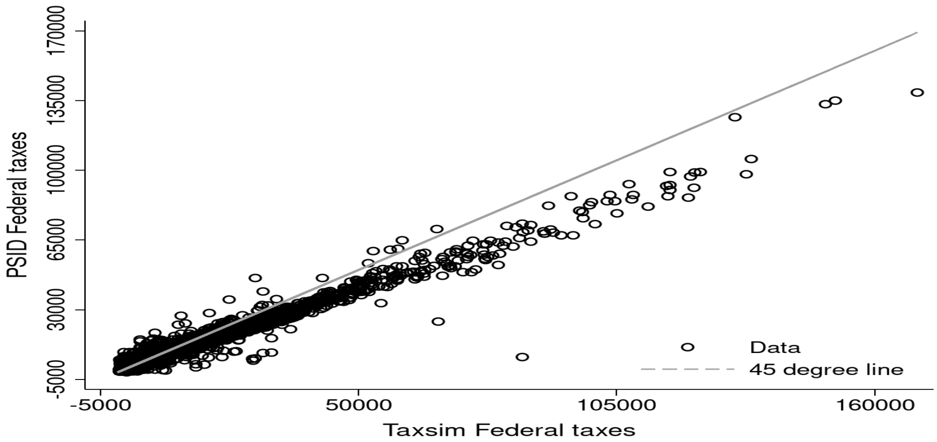

Figure 20: Comparison of NBER TAXSIM with PSID federal taxes

Post-tax family earnings is defined as pre-tax earnings minus net federal taxes paid, unemployment benefits and foodstamps. I compute the τ and χ by regressing after tax earnings on pre-tax earnings allowing the parameters to vary by year and total number of kids in the household. Moreover, I estimate these coefficients separately for households that receive government transfers and those who do not. The estimated progressivity of the tax system is 16% which is very close to the 18% estimated by Heathcote et al. (2017). Figure 21 shows the actual and predicted average tax rate faced by every household and year in the sample. The predicted average tax rate using Equation 16 captures the concavity of the actual tax rate quite well with an R^2 of 55%.

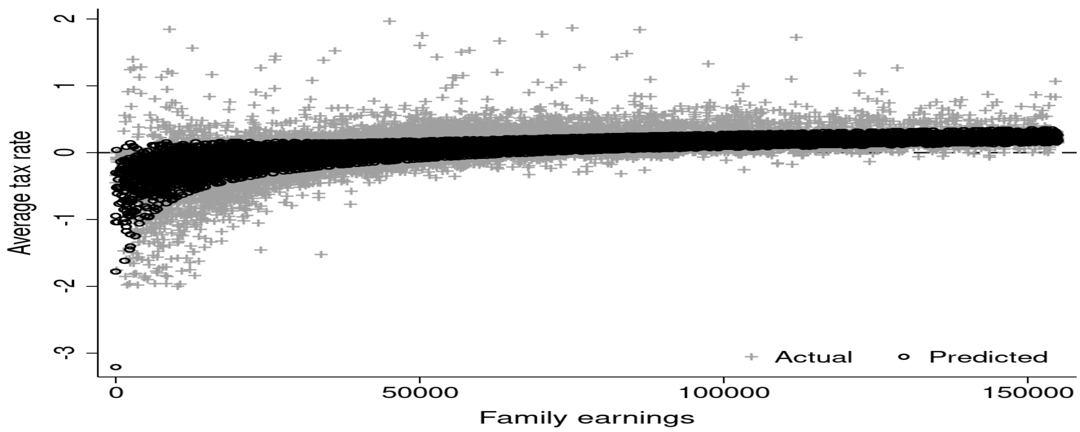

Figure 21: Approximation of the Tax function

E Two earners Model and Reduced form

I extend the baseline model by incorporating another earner who also works. First, I describe the wage process the two earner's face. Second, specify the utility function and first order conditions. Third, describe the new reduced form structure and decompose consumption smoothing. Lastly, specify the moment conditions that I use to estimate the transmission coefficients.

E.1 Wage Process

For each earner within the household, wage is a function of both a permanent and transitory component. The wage process is written as:

$$log\ W_{i,j,t} = x'_{i,j,t}\beta^j_w + F_{i,j,t} + u_{i,j,t} \tag{35}$$

$$F_{i,j,t} = F_{i,j,t-1} + v_{i,j,t} = F_{i,j,0} + \sum_{s=1}^{t} v_{i,j,s} \tag{36}$$

where, $x_{i,j,t}$ are observed characteristics of household i, earner j at time t. j = 1, 2 and 1 refers to primary and secondary earner respectively. $u_{i,j,t}$ and $v_{i,j,t}$ are temporary and permanent shocks to wages with $F_{i,j,0}$ being the initial condition in wages. This form implies that the growth in residual log wages is a sum of the difference in the transitory components and the permanent wage shock.

$$\Delta w_{i,j,t} = \Delta u_{i,j,t} + v_{i,j,t} \tag{37}$$

where $\Delta w_{i,j,t} = \Delta \ln W_{i,j,t} - \Delta x'_{i,j,t}\beta^j_w$ and Δ is the first-difference operator. The variance of permanent and transitory shocks are denoted by $\sigma^2_{v_j,s(t)}$ and $\sigma^2_{u_j,s(t)}$ respectively where, $s(t)$ refers to the aggregate state. I assume that permanent (transitory) shocks are contemporaneously correlated within a family with covariance being denoted by $\sigma_{v_1,v_2,s(t)}\left(\sigma_{u_1,u_2,s(t)}\right)$. Theoretically this correlation can be positive or negative. Finally, I assume that permanent and transitory shocks are uncorrelated between and within individuals.

$$
\begin{aligned}
\mathbb{E}\left(u_{i,j,t}\right) = \mathbb{E}\left(v_{i,j,t}\right) &= 0 \,\forall j \\
\mathbb{E}\left(v_{i,j_1,t} v_{i,j_2,t+r}\right) &= \begin{cases} \sigma^2_{v_j,s(t)} & \text{if } j_1 = j_2 = j \in \{1,2\}, r = 0 \\ \sigma_{v_1,v_2,s(t)} & \text{if } j_1 \neq j_2, r = 0 \\ 0 & \text{otherwise} \end{cases} \\
\mathbb{E}\left(u_{i,j_1,t} u_{i,j_2,t+r}\right) &= \begin{cases} \sigma^2_{u_j,s(t)} & \text{if } j_1 = j_2 = j \in \{1,2\}, r = 0 \\ \sigma_{u_1,u_2,s(t)} & \text{if } j_1 \neq j_2, r = 0 \\ 0 & \text{otherwise} \end{cases} \\
\mathbb{E}\left(u_{i,j,t} v_{i,j,t+r}\right) &= 0 \,\forall j, r
\end{aligned}
$$

E.2 Household Problem

The second earner also works full-time and the new utility function includes the hours of the second earner as well. The utility function is separable over time but can be non-separable within each period. The household are trying to maximize the following expression:

$$\max \mathbb{E}_0 \sum_{t=0}^{T} \beta^t u\left(C_t, H_{1,t}, H_{2,t}\right) \tag{38}$$

where β is the time discount factor, $H_{1,t}$, and $H_{2,t}$ denote hours worked by first and second earner. The households choose hours of each earner, joint consumption and asset allocations given their wage process and aggregate state of the world and subject to the budget constraint.

E.3 Transmission Coefficients

Following BPS, consumption and hours of each earner against the temporary and permanent wage shocks can be expressed as:

$$\begin{pmatrix} \Delta c_{i,t}^{s(t)} \\ \Delta h_{i,1,t}^{s(t)} \\ \Delta h_{i,2,t}^{s(t)} \end{pmatrix} \approx \begin{pmatrix} \kappa_{c,u_1}^{s(t)} & \kappa_{c,u_2}^{s(t)} & \kappa_{c,v_1}^{s(t)} & \kappa_{c,v_2}^{s(t)} \\ \kappa_{h_1,u_1}^{s(t)} & \kappa_{h_1,u_2}^{s(t)} & \kappa_{h_1,v_1}^{s(t)} & \kappa_{h_1,v_2}^{s(t)} \\ \kappa_{h_2,u_1}^{s(t)} & \kappa_{h_2,u_2}^{s(t)} & \kappa_{h_2,v_1}^{s(t)} & \kappa_{h_2,v_2}^{s(t)} \end{pmatrix} \begin{pmatrix} \Delta u_{i,1,t} \\ \Delta u_{i,2,t} \\ v_{i,1,t} \\ v_{i,2,t} \end{pmatrix} \tag{39}$$

Equation 39 gives us the evolution of consumption and hours of each earner against wage shocks. The pass-through into consumption against first earner permanent wage shock is explained by $\kappa_{c,v_1}^{s(t)}$. As before, $\kappa_{h_1,v_1}^{s(t)} < 0$ implies that the first earner hours are used to smooth consumption smoothing. The *added worker effect* is understood through $\kappa_{h_2,v_1}^{s(t)}$. $\kappa_{h_2,v_1}^{s}(t) < 0$ implies that the spouse's hours increases in response to a negative permanent wage shock to the first earner. Thus, spousal labour supply provides consumption smoothing.

Consumption smoothing can be distinguished into three channels using a similar method as in equation 7:

$$1 \approx \underbrace{\frac{-s\kappa_{h_1,v_1}^{s(t)}}{s-\kappa_{c,v_1}^{s(t)}}}_{\substack{\text{Own Labour} \\ \text{Supply}}} - \underbrace{\frac{(1-s)\,\kappa_{h_2,v_1}^{s(t)}}{s-\kappa_{c,v_1}^{s(t)}}}_{\substack{\text{Spousal} \\ \text{Labour Supply}}} + \underbrace{\text{Residual}}_{\substack{\text{Saving and} \\ \text{borrowing}}} \tag{40}$$

where, s is the share of first earner's human wealth (present discounted value of lifetime earnings) in total family human wealth (sum of first and second earner human wealth).

E.4 Moment Conditions

To avoid clutter and making the equations dense, I avoid using the aggregate state superscript $s(t)$. I include measurement error as before. The variance of primary and secondary earner wage and income is given by $var\left(\varepsilon_j^w\right)$, and $var\left(\varepsilon_j^y\right)$ respectively where $j = \{1,2\}$. I also allow for the measurement error of wage and income to be correlated. The variance of measurement error in consumption is denoted by $var\left(\varepsilon^{c}\right)$.

E.4.1 Wage Variance and Covariance

$$-\text{Cov}\left(\Delta^2 w_{i,1,t},\ \Delta^2 w_{i,1,t+2}\right) = \sigma^2_{u_1} + var\left(\varepsilon^w_1\right) \tag{41}$$

$$\text{Var}\left(\Delta^2 w_{i,1,t}\right) = 2\sigma^2_{u_1} + 2\sigma^2_{v_1} + 2var\left(\varepsilon^w_1\right) \tag{42}$$

$$-\text{Cov}\left(\Delta^2 w_{i,2,t},\ \Delta^2 w_{i,2,t+2}\right) = \sigma^2_{u_2} + var\left(\varepsilon^w_2\right) \tag{43}$$

$$\text{Var}\left(\Delta^2 w_{i,2,t}\right) = 2\sigma^2_{u_2} + 2\sigma^2_{v_2} + 2var\left(\varepsilon^w_2\right) \tag{44}$$

$$-\text{Cov}\left(\Delta^2 w_{i,1,t},\ \Delta^2 w_{i,2,t+2}\right) = \sigma^2_{u_1,u_2} \tag{45}$$

$$-\text{Cov}\left(\Delta^2 w_{i,2,t},\ \Delta^2 w_{i,1,t+2}\right) = \sigma^2_{u_1,u_2} \tag{46}$$

$$\text{Cov}\left(\Delta^2 w_{i,1,t},\ \Delta^2 w_{i,2,t}\right) = 2\sigma^2_{u_1,u_2} + 2\sigma^2_{v_1,v_2} \tag{47}$$

E.4.2 Identification of Transmission Coefficients

$$-\text{Cov}\left(\Delta^2 c_{i,t},\ \Delta^2 w_{i,1,t+2}\right) = \kappa_{c,u_1}\sigma^2_{u_1} + \kappa_{c,u_2}\sigma_{u_1,u_2} \tag{48}$$

$$-\text{Cov}\left(\Delta^2 c_{i,t},\ \Delta^2 w_{i,2,t+2}\right) = \kappa_{c,u_1}\sigma_{u_1,u_2} + \kappa_{c,u_2}\sigma^2_{u_2} \tag{49}$$

$$-\text{Cov}\left(\Delta^2 y_{i,1,t},\ \Delta^2 w_{i,1,t+2}\right) = \kappa_{y_1,u_1}\sigma^2_{u_1} + \kappa_{y_1,u_2}\sigma_{u_1,u_2} + cov\left(\varepsilon^y_1, \varepsilon^w_1\right) \tag{50}$$

$$\text{Cov}\left(\Delta^2 y_{i,1,t},\ \Delta^2 w_{i,2,t+2}\right) = \kappa_{y_1,u_1}\sigma_{u_1,u_2} + \kappa_{y_1,u_2}\sigma^2_{u_2} \tag{51}$$

$$-\text{Cov}\left(\Delta^2 y_{i,2,t},\ \Delta^2 w_{i,2,t+2}\right) = \kappa_{y_2,u_1}\sigma_{u_1,u_2} + \kappa_{y_2,u_2}\sigma^2_{u_2} + cov\left(\varepsilon^y_2, \varepsilon^w_2\right) \tag{52}$$

$$-\text{Cov}\left(\Delta^2 y_{i,2,t},\ \Delta^2 w_{i,1,t+2}\right) = \kappa_{y_2,u_1}\sigma^2_{u_1} + \kappa_{y_2,u_2}\sigma_{u_1,u_2} \tag{53}$$

$$\text{Cov}\left(\Delta^2 c_{i,t},\ \Delta^2 w_{i,1,t}\right) = 2\kappa_{c,u_1}\sigma^2_{u_1} + 2\kappa_{c,u_2}\sigma_{u_1,u_2} + 2\kappa_{c,v_1}\sigma^2_{v_1} + 2\kappa_{c,v_2}\sigma_{v_1,v_2} \tag{54}$$

$$\text{Cov}\left(\Delta^2 c_{i,t},\ \Delta^2 w_{i,2,t}\right) = 2\kappa_{c,u_1}\sigma_{u_1,u_2} + +2\kappa_{c,u_2}\sigma^2_{u_2} + 2\kappa_{c,v_1}\sigma_{v_1,v_2} + 2\kappa_{c,v_2}\sigma^2_{v_2} \tag{55}$$

$$\text{Cov}\left(\Delta^2 y_{i,1,t},\ \Delta^2 w_{i,1,t}\right) = 2\left(\kappa_{y_1,u_1}\sigma^2_{u_1} + \kappa_{y_1,u_2}\sigma_{u_1,u_2} + \kappa_{y_1,v_1}\sigma^2_{v_1} + \kappa_{y_1,v_2}\sigma_{v_1,v_2} + cov\left(\varepsilon^y_1, \varepsilon^w_1\right)\right) \tag{56}$$

$$\text{Cov}\left(\Delta^2 y_{i,1,t},\ \Delta^2 w_{i,2,t}\right) = 2\kappa_{y_1,u_1}\sigma_{u_1,u_2} + 2\kappa_{y_1,u_2}\sigma^2_{u_2} + 2\kappa_{y_1,v_1}\sigma_{v_1,v_2} + 2\kappa_{y_1,v_2}\sigma^2_{v_2} \tag{57}$$

$$\text{Cov}\left(\Delta^2 y_{i,2,t},\ \Delta^2 w_{i,2,t}\right) = 2\kappa_{y_2,u_1}\sigma_{u_1,u_2} + 2\kappa_{y_2,u_2}\sigma^2_{u_2} + 2\kappa_{y_2,v_1}\sigma_{v_1,v_2} + 2\kappa_{y_2,v_2}\sigma^2_{v_2} + 2cov\left(\varepsilon^y_2, \varepsilon^w_2\right) \tag{58}$$

$$\text{Cov}\left(\Delta^2 y_{i,2,t},\ \Delta^2 w_{i,1,t}\right) = 2\kappa_{y_2,u_1}\sigma^2_{u_1} + 2\kappa_{y_2,u_2}\sigma_{u_1,u_2} + 2\kappa_{y_2,v_1}\sigma^2_{v_1} + 2\kappa_{y_2,v_2}\sigma_{v_1,v_2} \tag{59}$$

Equations 48, and 49 together identify κ_{c,u_1}, and κ_{c,u_2}. Equations 50, and 51 jointly identify κ_{y_1,u_1}, and κ_{y_1,u_2}. To identify κ_{y_2,u_2}, and κ_{y_2,u_1} I use equations 52, and 53. Once all the coefficients against transitory shocks are identified, I then identify the transmission coefficients of permanent shocks. κ_{c,v_1}, and κ_{c,v_2} are identified by jointly using 54, and 55. κ_{y_1,v_1}, and κ_{y_1,v_2} are identified together through equations 56, and 57. κ_{y_2,v_2}, and can be identified through equations 58, and 59.

Over-identifying restrictions: Additional 18 moments were used in the estimation of the transmission coefficients:

$$
\begin{aligned}
\mathrm{Var}\left(\Delta^2 c_{i,t}\right) &= 2\left(var\left(\varepsilon^c\right) + \kappa_{c,v_1}^2\sigma_{v_1}^2 + \kappa_{c,v_2}^2\sigma_{v_2}^2 + 2\kappa_{c,v_1}\kappa_{c,v_2}\sigma_{v_1,v_2}\right) \\
\mathrm{Var}\left(\Delta^2 y_{i,1,t}\right) &= 2\left(\kappa_{y_1,u_1}^2\sigma_{u_1}^2 + 2\kappa_{y_1,u_1}\kappa_{y_1,u_2}\sigma_{u_1,u_2} + \kappa_{y_1,u_2}^2\sigma_{u_2}^2 + var\left(\varepsilon_1^y\right)\right) \\
&+ 2\left(\kappa_{y_1,v_1}^2\sigma_{v_1}^2 + 2\kappa_{y_1,v_1}\kappa_{y_1,v_2}\sigma_{v_1,v_2} + \kappa_{y_1,v_2}^2\sigma_{v_2}^2\right) \\
-\mathrm{Cov}\left(\Delta^2 y_{i,1,t},\, \Delta^2 y_{i,1,t+2}\right) &= \kappa_{y_1,u_1}^2\sigma_{u_1}^2 + 2\kappa_{y_1,u_1}\kappa_{y_1,u_2}\sigma_{u_1,u_2} + \kappa_{y_1,u_2}^2\sigma_{u_2}^2 + var\left(\varepsilon_1^y\right) \\
\mathrm{Var}\left(\Delta^2 y_{i,2,t}\right) &= 2\left(\kappa_{y_2,u_1}^2\sigma_{u_1}^2 + 2\kappa_{y_2,u_1}\kappa_{y_2,u_2}\sigma_{u_1,u_2} + \kappa_{y_2,u_2}^2\sigma_{u_2}^2 + var\left(\varepsilon_2^y\right)\right) \\
&+ 2\left(\kappa_{y_2,v_1}^2\sigma_{v_1}^2 + 2\kappa_{y_2,v_1}\kappa_{y_2,v_2}\sigma_{v_1,v_2} + \kappa_{y_2,v_2}^2\sigma_{v_2}^2\right) \\
-\mathrm{Cov}\left(\Delta^2 y_{i,2,t},\, \Delta^2 y_{i,2,t+2}\right) &= \kappa_{y_2,u_1}^2\sigma_{u_1}^2 + 2\kappa_{y_2,u_1}\kappa_{y_2,u_2}\sigma_{u_1,u_2} + \kappa_{y_2,u_2}^2\sigma_{u_2}^2 + var\left(\varepsilon_2^y\right) \\
\mathrm{Cov}\left(\Delta^2 y_{i,1,t},\, \Delta^2 y_{i,2,t}\right) &= 2\left(\kappa_{y_1,u_1}\kappa_{y_2,u_1}\sigma_{u_1}^2 + \kappa_{y_1,u_1}\kappa_{y_2,u_2}\sigma_{u_1,u_2} + \kappa_{y_1,u_2}\kappa_{y_2,u_1}\sigma_{u_1,u_2} + \kappa_{y_1,u_2}\kappa_{y_2,u_2}\sigma_{u_2}^2\right) \\
&+ 2\left(\kappa_{y_1,v_1}\kappa_{y_2,v_1}\sigma_{v_1}^2 + \kappa_{y_1,v_1}\kappa_{y_2,v_2}\sigma_{v_1,v_2} + \kappa_{y_1,v_2}\kappa_{y_2,v_1}\sigma_{v_1,v_2} + \kappa_{y_1,v_2}\kappa_{y_2,v_2}\sigma_{v_2}^2\right) \\
-\mathrm{Cov}\left(\Delta^2 c_{i,t+2},\, \Delta^2 w_{i,1,t}\right) &= \kappa_{c,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\sigma_{u_1,u_2} \\
-\mathrm{Cov}\left(\Delta^2 c_{i,t+2},\, \Delta^2 w_{i,2,t}\right) &= \kappa_{c,u_1}\sigma_{u_1,u_2} + \kappa_{c,u_2}\sigma_{u_2}^2 \\
\mathrm{Cov}\left(\Delta^2 c_{i,t},\, \Delta^2 y_{i,1,t}\right) &= 2\left(\kappa_{c,u_1}\kappa_{y_1,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\kappa_{y_1,u_2}\sigma_{u_2}^2 + \left(\kappa_{c,u_1}\kappa_{y_1,u_2} + \kappa_{c,u_2}\kappa_{y_1,u_1}\right)\sigma_{u_1,u_2}\right) \\
&+ 2\left(\kappa_{c,v_1}\kappa_{y_1,v_1}\sigma_{v_1}^2 + \kappa_{c,v_2}\kappa_{y_1,v_2}\sigma_{v_2}^2 + \left(\kappa_{c,v_1}\kappa_{y_1,v_2} + \kappa_{c,v_2}\kappa_{y_1,v_1}\right)\sigma_{v_1,v_2}\right) \\
-\mathrm{Cov}\left(\Delta^2 c_{i,t},\, \Delta^2 y_{i,1,t+2}\right) &= \kappa_{c,u_1}\kappa_{y_1,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\kappa_{y_1,u_2}\sigma_{u_2}^2 + \left(\kappa_{c,u_1}\kappa_{y_1,u_2} + \kappa_{c,u_2}\kappa_{y_1,u_1}\right)\sigma_{u_1,u_2} \\
-\mathrm{Cov}\left(\Delta^2 c_{i,t+2},\, \Delta^2 y_{i,1,t}\right) &= \kappa_{c,u_1}\kappa_{y_1,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\kappa_{y_1,u_2}\sigma_{u_2}^2 + \left(\kappa_{c,u_1}\kappa_{y_1,u_2} + \kappa_{c,u_2}\kappa_{y_1,u_1}\right)\sigma_{u_1,u_2} \\
\mathrm{Cov}\left(\Delta^2 c_{i,t},\, \Delta^2 y_{i,2,t}\right) &= 2\left(\kappa_{c,u_1}\kappa_{y_2,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\kappa_{y_2,u_2}\sigma_{u_2}^2 + \left(\kappa_{c,u_1}\kappa_{y_2,u_2} + \kappa_{c,u_2}\kappa_{y_2,u_1}\right)\sigma_{u_1,u_2}\right) \\
&+ 2\left(\kappa_{c,v_1}\kappa_{y_2,v_1}\sigma_{v_1}^2 + \kappa_{c,v_2}\kappa_{y_2,v_2}\sigma_{v_2}^2 + \left(\kappa_{c,v_1}\kappa_{y_2,v_2} + \kappa_{c,v_2}\kappa_{y_2,v_1}\right)\sigma_{v_1,v_2}\right) \\
-\mathrm{Cov}\left(\Delta^2 c_{i,t},\, \Delta^2 y_{i,2,t+2}\right) &= \kappa_{c,u_1}\kappa_{y_2,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\kappa_{y_2,u_2}\sigma_{u_2}^2 + \left(\kappa_{c,u_1}\kappa_{y_2,u_2} + \kappa_{c,u_2}\kappa_{y_2,u_1}\right)\sigma_{u_1,u_2} \\
-\mathrm{Cov}\left(\Delta^2 c_{i,t+2},\, \Delta^2 y_{i,2,t}\right) &= \kappa_{c,u_1}\kappa_{y_2,u_1}\sigma_{u_1}^2 + \kappa_{c,u_2}\kappa_{y_2,u_2}\sigma_{u_2}^2 + \left(\kappa_{c,u_1}\kappa_{y_2,u_2} + \kappa_{c,u_2}\kappa_{y_2,u_1}\right)\sigma_{u_1,u_2} \\
-\mathrm{Cov}\left(\Delta^2 y_{i,1,t+2},\, \Delta^2 w_{i,1,t}\right) &= \kappa_{y_1,u_1}\sigma_{u_1}^2 + \kappa_{y_1,u_2}\sigma_{u_1,u_2} + +cov\left(\varepsilon_1^y, \varepsilon_1^w\right) \\
-\mathrm{Cov}\left(\Delta^2 y_{i,1,t+2},\, \Delta^2 w_{i,2,t}\right) &= \kappa_{y_1,u_1}\sigma_{u_1,u_2} + \kappa_{y_1,u_2}\sigma_{u_2}^2 \\
-\mathrm{Cov}\left(\Delta^2 y_{i,2,t+2},\, \Delta^2 w_{i,2,t}\right) &= \kappa_{y_2,u_1}\sigma_{u_1,u_2} + \kappa_{y_2,u_2}\sigma_{u_2}^2 + cov\left(\varepsilon_2^y, \varepsilon_2^w\right) \\
-\mathrm{Cov}\left(\Delta^2 y_{i,2,t+2},\, \Delta^2 w_{i,1,t}\right) &= \kappa_{y_2,u_1}\sigma_{u_1}^2 + \kappa_{y_2,u_2}\sigma_{u_1,u_2}
\end{aligned}
$$

E.5 Wage Covariance and Transmission Coefficients Results

Figure 22 shows the variances and covariances with their 90% confidence interval for both recessions and expansions. The variance of the first earner's transitory shock is procyclical but insignificant and permanent shock is countercyclical and significant. The variance of the spouse's transitory shock also is higher during expansions than recessions but these estimates are not significantly different from each other. The secondary earner permanent shock variance is countercyclical (0.035 in recession and 0.032 in expansion) and this difference is insignificant. Thus, the spouse's temporary and permanent variances do not vary over the business cycle.

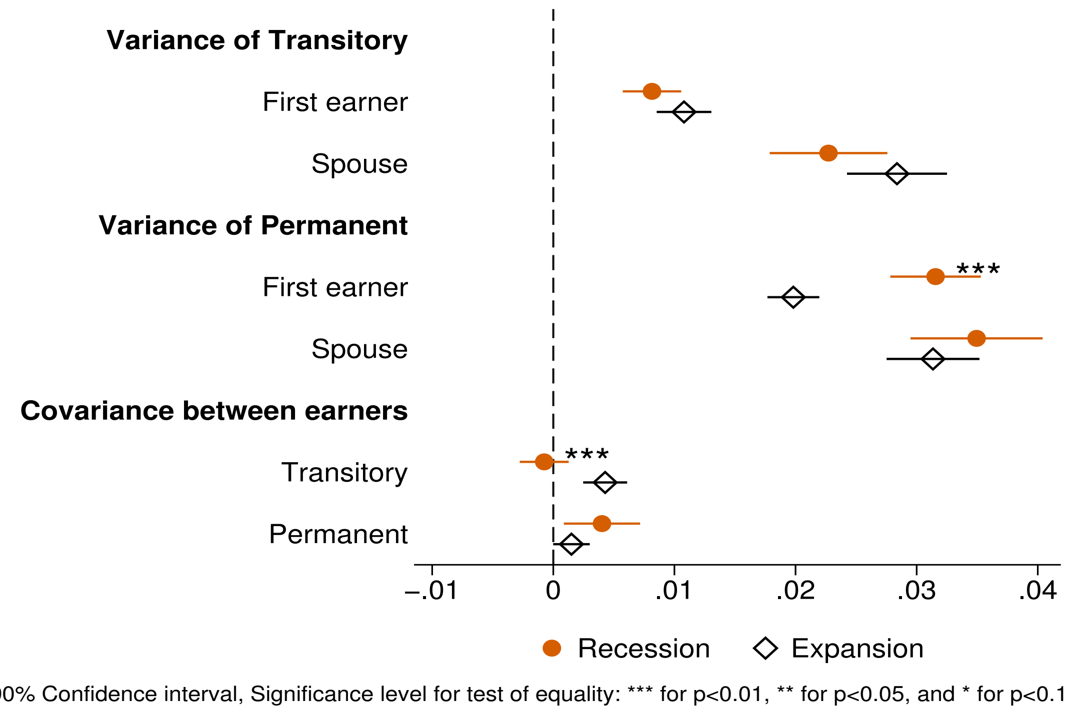

Figure 22: Wage parameters

Given that both the individual husband and wife's transitory shocks are procyclical, the covariance between their transitory shocks is also procyclical. The covariance is -0.001 during recessions and 0.004 during expansions. Similarly, the covariance between their permanent shocks is counteryclical, with the estimate falling from 0.004 in recessions to 0.002 in expansions. The differences in the business cycle estimates are statistically significant for transitory shocks. These estimates show that marital sorting does lead to husband and wife getting similarly affected during recessions and expansions. Moreover, the covariance estimates become insignificant from zero when I randomly match them. This implies that the above estimates are economically meaningful.

Figure 23 shows the transmission coefficients from the two earner reduced form specification. The transmission coefficient of the primary earner are quite similar to the one earner reduced form specification. Thus, the transmission coefficients are quite robust.

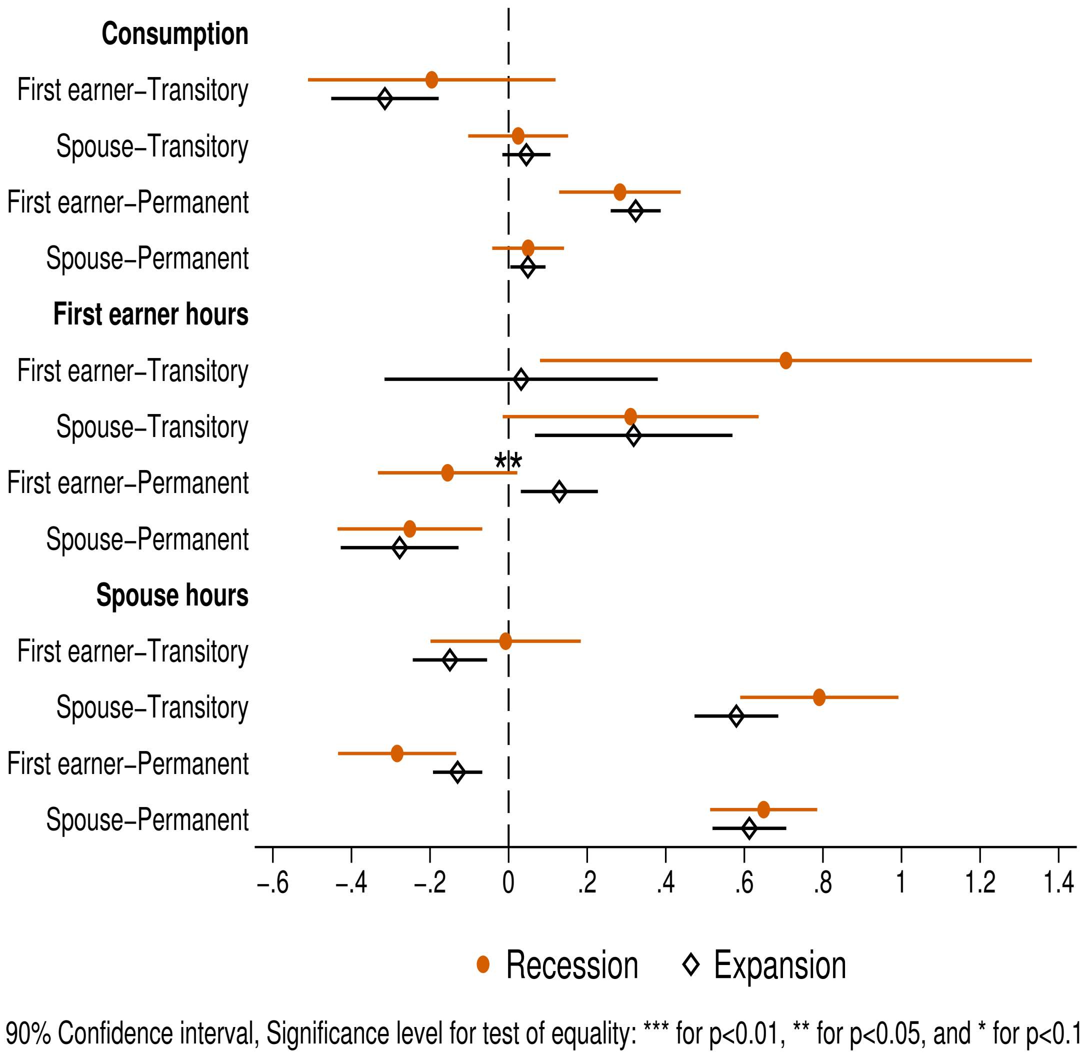

Figure 23: Transmission Coefficients against transitory and permanent wage shocks

The coefficient of consumption to second earner's transitory and permanent wage shock is very close to zero in both recessions and expansions, and the differences are insignificantly different from zero. The transmission coefficient of spouse transitory wage shocks into spouse hours is 0.79 and 0.58 in expansions and recessions respectively. They are significantly different to each other at the 13% level of significance. Attanasio et al. (2018) also find that women's Frisch elasticities are higher during recessions than expansions. The *added worker effect* is present in both recession and expansion. But the null hypothesis that the coefficients in recessions and expansions are equal can be rejected only at the 11% level of significance. The transmission coefficient into spouse's hours against their own permanent wage shock are 0.65 and 0.61 in recessions and expansions respectively. Evers et al. (2008) find the mean Marshallian elasticity for women to be 0.34 across many studies.

F Model Appendix

F.1 Numerical Solution method

I use backward induction combined with the endogenous grid method proposed by Carroll (2006) along with value function iteration proposed by Fella (2014) to find the global solution of liquid and illiquid assets, consumption and leisure. The permanent wage grid is defined over twice of the variance of wage at each point of time. The permanent wage process is defined over 5 grid points for each age. The grid for liquid asset includes 80 points at each age. The distance between two adjacent grid points increases with the asset level such that the grid points are denser around the low asset levels where borrowing constraints are more likely to bind. The minimum asset holding is -0.53 which is a quarter of average scaled annual earnings of $61630 (scale = 5200*exp(1.71)). The scaling includes two terms: first is to scale the annual time period allocation by 5200 (100 hours every week) and the second is by the level of wages (exp(1.71)).

The illiquid asset grid contains 40 points each period, where the minimum is 0 and maximum is 0.9 times sum of highest wage and twice asset holding that period. I use Gauss-Hermite quadrature method to compute the probability and grid points for transitory and permanent shocks. I have 5 grid points for each. They are used to define next period' expected utility.