Saving on a Rainy Day, Borrowing for a Rainy Day

Sule, A., Crossley T. and Low, H.

April 2012

CWPE 1222

Saving on a Rainy Day, Borrowing for a Rainy Day*

Sule Alan
University of Cambridge and Koc University

Thomas Crossley
University of Cambridge, Koc University and Institute for Fiscal Studies

Hamish Low
University of Cambridge and Institute for Fiscal Studies

May 4, 2012

Abstract

The aim of this paper is to understand what a recession means for individual consumers, and to model in a life-cycle framework how individuals respond to recessions. Our focus is on the sharp increase in savings rates that have been observed in the current and recent recessions. We show empirically that these saving spikes were short-lived and common to all working age groups. We then study life-cycle models in which recessions involve one or more of: (i) an aggregate permanent negative shock to individual income; (ii) an increase in the variance of idiosyncratic permanent shocks; (iii) a tightening of credit constraints; (iv) asset market crashes. In simulations and in the data we aggregate explicitly from individual behavior. We model credit tightening as a constraint on new borrowing and this generates an option value of borrowing in good times. We show that the rise in the aggregate savings ratio is driven by increases in uncertainty, rather than tightening of credit; temporary shocks to the supply of credit generate increases in saving only among younger agents.

JEL codes: D91, E21, D14, G01

Keywords: credit constraints, savings, recessions, uncertainty

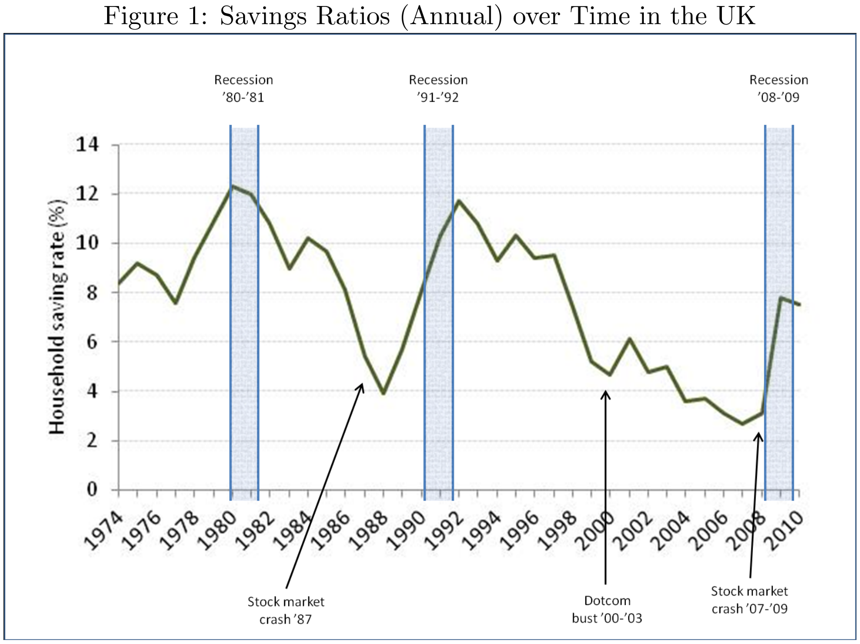
*We are grateful to Olympia Bover, Chris Carroll, Cristina deNardi and various conference and seminar participants for comments, and to Cormac O'Dea for help with the data. Low gratefully acknowledges funding from the ESRC as a Research Fellow, grant number RES-063-27-0211. This research was also co-funded by the ESRC-funded Centre for Microeconomic Analysis of Public Policy (CPP, reference RES-544-28-5001). All errors are our own.

1 Introduction

One of the striking aspects of the current recession, and of recent recessions, has been the extent that consumption has collapsed in the recession, relative to the fall in income. This has led to savings rates in the aggregate data spiking: for example, from 0.5% to 8.5% in the UK in the 2008-09 recession, as shown in Figure 1. The natural question to ask is why are households not willing to borrow or run down savings to smooth consumption through recessions: why are they saving on a rainy day? Understanding this savings behaviour is crucial to understanding how recessions change the opportunities and economic environment that households face.

There are two aims of this paper: first, we use a calibrated life-cycle model to show which changes in the economic environment in recessions can lead to the rise in the savings ratio. Second, we use micro data on household behaviour to analyse which households cut their consumption, and how the resulting spikes in savings behaviour differ by the age of the household when the recession strikes. These empirical facts, combined with the model, enable a disentangling of the effect of reduction in credit supply through recessions compared to a reduction in credit demand (due to increased uncertainty). Underlying this approach is a recognition that the impact of recessions on income is only one part of the story in understanding the effect of recessions on households.

Figure 1: Savings Ratios (Annual) over Time in the UK



At the heart of our analysis is a careful definition of what a recession means for a household, and the use of a life-cycle model of behaviour to analyse how households respond to recessions. The first component is a fall in the level of income. This fall comprises an aggregate component, but there is also substantial heterogeneity among households in the size of the fall they experience. Behaviour differs according to how persistent this aggregate shock to income is. To the extent that this is transitory, income bounces back after the recession ends, and this should lead to reductions in saving and consumption smoothing. The more persistent the shock is, the greater the consumption fall through the recession. The consumption response will therefore help to identify how permanent the aggregate shock is.

The second component of recessions is a rise in the uncertainty associated with future income, partly due to increased probabilities of job loss, and partly due to the reorganisation of production which follows recessions and which results in increased permanent risk. Carroll (1992) discusses how this might impact on aggregate savings, and this is also discussed in the Economic Report of the President (2010).

The third component of recessions is a reduction in the supply of credit. Like many papers in the literature we model households as facing a constraint on the stock of debt. However, an innovation in this paper is the development of a life-cycle model in which households can also face a constraint on the flow of new borrowing. Recessions, notably the recent one, are not characterized primarily by the calling of existing loans, but rather by a shock to the supply of new loans. Thus we consider a model in which a recession is associated with a contraction in the availability of new lines of credit. By contrast, Carroll et al. (2012) and Guerrieri and Lorenzoni (2011) model credit supply shocks as being reductions in the stock of credit.

Finally, recessions are often accompanied by sharp declines in asset prices, which erode households' wealth and cause a permanent reduction in wealth. Of course, the extent that wealth is eroded depends on choices the household has made about holdings of risky assets and may well depend on age, and this again generates substantial heterogeneity in the way a recession impacts on households. This wealth loss may induce households to cut consumption and increase saving to rebuild their balance sheets, as emphasised by Christelis, Georgarakos and Jappelli (2011) and Moore and Palumbo (2011). The fall in asset prices also affects the demand for credit as the fall in asset prices causes directly an increase in leverage (the debt to asset ratio of households with mortgages and other debts), and this leads to a desire to deleverage. To capture these effects we must model households as having access to at least two assets, one of them risky.

Our focus is on how much of the savings rate increase can be explained with the mechanisms above. There are other mechanisms which are potentially important. For example, anticipation of future tax liabilities if losses to net income are buffered by government tax cuts and transfers will increase current saving. Alternatively, irreversibility of some components of consumption may interact with increases in uncertainty to generate an option value to purchase delays (as in the model of firm investment by Bloom, 2009).

Our first contribution is to characterise how our model of the flow credit constraint affects borrowing. We show that this constraint interacts with availability of a second (risky) asset in interesting ways. In particular, the fact that future borrowing may be constrained to be no greater than current borrowing imparts an option value to current borrowing. This will induce "precautionary borrowing": that is, borrowing to maintain future access to credit ("borrowing for a rainy day"). This is particularly likely when the short position in bonds can be offset by a long position in risky assets (rather than just consumed). A natural way to think of this precautionary borrowing is in the context of households thinking of a credit supply shock in a recession, but the mechanism will be present whenever households realise that a constraint on new borrowing may arise in the future.

Empirically, we focus on UK data and the empirical pattern of savings that we are trying to understand is shown in Figure 1. We use UK data to estimate some inputs into the model and then simulate behaviour through different sorts of recession. We then use micro saving data aggregated to the cohort level to discriminate between alternative mechanisms that might generate the aggregate saving increase. Our use of the differential response of different age groups to an aggregate shock to discriminate between alternative models is in the same spirit as Attanasio and Weber (1994), who study the effect of housing wealth on consumption.

Our cohort-based analysis of the microeconomic data suggest that underlying this aggregate phenomenon is an increase in savings rates that is common across different age groups, and further that the increase is reversed quickly at the end of the recession. This focus on age effects motivates our use of a life-cycle model because different channels will have different impacts by age. Our model of recessions as only comprising an aggregate shock to income can not generate the observed saving behaviour, despite our estimates of the aggregate shocks to income being highly persistent. However, when a recession increases the idiosyncratic uncertainty that households face, this leads to sharp rises in savings similar to those we observe in the data, and a contraction in the demand for credit. Further, this pattern is observed across all age groups. By contrast, when a recession is associated with a contraction in the supply of new credit, this has less of an impact on saving, and the impact is mainly on the young, with the old even dis-saving. These differences between the effect on the saving ratio of a contraction in the supply of credit compared to the effect of increased uncertainty and a reduction in the demand for credit lead to the conclusion that, from the households perspective, the key aspect of recessions is the increased uncertainty. In terms of the quantities of the savings ratio changes explained, a standard income shock, even if permanent, can only explain a quarter of the increase; including a credit supply contraction reduces the amount explained, particularly for the old; whereas including an increase in the amount of uncertainty explains over half of the increase.

In terms of the most recent crisis, Chakrabarti et al. (2011) find that the effect on savings rates in the US has also been common to all age groups, and Glover et al. (2011) empahsise in an OLG model the potential age patterns induced by the recent recession. DeNardi et al. (2011) focus on the fall in consumption in the US and emphasise the importance of wealth effects and changes in income expectations in explaining this fall. Further, there has been a debate about how much of the saving response has been due to the contraction in the supply of credit and how much to a fall in demand for credit. Using various methodologies, Guerrieri and Lorenzoni (2011) argue that the contraction in the supply of credit increased saving and led to the recession and Mian and Sufi (2009, 2010) show the extent that credit supply contracted after 2007 and the impact of this contraction. Our work takes a different tack. We provide microeconomic evidence and an explicitly aggregated life-cycle microeconomic model to quantify how much of the change in individual behaviour is due to changes in uncertainty. That uncertainty might be an important part of the story in this recent recession has also been suggested by Mody et al. (2012) on the basis of cross-country aggregate regressions.

The rest of the paper is organised as follows. Section 2 presents a model of consumer behaviour through recessions and over the life-cycle. Section 3 estimates the effects of recessions on saving behaviour at different ages through the last 3 recessions, and the persistence of those effects. As noted above, we use these facts to distinguish between alternative models. Section 4 describes how additional parameters required for calibrating our models are obtained. Section 5 simulates the different models to show the effects of recessions and how well these effects match the data. Section 6 simulates the effect of an asset price crash. Section 7 concludes.

2 Life-Cycle Model of Saving through Recessions

Our model of saving behaviour assumes that households live for a known, finite lifetime. In each period of their life, they choose how much to consume or save, and whether to allocate their savings to a risky or safe asset. There is uncertainty over income, partly idiosyncratic, partly aggregate due to business cycle variations. Heterogeneity among households arises due to different realisations of their idiosyncratic shocks.

Households maximise

$$V_t\left(x_t, d_{t-1}\right) = \max_{c_t, q_t, d_t} \left[u(c_t) + \beta E[V_{t+1}(x_{t+1}, d_t)]\right]$$

subject to

$$c_t + q_t - d_t \leq x_t$$

$$x_{t+1} = (1 + r^q_{t+1})q_t - (1 + r)d_t + y_{t+1}$$

where q_t is holding of the risky asset at the end of the period, d_t is debt held at the end of the period (a negative value of d_t means positive bond holdings), and x_t is cash on hand at the start of the period. The return on the risky asset is r^q_{t+1} and the interest cost of debt (or return on bonds) is r. We assume that the interest cost of debt is constant and safe.[1] Agents can hold long or short positions in bonds but cannot short-sell the risky asset.

Credit Constraints One of the important contributions of this paper is a novel characterisation of the credit constraints that households face and how these constraints might change through recessions. In particular, we contrast constraints on the stock of debt with constraints on the flow of additional debt.

The credit constraints that households face over their life-times can be modelled in different ways. The two most standard ways are: one, an implicit constraint that households cannot borrow more than they can repay with certainty; two, an explicit quantity constraint, such that debt cannot be more than a certain level. In our model, households always face the implicit constraint. Additionally, in terms of an explicitly quantity constraint, we want to capture the limit of debt that is imposed by a household's income. In particular, we impose that the stock of debt an household holds cannot exceed three times their annual income.

These constraints are constraints on the stock of debt held. However, the contraction of liquidity during an economic down turn is not primarily a tightening of these constraints: the key aspect of the "credit crunch" of 2008 for households was not the calling of existing loans, but drying up of credit for new borrowing.[2] For this reason, we also consider a flow constraint on debt.[3] Rather than a constraint on the stock of debt not being greater than a certain amount, the flow constraint is on the ability to take out additional debt. This means that at least the interest on the stock of debt has to be repaid.

$$\text{If } d_t > 0 \qquad d_t \leq d_{t-1} \tag{1}$$

We introduce this constraint only when we model a recession as restricting the supply of credit. Because the choice set depends now on past borrowing, this constraint adds an additional state variable to the problem.

[1] Crossley, Low and O'Dea (2012) show that real mortgage rates in the UK changed very little despite the substantial easing of monetary policy through the recent recession.

[2] In the US, there was some tightening of unsecured credit lines as documented by Chakrabarti et al. (2011), but the contraction of credit was more associated with difficulties of accessing new credit. If we modelled a credit supply shock recession as containing a forced reduction in the stock of debt, then we can of course generate any pattern in savings rates that we wish.

[3] Attanasio et al. (2012) introduce a similar constraint to their model of housing purchases and mortgage debt to capture the difficulty of increasing a mortgage versus continuing with an existing mortgage.

In practice, for households already heavily in debt, this flow constraint on new borrowing may not bind because these households will have to repay more than the interest service in order to satisfy the implicit no bankruptcy constraint. However, as emphasized in Crossley and Low (2011), credit constraints can affect behavior even when they do not bind. With the possibility of a flow constraint if a recession hits, the first-order conditions for the choice of equity and of debt are:[4]

$$u_c(x_t + d_t - q_t) = \beta E_t[(1+r)\frac{\partial V_{t+1}}{\partial x_{t+1}} - \frac{\partial V_{t+1}}{\partial d_t}] \tag{2}$$

$$u_c(x_t + d_t - q_t) = \beta E_t[(1+r^q_{t+1})\frac{\partial V_{t+1}}{\partial x_{t+1}}] \tag{3}$$

The second of these is the standard Euler equation for a risky asset in a two-asset life-cycle model. The first is the Euler equation for the risk free asset and differs from the familiar case by the additional term in the derivative of the expected value function in $t+1$, $\frac{\partial V_{t+1}}{\partial d_t}$. $E[V_{t+1}]$ varies directly with d_t, in addition to the indirect effect through x_{t+1}, because if a recession occurs in $t+1$ additional borrowing will be constrained by d_t. If the recession is realized, then greater prior debt holdings increases utility at $t+1$ by relaxing the borrowing constraint, and so $E[\frac{\partial V_{t+1}}{\partial d_t}] \geq 0$. If the recession is not realized, then $\frac{\partial V_{t+1}}{\partial d_t} = 0$. Relative to the standard two-asset life-cycle model, this term means a lower value for the marginal utility of consumption at t, which is the left-hand size of equation (2): all else equal, this would imply higher consumption (and hence lower savings) in good times. This effect is present because there is more than one asset in the model: borrowing in period t can be used to buy the risky asset and this holding of the risky asset increases possibilities for consumption in the next period if the borrowing constraint binds. We refer to this as "precautionary borrowing": agents borrow preemptively in good times to ensure access to credit and thus to enable higher consumption in bad times. However, all else is of course not equal, in particular because agents may be less able to insure through borrowing in the future, the expected future marginal value of cash-on-hand in $t+1$ ($ie.E[(1+r)\frac{\partial V_{t+1}}{\partial x_{t+1}}]$) will be higher in environments where the potential borrowing constraint is present, which raises the marginal utility of current consumption, implying lower consumption and higher precautionary saving in good times.

To understand the overall effect on consumption and leverage, we rewrite the problem in terms of consumption and leverage, assume isoelastic preferences with coefficient of relative risk aversion γ, and

[4] With corresponding derivatives:

$$x_t : \frac{\partial V_t}{\partial x_t} = u_{c_t}$$

$$d_{t-1} : \frac{\partial V_t}{\partial d_{t-1}} = \begin{cases} -\mu_t & if \;\; d_{t-1} > 0 \;\&\; in\ a\ recession \\ 0 & otherwise \end{cases}$$

take second-order approximations to the first-order conditions. We then obtain the following consumption Euler equations, one for each asset:

$$\Delta \ln c_{t+1} = \frac{1}{\gamma}(r - \delta) + \frac{(\gamma - 1)}{2}\sigma^2_{\ln c_{t+1}} - \frac{\partial V_{t+1}}{\partial d_t} \tag{4}$$

$$\Delta \ln c_{t+1} = \frac{1}{\gamma}(\bar{r}_q - \delta) + \frac{(\gamma - 1)}{2}\sigma^2_{\ln c_{t+1}} - \frac{\sigma_{\ln c \ln R^q}}{2} \tag{5}$$

As with equation (2), the Euler equation for the risk free asset (equation 4) differs from the standard consumption growth equation because of the last term. This arises due to the option value of current borrowing arising from the constraint on new borrowing. This term reduces current consumption growth. By contrast, it is well known that a possible future constraint on the stock of borrowing leads to faster consumption growth.

Rearranging the Euler equation for the risky asset (equation 5) gives:

$$\sigma_{\ln c \ln R^q} = \frac{2}{\gamma}(\bar{r}_q - \delta) + (\gamma - 1)\sigma^2_{\ln c_{t+1}} - 2\Delta \ln c_{t+1}.$$

Thus, lower consumption growth induced by the option value to borrow implies a higher covariance between future consumption and the risky return ($\sigma_{\ln c \ln R^q}$). This in turn implies a more leveraged portfolio. Clearly the variance of log consumption is likely to differ across different models and this may mitigate or exacerbate the impact on leverage and on consumption growth of the option value. In section *4.3,* we use simulation to show the extent that consumption growth is reduced and leverage is increased by the inclusion of the option value of borrowing today.

Income Process To solve our life-cycle model we need to specify the income process that agents face. We follow a large number of papers in the literature (for example, MaCurdy, 1982, Abowd and Card, 1989, Carroll and Samwick, 1997) in assuming a simple permanent-transitory decomposition of the process, but augment this in a natural way to allow for aggregate shocks.

We define Y_{iat} as stochastic labour income for household i who is age a in period t:

$$\ln Y_{iat} = \ln Y^P_{iat} + \lambda D_t + u_{iat}, \qquad u_{iat} \sim N(0, \sigma^2_u) \tag{6}$$

With permanent income:

$$\ln Y^P_{iat} = \ln Y^P_{iat-1} + f(a) + \theta D_t + \eta_{iat} \qquad \eta_{iat} \sim N(0, \sigma^2_{\eta,t})$$

where $f(a)$ captures the deterministic age-trend. D_t is a dummy indicator for the aggregate shock, and equals 1 when in a recession, and 0 otherwise. Household income is subject to two aggregate shocks which occur when the economy is in recession. The parameter θ captures the permanent effect of a recession which is common across all households. The parameter λ captures the transitory reduction in income which lasts only as long as the economy is in recession. This characterisation of the effect of recessions is particularly stark, and in practice, recession shocks may have persistent but not permanent effects. To the extent that the shocks of recessions are less persistent than we estimate in section 4.1.1, the puzzle of why savings rates increase in recessions is exacerbated.[5]

In addition to these aggregate shocks, households are subject to permanent and transitory idiosyncratic shocks, η_{iat} and u_{iat} respectively. The variance of the transitory shock is assumed to be constant over the business cycle, but we consider allowing the variance of the permanent shock to be higher in recessions than in booms. We make this assumption on the cyclical properties of the transitory and permanent variances to correspond to the evidence in Blundell, Low and Preston (2011). It is also consistent with Storesletten, Telmer and Yaron (2001) who show that uncertainty is higher in recessions in the US, but without decomposing the increase into the permanent and transitory variances. The values of the permanent variance over the business cycle that we take from Blundell et al. (2011) are estimated from the evolution of inequality in consumption, and not from the level of consumption which we use to evaluate the model below.

Risky Assets We model the risky asset, q_t, as a composite of the different risky assets that are available in the economy, such as stocks, housing and pension savings in defined contribution schemes. This composite asset is fully liquid. Households are able to borrow at the risk-free rate and many households do borrow and purchase the risky asset. This generates a certain amount of leverage, which declines with age. Different assets do have different degrees of liquidity. For example, it is clear that buying and selling housing is subject to transactions costs. On the other hand, the wealth in housing can still be thought of as liquid if the amount of debt held against the house can be varied with negligible cost.[6]

Excess returns are i.i.d.

$$r^q_{t+1} - r = \mu + \varepsilon_{t+1}$$

where $\varepsilon_{t+1} \backsim N(0, \sigma^2_\varepsilon)$.

[5] This income procss captures the effect a recession on individual incomes. It does not translate into how aggreate output is affected by recessions. This is because aggregate output will recover partly through the process of new cohorts entering the labour force. Our focus is on how particular cohorts are affected, and we can identify this by looking at the effects on individuals.

[6] However, being able to access housing wealth through credit is not identical to a frictionless risky asset partly because using credit changes leverage and the return on net wealth.

There is a probability, p, of an asset price crash. We assume that this probability differs with the aggregate state of the economy, being higher in a recession than in a boom ($p_R > p_B$). The return on the risky asset in a crash is given by $-\phi$. There is evidence that the volatility of asset returns increases in crash periods but this is typically short lived. Since we model the asset demand at the annual frequency, we assume away the change in volatility of the risky asset in recessionary periods. Another assumption we make here is that the risk-free rate is not affected by the recession or crash. It is plausible that a crash in stock markets can push down government bond yields (a "flight to safety" by investors). Moreover, recessions are typically associated with the intervention of monetary authorities (usually in the form of lowering the short rates). However, the international historical evidence on the direction of government bond yields during crashes is mixed (see Barro, 2006). In the context of the most recent recession, survey evidence in the UK suggests that movements in government bond yields and short term rates had a very limited impact on the rates faced by consumers (Crossley, Low and O'Dea, 2012).

Recession Process The aggregate economy evolves between a boom and a recession according to a first-order Markov process. The probability of a boom persisting is high (set to 0.9), whereas the probability of a recession persisting is only 0.5. We calibrate these numbers to match the observed durations of booms and recessions in the UK over the last 40 years.

	Boom $t+1$	Recession $t+1$
Boom t	π	$1-\pi$
Recession t	$1-\rho$	ρ

We consider three different models of what happens in a recession:

1. *Income shock*: when a recession occurs, the income of all households is subject to a negative shock. This aggregate shock to income is a negative permanent effect which reduces income both in the recession and persisting after the recession ends. In our simulations, we do not include a negative transitory effect because these prove insignificant in our estimates of the effects of recessions on income in section 4.1.1 below.

2. *Variance shock:* in addition to the aggregate shock reducing mean income, the variance of idiosyncratic permanent shocks rises in a recession. We assume:

$$\eta_{it} \sim N(0, \sigma^2_{\eta,L}) \qquad \text{in boom}$$

$$\eta_{it} \sim N(0, \sigma^2_{\eta,H}) \qquad \text{in recession}$$

   and we take estimates of these variances from Blundell, Low and Preston (2011).

3. *Credit supply shock:* in addition to the aggregate shock reducing mean income, the credit market tightens. We model a credit market tightening as being on the supply of new credit lines as in

equation (1). This implies that so long as consumers pay back the interest on their loans, they will not be affected directly by the reduction in credit.

In each of the three models of recession, there is also a probability of a crash in asset prices occurring, and this probability is higher in recessions than in booms. At high frequency, asset price crashes may well precede recessions, but in our framework, a period is one year.

3 Saving Rates

This section outlines the key empirical facts about recessions that the paper aims to explain. We focus on the amount of saving carried out by different cohorts and show how this is affected by different recessions.

3.1 Data

Our data is drawn from the 1976-2010 Family Expenditure Survey. Within this time period, the UK experienced three recessions, and three substantial stock market declines. The recessions were in 1980-1981, 1990-1991 and 2008-2009. The sharp stock market declines were in 1987, 2001 and 2008. households born in different years have therefore experienced very different patterns of aggregate shocks. Our sample includes all households where the head of the household is aged between 25 and 64. We divide the sample into cohorts, with each cohort spanning a 10-year year-of-birth range. In table 1, we report the age range of each cohort for each of these major macroeconomic events.

Table 1: Age Range of Cohorts in Crisis Years

			Cohort		
Year of Interview	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1981	51 – 60	41 – 50	31 – 40		
1987	57 – 66	47 – 56	37 – 46		
1991		51 – 60	41 – 50	31 – 40	
2001			51 – 60	41 – 50	
2008				48 – 57	38 – 47

3.2 Measurement of Savings

Our main measures of savings are cohort specific saving rates, i.e. what fraction of cohort income is saved by that cohort.

$$S_c = \frac{\frac{1}{N_c}\sum S_{ic}}{\frac{1}{N_c}\sum Y_{ic}}$$

This measure of savings corresponds closest to the aggregate savings ratio in Figure 1. We can interpret our results on the savings ratio by cohort as indicating which cohorts contribute to the aggregate savings pattern.[7] Further, by calculating the savings ratio in this way, we avoid the issue of taking the ratio of two variables each subject to measurement error.

We calculate this cohort specific savings rate using consumption data

$$S_c = 1 - \frac{\frac{1}{N_{ct}} \sum_{i \in c,t} c_{ic} k_t^C}{\frac{1}{N_{ct}} \sum_{i \in c,t} y_i k_t^Y}$$

The k terms are scaling factors used to ensure the micro data aggregates up to the national account numbers.

$$k_t^C = \left(\frac{\hat{C}_t}{\frac{1}{N_t} \sum_{i \in t} c_i} \right), \qquad k_t^Y = \left(\frac{\hat{Y}_t}{\frac{1}{N_t} \sum_{i \in t} y_i} \right)$$

This assumes that under-reporting does not vary systematically by cohort at a point in time. We can interpret this scaling as apportioning the aggregate savings across cohorts in the proportion observed in the micro data at each point in time (see also Crossley, Low and O'Dea, 2012).[8]

3.3 Patterns of Saving

The savings ratios of the cohorts we study are displayed in Figure 2. A visible increase is saving is associated with each recession, and the increase appears common to all cohorts of working age at each recession.

To further explore the effect of recessions on cohort level savings, we run regressions on the cohort data of the following forms:

$$\begin{aligned} S_{ct} &= \gamma_0 + \gamma_1 time + \gamma_2 age + \gamma_3 age^2 + \sum \phi_c cohort \\ &\quad + \text{recession and crash variables interacted with age} \end{aligned}$$

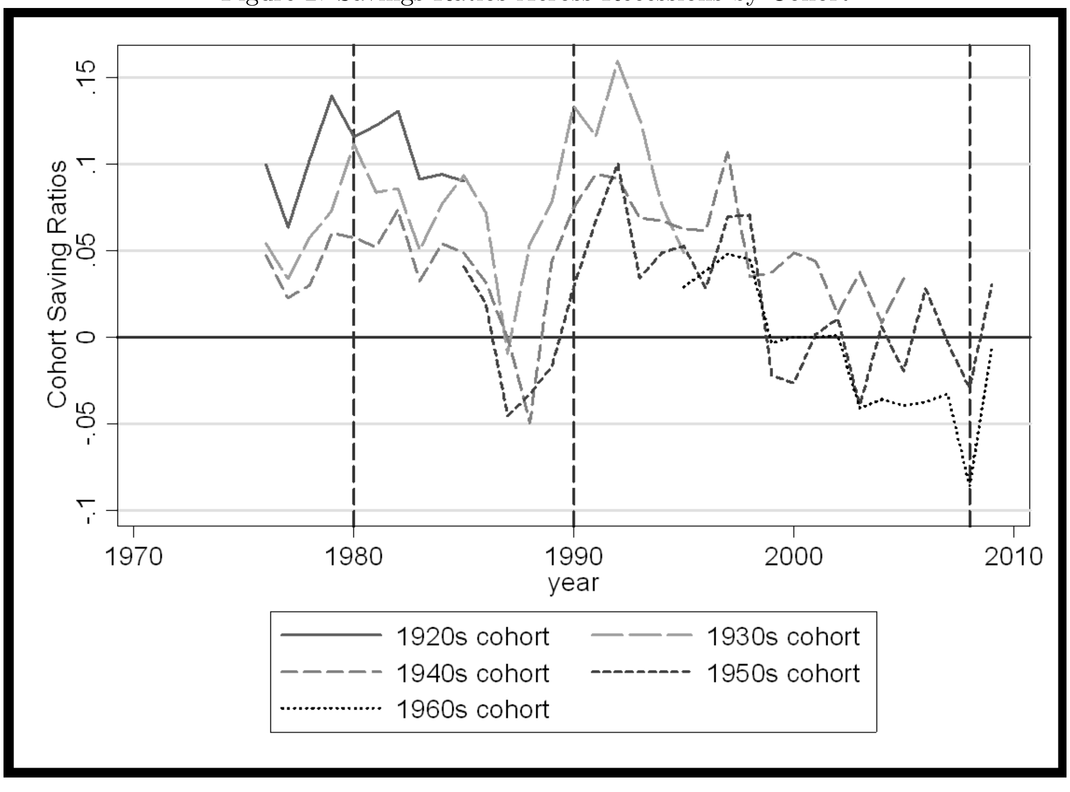
[7] The contribution of each cohort to the aggregate savings ratio will depend on its share of total income.

[8] It is possible to relate this aggregate savings ratio back to the savings ratios of individuals within a cohort:

$$\begin{aligned} S_c &= 1 - \frac{\frac{1}{N_{ct}} \sum_{i \in c,t} c_{ic} k_t^C}{\frac{1}{N_{ct}} \sum_{i \in c,t} y_i k_t^Y} \\ &= \frac{1}{N_{ct}} \sum_{i \in c,t} \left(1 - \frac{c_{ic} k_t^C}{y_i k_t^Y} \right) \left(\frac{y_i}{\bar{y}_c} \right) \end{aligned}$$

That is, our cohort saving measure is a weighted average of household saving ratios where the weights are proportional to the share of household income in total cohort income. This is sometimes called a plutocratic measure: as the rich contribute much more total saving by cohort they are given a higher weight in the average. The widely reported aggregate household saving ratio (as in Figure 1) weights individual household savings rates in the same way.

Figure 2: Savings Ratios Across Recessions by Cohort



$$\Delta S_{ct} = \beta_0 + \beta_1 age + \text{recession and crash variables}$$

When we run the regression in differences, β_0 contains both linear time trend and the linear part of the age profile and β_1 captures the concavity in age. Any cohort effects are differenced out. It is however important to stress the need for the time trend: over this time period, savings rates were trending down at 0.3% per year and so the level of the savings rate was different at the start of each of the three recessions. The results are presented in Table 2.

Table 2: The Effect of Recessions on Saving

	Savings Rate				Δ*Savings Rate*
Constant	**0.0267** (.0049)	**0.0268** (.0048)	**0.0271** (.0051)	**0.0274** (.006)	-0.0028 (.0058)
Age	-0.0035 (.0042)	-0.0032 (.0041)	-0.00295 (.0044)	-0.0007 (.0062)	-0.00009 (.0005)
Age^2	0.00007 (.00005)	0.000065 (.000046)	0.000061 (.00005)	0.00004 (.00007)	
Time	**-0.0029** (.00035)	**-0.00295** (.00036)	**-0.00290** (.000349)	**-0.0274** (.0004)	
Recession*	**0.0390** (.0093)				
Recession 1981/1982		0.0206 (.0137)			
Recession 1991/1992		**0.0639** (.0132)			
Recession 2009		0.0180 (.023)			
Recession Age 30s			**0.0429** (.0169)		
Recession Age 40s			**0.0328** (.0153)		
Recession Age 50s			**0.0418** (.0156)		
Recession Onset				0.0108 (.012)	0.0115 (.0131)
Recession Onset + 1				**0.030** (.012)	**0.0224** (.0131)
Recession Onset + 2				**0.051** (.014)	**0.0211** (.0148)
Recession Onset + 3				0.0118 (.014)	**-0.0365** (.0148)
F-Test (p-value)		3.42 (0.0370)	0.13 (0.8765)	4.24 (0.004)	3.24 (0.0166)

There are three main points to draw from these regressions: first, the savings ratio spikes up after a recession starts by about 4 percentage points. Second, the rise in savings happens across all the age groups we consider. Finally, in the third year after the start of the recession, savings fall back sharply, and there is no significant difference in the level of savings compared to pre-recession.

4 Calibration

In this section, we estimate the inputs and detail our calibration. We discuss first the parameter values and the estimation of the parameter values. We then simulate the three models but assuming that there is no realised recession or crash. This defines three sets of baseline behaviour to compare to behaviour when the recession is realised. There are three different baselines because there are three different models of a recession and each one generates potentially different ex-ante behaviour.

4.1 Parameters

Some parameters come from direct estimation of the process assumed in the model, such as the income process and the rate of return of the composite asset. Others are taken from estimates in the literature. We discuss these in turn.

4.1.1 Labour Income

We estimate the labour income process that the household faces as comprising idiosyncratic and aggregate components, as outlined in section 2. A recession impacts on the income process through the aggregate components and through changing the variance of the idiosyncratic components. We use a definition of income from the data as household net income with capital gains removed by using the average tax rate.

We regress the difference of income on household characteristics, as well as dummies indicating the presence of the recession.

$$\Delta \ln Y_{iat} = \alpha_0 + X'\beta + \theta D_t + \lambda \Delta D_t + \eta_{iat} + \Delta u_{iat} \tag{7}$$

This regression identifies the average size of the shock of a recession, rather than the distribution of different shocks. We can, more generally, allow the effect of aggregate shocks to differ across households of different ages:

$$\begin{aligned} \Delta \ln Y_{iat} &= \alpha_0 + \alpha_1 age \\ &\quad + \sum \theta^a D_t I\{a\} + \sum \lambda^a D_t^D I\{a\} + \eta_{it} + \Delta u_{iat} \end{aligned}$$

In our regression to identify the recession effects on income, we use cohort level means and run the regression:

$$\Delta \ln Y_{at} = \alpha_0 + \alpha_1 age + \sum \theta^a D_t I\{a\} + \sum \lambda^a D_t^D I\{a\} + \overline{\{\eta_{iat} + \Delta u_{iat}\}}$$

We report results of this regression in Table 3. The key point to take from this table is that, from the perspective of a household of whatever age, given this specific income process, recessions have permanent

Figure 3: Income Across Recessions by Cohort

Table 3: The Effect of Recessions on Income Growth

Constant	**0.0294**	**0.0293**	**0.0286**	**0.0294**
	(.0072)	(.0073)	(.0074)	(.0072)
Age	0.010	0.0098	0.00894	0.00968
	(.007)	(.0067)	(.007)	(.00676)
Age^2	**-0.00015**	**-0.00015**	**-0.00014**	**-0.00014**
	(.00007)	(.00007)	(.00008)	(.00008)
Permanent	**-0.0317**	**-0.0311**		
	(.0127)	(.0154)		
Transitory		-0.00097		
		(.0150)		
Perm$*30s$			-0.0327	
			(.0248)	
Perm$*40s$			-0.0242	
			(.0204)	
Perm$*50s$			**-0.0381**	
			(.0205)	
Perm$*$1980				**-0.0369**
				(.0197)
Perm$*$1990				-0.0278
				(.0197)
Perm$*$2008				-0.0296
				(.0241)
Joint Significance $F(2,89)$			0.12 ($p = 0.88$)	0.06 ($p = 0.94$)

rather than transitory effects on income. The fact that we estimate that recessions induce permanent shocks to household income is consistent with the absence of consumption smoothing through recessions which we saw in figure 1. To the extent that the effect of recessions is persistent but not permanent, the rise in savings shown in figure 1 would be even harder to explain because consumption smoothing is easier the less permanent are shocks.

4.1.2 Real Returns and Capital Income

The return on the composite asset is a weighted return of the different components, specifically equity and housing. The weights used are plutocratic weights. Mortgage debt is included in the safe asset, and this creates a net position in the safe asset.

Figure 4 shows the estimated pattern of returns on equity, on housing and on our composite asset, which comprises $6/7^{th}$ housing and $1/7^{th}$equity. There is a clear correlation between the returns on housing and the business cycle, with returns falling sharply in each of the three recessions. There is more volatility in the return to equity.

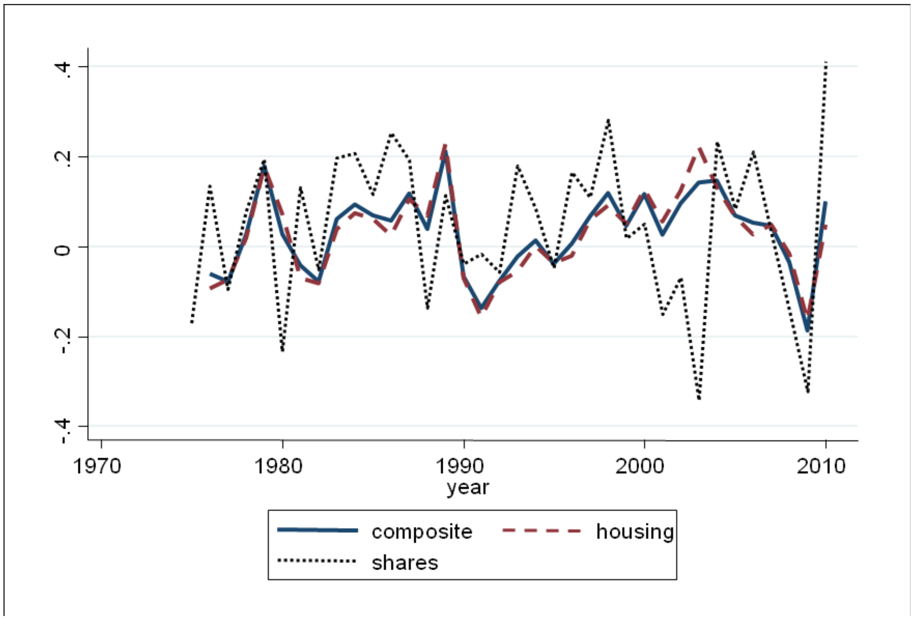


Figure 4: Real Returns over the Business Cycle

4.2 Parameter Values

Table 4 presents the parameter values we use for the simulations. We set the coefficient of relative risk aversion to 2. This value is consistent with the estimates obtained from consumption studies (see Attanasio et al (1999), Gourinchas and Parker (2002)). The discount rate is set to be 7% so that the wealth accumulation over the life cycle matches the data: the peak of the age-networth profile is 2.5 times the average annual income. Asset market annual crash probabilities are set to 2% and 4% for boom years and recessions, respectively. These values are consistent with those calibrated in Barro (2006), Barro and Ursua (2008), and those estimated in Alan (2011).[9]

Parameters of the distribution of returns are estimated using the composite asset described earlier. Accordingly, mean return is set to 3.5% with the standard deviation of 7.6%. Saving ratios are calculated using the total income which is labour income plus capital income. In our two asset model, capital income is interest income (which will be negative if in debt) plus dividend income. While the former is straightforward to calculate, we need an explicit asset pricing model for the latter. We use the dividend discount model with a constant growth rate, where dividend income received by the individual is

$$(\mu - g)q_t$$

[9] Barro (2006) calibrates a disaster probability of $1.5 - 2$ percent a year by analysing 20th century disasters using GDP and stock market data from 35 countries. In follow up work using aggregate consumption data from 21 countries, Barro and Ursua (2008) calibrate the disaster probability to 3.6 percent a year. Alan (2011) estimates a range of 1 to 5 percent a year using SCF and CEX.

$\gamma = 2.0$	coefficient of relative risk aversion
$\delta = 0.07$	discount rate
$\sigma_{n,B} = 0.1$	permanent shock in boom
$\sigma_{n,R} = 0.15$	permanent shock in recession
$p_B = 0.02$	probability of a crash in boom
$p_R = 0.04$	probability of a crash in recession
$\phi = 15\%$	size of crash in risky asset
$\sigma_\varepsilon = 0.076$	standard deviation of return on risky asset
$\mu = 0.035$	mean return on risky asset
$r = 0.02$	interest rate
$g = 0.02$	corporate earnings growth rate

Table 4: Parameter Values

where μ is the required return and g is the long-run corporate earnings growth rate. We set μ equal to historical mean return on our composite risky asset and we set g equal to long-run annualised growth rate of UK GDP.[10] Finally, we set the risk-free rate r to 2%.

Our economy comprises 10000 individuals simulated for 60 years from age 22, retiring at age 62, and then retired for 20 years.

4.3 Baseline Simulations

The baseline simulations of asset accumulation, consumption and leverage are shown in Figure 5. On the left hand side, we compare the benchmark model where a recession is just an income shock with the extension allowing for higher idiosyncratic uncertainty in recessions. On the right hand side, we compare the income shock recession model with a model of a recession as a contraction in the flow of credit. We show behaviour up until retirement to focus on the behaviour of working age households, which are the focus of our data analysis.

When a recession means higher uncertainty, households accumulate net worth faster in good times.

[10] Consider a simple dividend discount model for pricing a risky asset:

$$P_t = \sum_{t=0}^{\infty} \frac{D_{t+1}}{(1+\mu)^{t+1}}$$

where P_t is the fair price in period t, D_{t+1} is the next period's dividend and μ is the required return from the stock. Denote g as the constant earnings growth rate. Assuming $\mu > g$,the above equation converges to

$$P_t = \frac{D_{t+1}}{\mu - g}$$

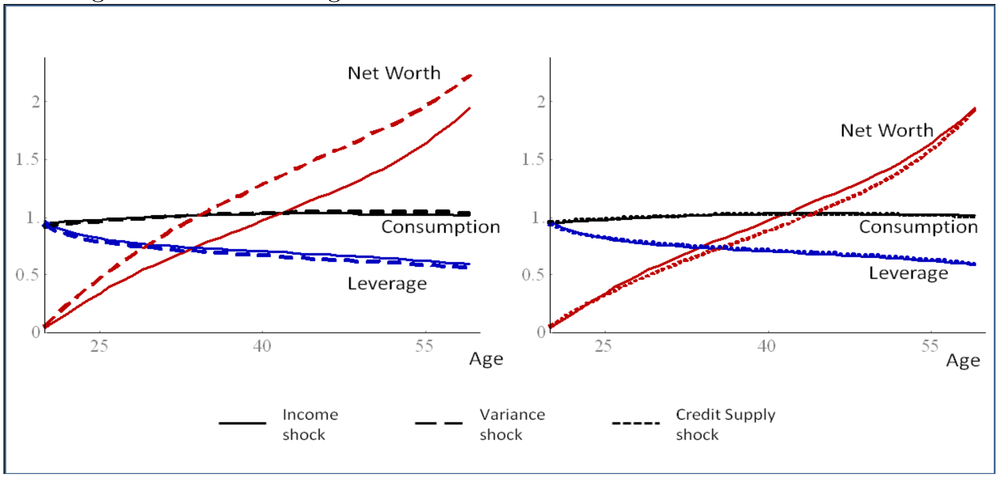
where $D_{t+1} = D_t(1+g)$, the dividend per share the individual is assumed to receive in period $t+1$. We can show that

$$(\mu - g)P_t Q_t = D_{t+1} Q_t$$

so that the individual who holds Q_t units of stock will have an income flow of $D_{t+1}Q_t$ next period. Or simply $(\mu - g)q_t$ where q_t=$P_t Q_t$, the value of stocks (our choice variable) in period t. Then, it follows that the individual's capital income in period $t+1$ is

$$(\mu - g)q_t - rd_t$$

Figure 5: Simulated Age Profiles in the Absence of a Recession or a Crash



They do this through lower consumption when young and hold slightly less leveraged positions than when a recession is only an income shock.

By contrast, when a recession means an inability to extend borrowing, this leads to preemptive precautionary borrowing, which can be seen by the leverage being somewhat higher, as in equation (5) above. Similarly, consumption growth is slower with this extra borrowing constraint, and net worth accumulates less fast, as in equation (4).

Two features of the data that were not targets in the calibration but which the model replicates quite well are the patterns of net worth and of leverage across households working lives. Leverage over the life-cycle in particular has not been much studied empirically but here we present evidence from the year 2000 British Household Panel Survey. We define leverage as the ratio of mortgage and liquid debt to gross housing wealth and gross liquid wealth. We report this ratio by age in Figure 6. The point to stress here is the clear age effect: leverage declines markedly as households approach retirement.

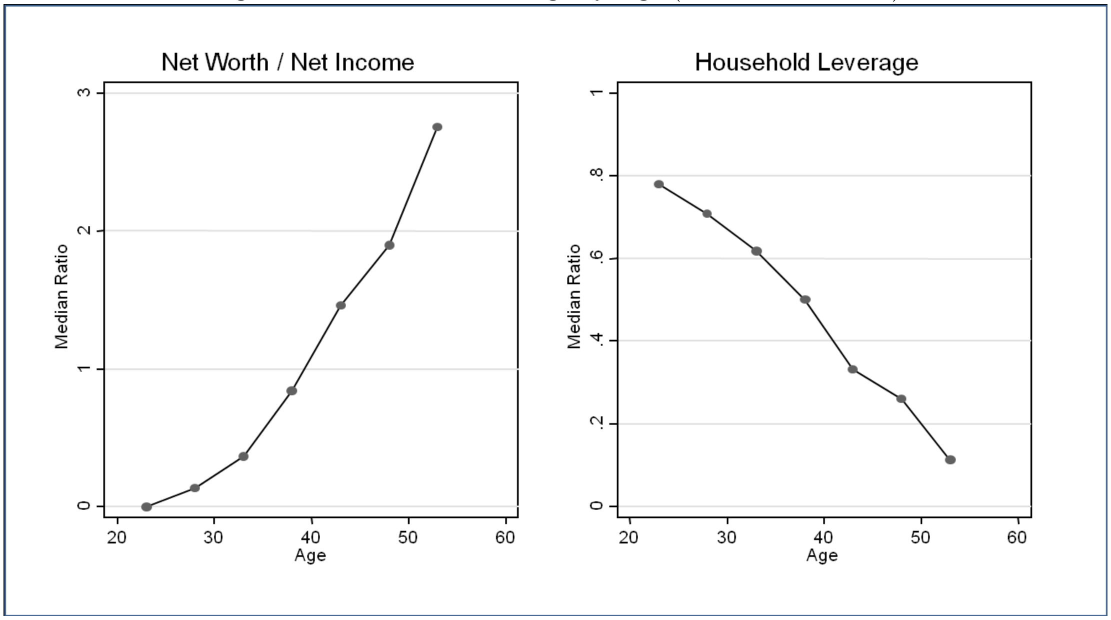
In the model, households borrow at the start of their lives in order to buy the risky asset. This generates a highly leveraged position, which gets unwound as households age, much as we see in the data in Figure 6. This leveraging leads to asset accumulation over the life-cycle (where by assets we mean net worth), and assets at retirement are then used to finance part of consumption in retirement.

Leverage has a substantial effect on portfolio returns. The portfolio return is

$$\begin{aligned} \hat{r}_t &= r_t^q \frac{q_t}{q_t - d_t} - r \frac{d_t}{q_t - d_t} \\ &= r + \frac{1}{1-L}\left(r_t^q - r\right) \end{aligned}$$

For our simulations, $\mu - r = 0.015$,and households aged 25 have $L = 0.8$ in both the simulations and

Figure 6: Wealth and Leverage by Age (in the 2000 BHPS)



the data. This implies the net portfolio return at the mean of the risky asset return of 0.035 is

$$\hat{r} = 0.02 + 5 * 0.015 = 0.095.$$

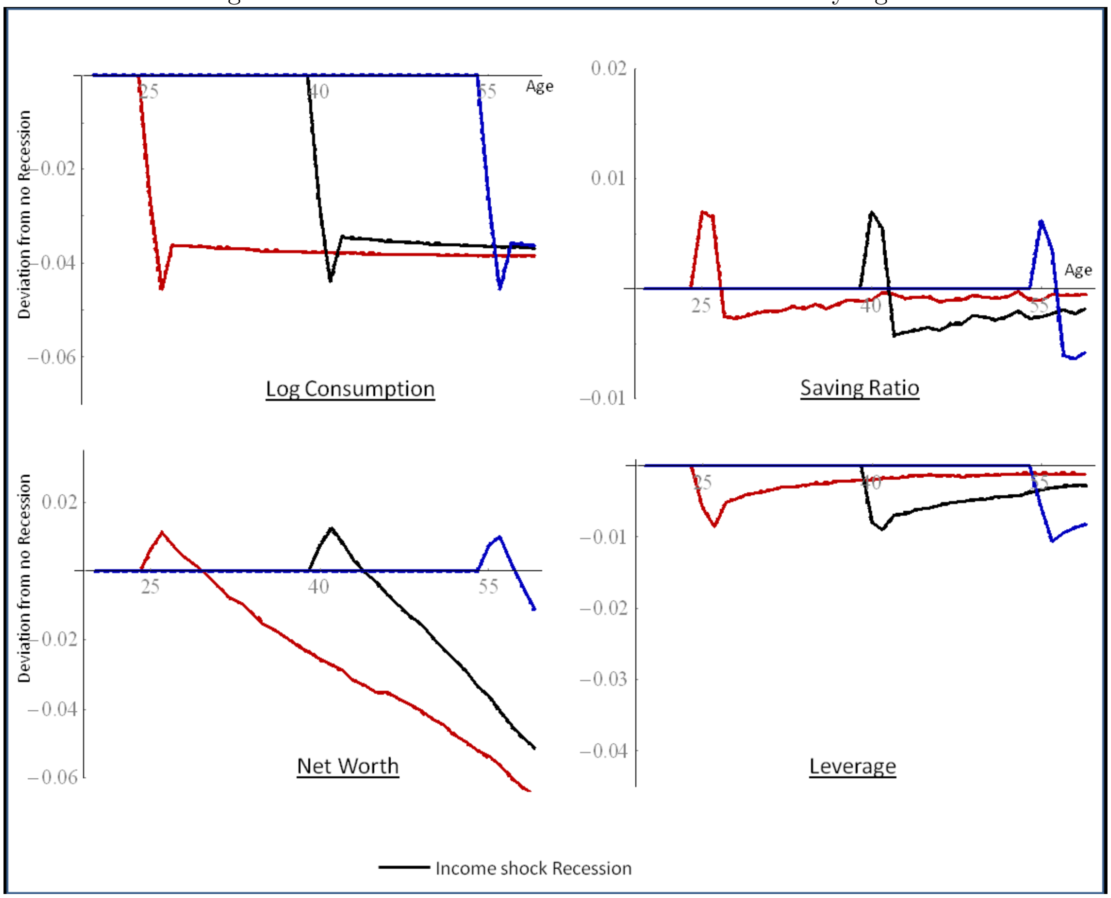
5 Simulated Responses to a Recession

In this section, we simulate how the different types of recession impact on household behaviour. We show the effects on consumption, on savings rates, on net worth and on leverage for households who are at different ages when the recession hits. We simulate first the effects of the income shock recession model and then the two extensions to a variance shock and a credit supply shock. The aim of this section is to show whether different sorts of recession can generate the pattern of savings behaviour that we observe, in particular the spike up in savings rates for all age groups at the start of recessions, followed by a sharp decline in savings.

5.1 Income Shock Recession

Figure 7 shows the effects of a recession for households who are age 25,40 and 55 when the recession hits. The top left graph shows deviations of consumption behaviour from the baseline of no recession being realised. The top right graph shows the corresponding effects on the saving ratio. When the recession hits, consumption falls sharply for households of all ages, reflecting the permanent nature of the shock to income. When the recession ends, consumption spikes back up somewhat towards the level if there

Figure 7: The Effects of an Income Shock Recession by Age

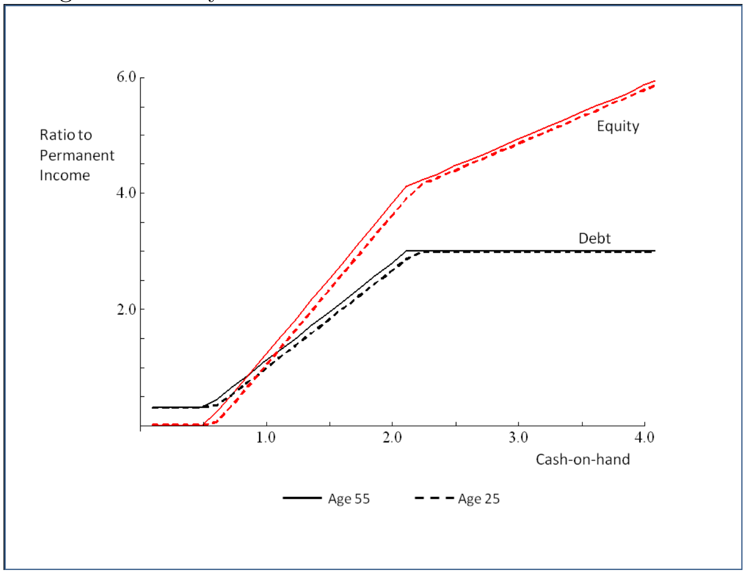


had been no recession. This spike back up happens when the economy is out of the recession because the probability of another negative permanent shock (i.e. being in a recession in the next period) is lower in a boom and thus uncertainty is lower.

This effect on consumption is mirrored in the effect on the savings ratio, which rises by 1 percentage point when the recession hits, before falling back at the end of the recession, and even falling below its pre-recession level as households run down extra savings accumulated during the recession. The bottom row of Figure 7 shows the impact of the recession on net worth on the left hand side and leverage on the right hand side.

The loss of income in the recession and the rise in risk of an asset market crash leads households to want to pay back their debts and to move out of equity. The initial deleveraging is caused by the selling off of equity and the fall in consumption that reduces debt. These figures show the average effects, but these mask the considerable heterogeneity across households. For example, 40% of households increase their debt holdings after the recession hits, whereas 60% reduce their debt.

Figure 8: Policy Functions for an Income Shock Recession



The deleveraging that is observed in these simulations can best be understood by looking at the policy functions describing the optimal choices that households make as a function of cash-on-hand. These are shown in Figure 8. As cash-on-hand increases, households demand for debt increases because households want to invest more into the risky asset and they do this through borrowing and thus leveraging their wealth. This increase in borrowing with cash-on-hand is in sharp contrast to a standard one asset model where borrowing is undertaken by those who have less cash-on-hand and want to maintain consumption. This increase is also in contrast to a two asset model where buying the risky asset on margin is not permitted (as in Gomes and Michaelides, 2005). However, the mechanism we highlight is particularly important when the bulk of borrowing that is undertaken is secured borrowing, such as to finance house purchases.

Modelling recessions in this way of affecting only mean income does not generate the sort of changes in savings behaviour that we see in the data. On the other hand, part of the rise in savings is generated by this simple characterisation of savings: being in a recession increases the probability of being in a recession in the next period with the corresponding fall in income and so precautionary savings will increase for this reason. The point of our simulations is to show that the magnitude of this direct precautionary effect is much smaller than we observe in the data. This leads to the conclusion that recessions change the economic environment in additional ways that we have to model to capture the household behaviour that we observe in the data.

5.2 Variance Shock Recession

In Figure 9 we compare the effects on consumption and the savings ratio of a recession which involves a shock to both the mean and the variance with the model where there is only a shock to the mean. The figures plot deviations from the baseline of no recession being realised, but as shown in Figure 5 there are differences in the baseline for the two models, with the variance shock model generating greater net wealth and less leverage than in the income shock model.

The first point to stress is that consumption falls markedly further in the recession with a variance shock and the savings ratio spikes up more than twice as far, despite the size of the aggregate shock being identical across the two models. This reflects the extra precautionary saving that a recession induces due to the increase in the variance of idiosyncratic permanent shocks. At the end of the recession, consumption remains lower when a recession has a variance shock than when a recession is only an income shock because there is a larger movement out of the risky asset following the variance shock recession. Moving out of the risky asset means expected returns fall and, on average, consumption is therefore lower. This difference in the portfolio allocation is shown clearly in Figure 9, with deleveraging being much more substantial following the variance shock recession. Including a variance shock as part of recessions means that our model is able to explain over half of the rise in the savings ratio observed in the data, whereas without the variance shock, only a quarter of the increase can be explained.

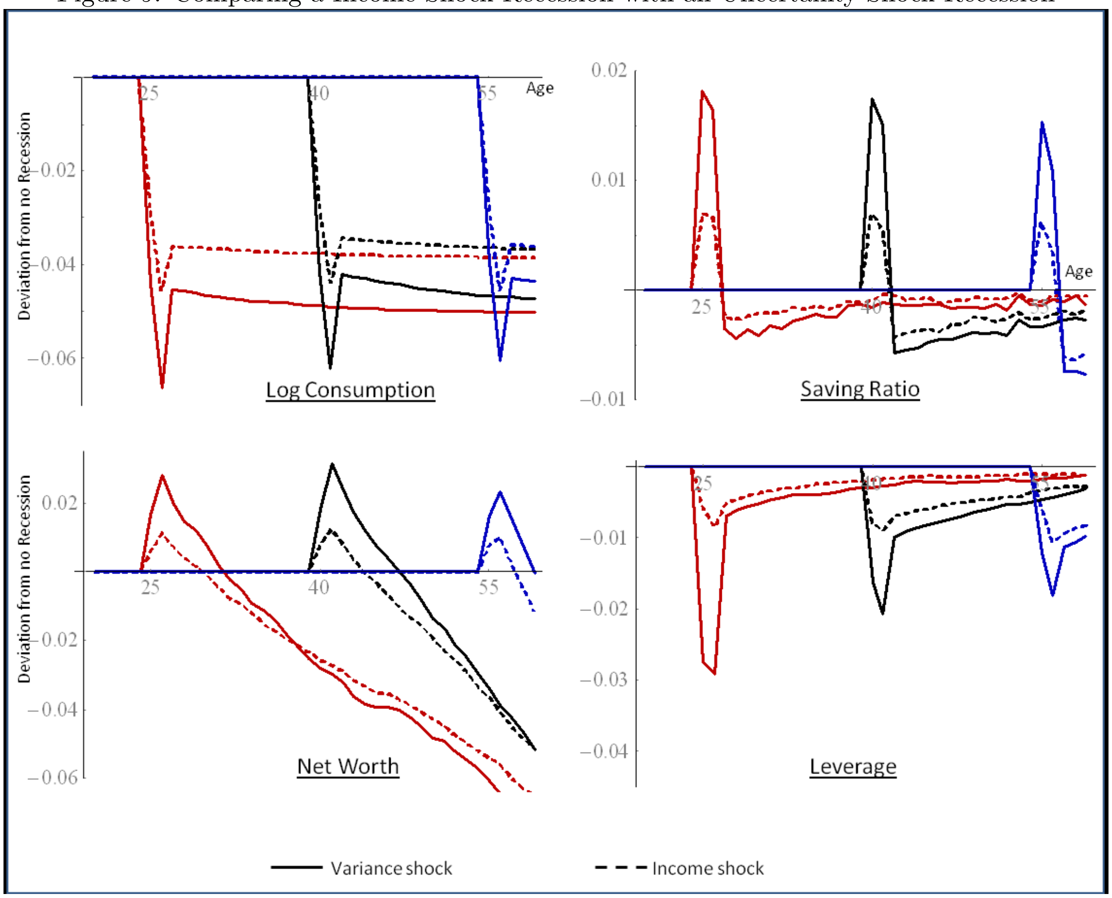
5.3 Credit Supply Shock Recession

The third type of recession combines an aggregate income shock with a restriction on the availability of additional credit. The purpose of introducing this third type of recession is to show the importance of a contraction in the supply of credit compared to the reduction in the demand for credit highlighted by the deleveraging pictures for income shock and variance shock recessions.

When a recession leads to a constraint on extra debt, those who wanted to increase their debt are unable to, which will have a direct effect increasing saving and leading to consumption falls. On the other hand, households borrow more in anticipation of the need for assets to protect consumption in a recession. The different impact on consumption of a credit supply shock recession being realised, compared to an income shock recession, is shown in Figure 10. There are two points to draw from these figures on the consumption effects: first, the contraction in credit leads to a smaller fall in consumption compared to an income shock recession across all ages. Second, there are differences by age, with the young experiencing larger falls in consumption, whereas those close to retirement experience less of a fall.

There are two reasons why the consumption fall may differ from the income shock recession. First, consumption may fall further when the credit constraint is imposed because of a direct effect on individuals

Figure 9: Comparing a Income Shock Recession with an Uncertainty Shock Recession



with low cash on hand being unable to borrow to smooth. Working in the opposite direction is the precautionary borrowing effect discussed above. This will be strong in a recession because the probability of being in a recession in the next period is high and so the option value generated by current borrowing is high. The simulations show that the latter dominates on average even among the young, although the average masks differences across individuals. At older ages, households have more cash on hand and so the direct effect is even weaker and the difference in consumption across the two types of recession is larger.

These differences in consumption are reflected in the impact on savings rates. Savings rates for the young spike up similarly when the credit supply contracts to the spike up in the income shock recession. On the other hand, there is much less of a spike up for the middle age when credit contracts, and even a decline for the old age. This is in contrast to the findings in the data in Table 2 where the savings rate spikes up for all ages, and declines sharply at the end of the recession. Even for the young, the credit supply shock leads to less than a quarter of the savings rate spike being explained and this is worse than the income shock model on its own. This is despite the constraint on new credit being imposed on the borrowing of all households. The savings patterns in this figure and in figure 9 are the main evidence we present in support of the behaviour of the savings rate being driven by extra uncertainty rather than by a contraction in the supply of credit or of an income shock alone.

These differences in savings and consumption are also reflected in differences in portfolio choices. One of the striking aspects of figure 10 is the substantial deleveraging that occurs alongside only a modest fall in consumption. To understand this, we show in figure 11 the policy functions describing the optimal choices for debt and equity both in good times and when in a recession. The top row shows policy functions for debt, the bottom row for equity. The desired amount of debt increases with cash-on-hand because households want to borrow to leverage purchases of the risky asset and they are more willing to do this when current resources are higher. This is where the constraint on new borrowing has an impact: even in recessions, there is heterogeneity among households over whether they experience positive or negative shocks to cash-on-hand. Those households with positive shocks will want to increase their debt but the constraint means this ability to borrow is restricted, as shown by the policy functions. This leads in turn to less purchases of the risky asset. Crucial to understanding the average paths in figure 10 is accounting for this heterogeneity in desired borrowing.

One aspect of these simulations is that each cohort experiences just one recession in their life-cycle, age 25, 40 *or* 55. Realistically, a cohort that experiences a recession at age 55 is likely to have experiences recessions in their past. One consequence of experiencing multiple recessions would be that they have less accumulated wealth when they experience the recession at age 55. We simulated an alternative situation

Figure 10: Comparing an Income Shock Recession with a Credit Supply Shock Recession

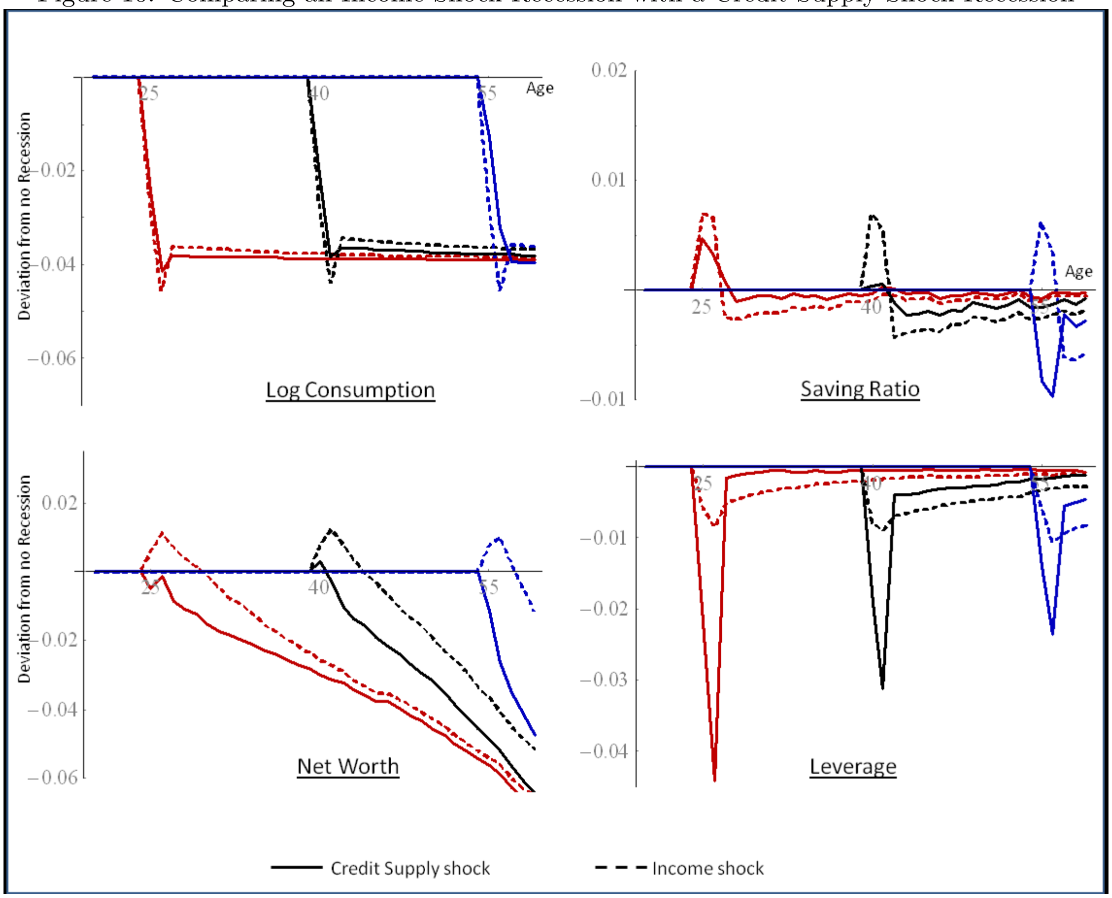
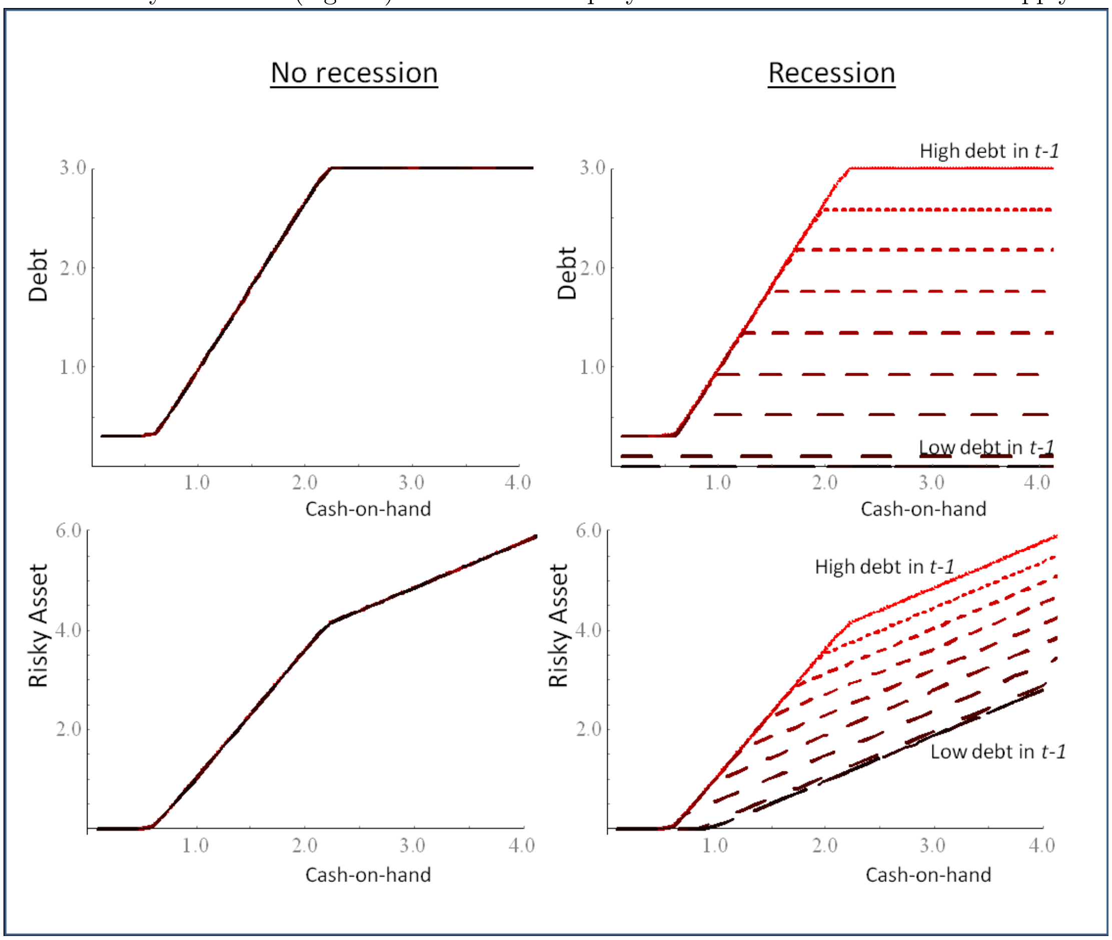


Figure 11: Policy Functions (Age 25) for Debt and Equity when a Recession is a Credit Supply Shock



in which a single cohort experiences realized recessions at ages 25, 40 *and* then at 55. These results are qualitatively very similar to the ones reported above and are available on request.

6 Simulated Responses to an Asset Market Crash

In each of the three recession scenarios considered, the probability of a crash in asset prices increased in the recession. However, there was no realisation of such a crash in any of the simulations. In this section, we show the effect of a crash in asset prices which happens when the recession occurs.

The crash in asset prices causes a direct wealth loss which is obviously greater the larger the holdings of the risky asset. This leads to a fall in consumption, as shown in Figure 12. The fall is greater for older households with more risky asset holdings. Consumption never fully recovers. Figure 12 also shows how these falls in consumption translate into changes in the savings ratio. Savings rates spike up following the crash, and this is particularly so for older households who want to rebuild their balance sheets. Further, savings ratios remain higher throughout the rest of the households' lifetimes than if would have been if the crash had not occurred alongside the recession.

While the asset price crash reduces the value of the asset, the value of debt that was held against the risky asset remains. In effect, this makes households much more leveraged than prior to the crash. This is particularly the case for younger houses: their initial highly leveraged positions leaves them more exposed to falls in asset prices. The bottom right hand panel of Figure 12 shows how leverage changes following the crash: households reduce their undesired highly leveraged positions by cutting consumption, selling assets and paying down debt. This deleveraging process continues for many years beyond the asset price fall and recession.

Since an asset crash generates a saving increase among the old, and a credit supply contraction generates a saving increase among the young, it might seem that the pattern we see in the data - of saving increases at all working ages - could be replicated by the combination of a crash in asset prices and a contraction of credit supply. However, the asset price crash leads to increases in saving that are much more persistent than what we see in the data. In contrast, a variance shock generates a short-lived increase in saving across a wide age range.

7 Conclusions

This paper provides a framework for understanding how recessions affect different households and for explaining the observed changes in behaviour that recessions cause. Our focus is on the spike in savings rates that happens at onset of a recession: households are saving *on* a rainy day. We calculate savings rates as the proportion of cohort level income that is actively saved. Once we allow for a time trend

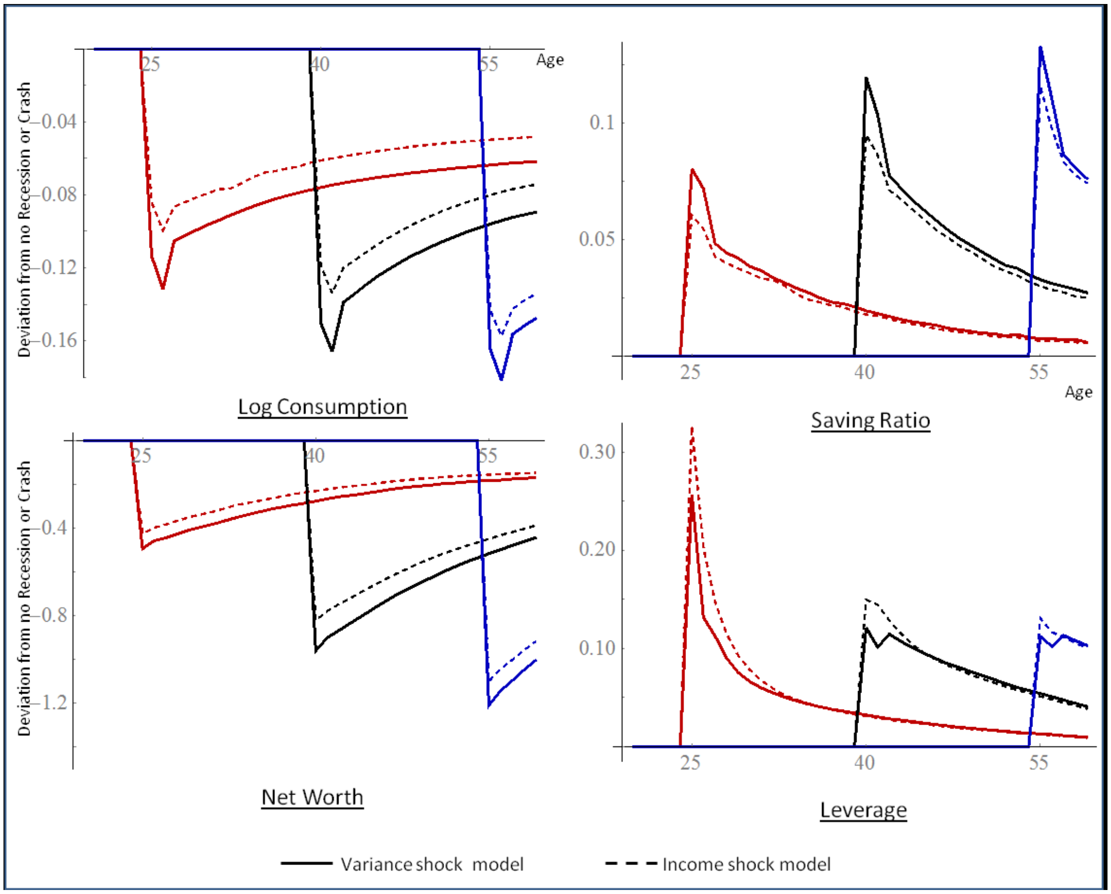


Figure 12: The Effects of a combined Crash and Recession at Different Ages

and age effects, savings rates are 4% higher in recessions. This rise happens in the first full year after the recession starts, and falls back quickly after the recession ends. This pattern is observed across all working-age groups. We show that this rise in savings cannot be explained with a model where recessions reflect only aggregate shocks to income.

We model the aggregate shocks to income of a recession as having both a permanent and a transitory component, but, guided by the cohort level data, we focus on the effects of the permanent component. We use our estimates of the income process and process for the risky asset to simulate behaviour through recessions, assuming that the realised recession lasts two periods. Even when a recession has only an aggregate permanent effect, savings rates do not rise in the way we see in the data. To the extent that aggregate shocks are persistent but not permanent, this puzzle of the spike in savings will be more pronounced. Indeed, the spike in saving is itself prime-facie evidence for the shocks being partly persistent.

We then enrich our analysis of a recession in three ways. In the first extension, idiosyncratic uncertainty increases in recessions. This emphasises reductions in the demand for credit and increased desire to save in a recession. Savings rise sharply when the recession starts, and then falls back after the recession ends, somewhat overshooting its long-term level. The fall back occurs because the end of the recession means extra precautionary balances are no longer needed and can be run down. This simulated rise in savings rates is observed for all age groups. The recession affects the demand for credit and the amount of leverage that households are willing to hold: households deleverage by moving out of the risky asset and reducing their demand for debt.

The second extension in our model of a recession focuses on the reduction in the supply of credit. We model this as reduced availability of new credit. We show that this extension generates an option value of borrowing when not in a recession and thus borrowing *for* a rainy day. This lowers consumption growth and increases leverage. By contrast, a constraint on the stock of debt would lead to greater consumption growth. In the simulations, when the recession happens, the reduction in the supply of new credit has a strong impact only on the young, but less of an impact on older households who choose to reduce saving in response to a recession. Our conclusion is that a contraction of credit is a less convincing explanation of the observed rise in savings which is observed across all working-age groups.

Third, simulations of a crash in the price of the risky asset show that such wealth losses can lead to very strong increases in the aggregate saving rate. However, older households are much more affected in terms of consumption falling and in terms of savings rates increasing. Moreover, savings rates rise following the crash, and in contrast to the effect of the recession alone, remain high as households try to restore their wealth holdings. The temporal and age patterns of saving are quite different. The fall in asset prices also has a direct effect making households more leveraged because their debt holdings are unchanged, and this leads households to move out of equity, and to pay back their debt in the periods after the crash. This is particularly so for the young who are highly leveraged.

Thus the pattern of saving increases we observe in recent recessions, with short-lived increases in saving across a wide range of ages, is best explained by a model in which a shock to uncertainty is a key feature of recessions. The introduction of uncertainty in this way explains over half of the increase in the savings rate. This explanation attributes the fall in borrowing more to a reduction in demand for credit rather than a contraction of supply. If on the other hand, the rise in the savings rate had a strong declining age profile, then a fall in the supply of credit would be more plausible. Finally, if asset price falls were an important part of the most recent recession, we should observe savings rates remaining high after the recession ends, as households rebuild wealth, in contrast to preceeding recessions.

Potentially important additions to our model are first allowing for the anticipation of future tax liabilities which may arise due to government tax cuts and transfers in recessions, and second, allowing for the irreversibility of some components of consumption, particularly durables. Finally, we have modelled the credit supply shock as a transitory reduction in the flow of new credit. Other researchers (for example Guerrieri and Lorenzoni, 2011) model the credit supply shock as a permanent reduction in the stock of debt that can be held. It would be interesting to analyse situations that blended these two effects, and to assess empirically their relative importance.

References

[1] Abowd, J. and Card, D. (1989) "On the covariance structure of earnings and hours changes," Econometrica 57:411-445

[2] Alan, S., (2011) "Do Disaster Expectations Explain Household Portfolios?" Forthcoming, Quantitative Economics

[3] Attanasio, Orazio P. and Weber, Guglielmo (1994) "The UK Consumption Boom of the Late 1980s: Aggregate Implications of Microeconomic Evidence" Economic Journal. 427 (November): 1269-1302

[4] Attanasio,O., J. Banks, C. Meghir and G. Weber (1999), "Humps and bumps in Lifetime Consumption" *Journal of Business and Economic Statistics*, 17 (1999), 22-35.

[5] Attanasio, O., Botazzi, R., Low, H., Nesheim, L. and M. Wakefield (2012) "Modelling the demand for housing over the life-cycle" *Review of Economic Dynamics, 15(1):1-18*

[6] Barro, R. (2006), "Rare Disasters and Asset Markets in the Twentieth Century", *Quarterly Journal of Economics*, (2006), 803-866.

[7] Barro R. J. and J. Ursua, "Rare Disasters and Asset Markets" *American Economic Review: Papers and Proceedings*, (2008), 98:2, 58-63.

[8] Blundell, R., Low, H. and Preston, I. (2011) “Decomposing income risk using cross-section data” Institute for Fiscal Studies Working Paper

[9] Bloom, N. (2009) “The impact of uncertainty shocks” *Econometrica*, Vol. 77, No. 3, 623–685

[10] Carroll, C. and Samwick, A. (1997) “The nature of precautionary saving” Journal of Monetary Economcis 40: 41-71

[11] Carroll, C., Jiri Slacalek, Martin Sommer (2012) “Dissecting Saving Dynamics: Measuring Wealth, Precautionary, and Credit Effects” mimeo

[12] Carroll, C. (1992) “The buffer stock theory of saving: some macroeconomic evidence” Brookings Papers on Economic Activity 1992(2): 61-156

[13] Chakrabarti, R., Lee, D., Van der Klaauw, W. and Zafar, B., (2011) “Household Debt and Saving During the 2007 Recession” NBER Working Paper Series, Vol. w16999.

[14] Christelis, D., Georgarakos, D. and Jappelli, T. (2011) “Wealth Shocks, Unemployment Shocks and Consumption in the Wake of the Great Recession,” CSEF Working Papers 279, Centre for Studies in Economics and Finance (CSEF), University of Naples, Italy

[15] Crossley,T. and H. Low (2011) “Job loss, credit constraints and consumption growth” University of Cambridge, mimeo

[16] Crossley, T, Low, H. and O’Dea, C. (2012) “Household consumption through recent recessions” Institute for Fiscal Studies Working Paper

[17] De Nardi, M., French, E. and D. Benson (2011) “Consumption and the Great Recession” NBER Working Paper No. 17688

[18] Economic Report of the President (2010)

[19] Glover, A., Heathcote, J., Krueger, D. and Rios-Rull, V. (2011) “Intergenerational Redistribution in the Great Recession”

[20] Gomes, F. and Michaelides,A. (2005) “Optimal Life-Cycle Asset Allocation:Understanding the Empirical Evidence”, *Journal of Finance*, April 2005, Vol. LX, No.2, pp. 869-904.

[21] Gourinchas, P. O. and J. A. Parker, “Consumption over the Life Cycle” *Econometrica* 70 (2002), no:1, 47-89.

[22] Guerrieri, V. and Lorenzoni, G. (2011) “Credit Crises, Precautionary Savings and the Liquidity Trap,” mimeo

[23] MaCurdy, T.E. (1982) “The use of time series processes to model the error structure of earnings in a longitudinal data analysis,” *Journal of Econometrics, 18:82-114*

[24] Mian, A. and Sufi, A.(2010) “Household Leverage and the Recession of 2007 to 2009” *IMF Economic Review, 58 (1), 74-117*

[25] Mian, A. and Sufi, A.,(2009), “The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis” Quarterly Journal of Economics, November 2009, 124(4), 1449-1496

[26] Mody, Ashoka, Franziska Ohnsorge, and Damiano Sandri (2012). “Precautionary Savings in the Great Recession,” IMF Working Paper 12/42. Forthcoming in the IMF Economic Review.

[27] Moore, K.B and. M.G. Palumbo, (2010), “The Finances of American Households in the Past Three Recessions: Evidence from the Survey of Consumer Finances.” Finance and Economics Discussion Series (2010-06), Federal Reserve Board.

[28] Storesletten K., C. Telmer and A.Yaron, (2004), “Cyclical dynamics in idiosyncratic labor market risk,” *Journal of Political Economy*, 112:695-717.