Risk pooling and precautionary savings in village economies

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[PRELIMINARY DRAFT]

Abstract

We propose a new method to test for efficient risk pooling that allows for inter-temporal smoothing, non-homothetic consumption and heterogeneous preferences. The method is composed of three steps. The first one allows for precautionary savings by the aggregate risk pooling group. The second utilizes the inverse Engel curve to estimate good-specific tests for efficient risk pooling. In the third step, we obtain consistent estimates of households’ risk and time preferences using a full risk sharing model, and incorporate heterogeneous preferences in testing for risk pooling. We apply this method using panel data from Indian villages. We find that precautionary savings by the village is minimal and households’ food consumption is smoother than non-food consumption. Lastly, while there is substantial and significant heterogeneity in estimated risk and time preferences, full risk pooling is rejected for both cases - with and without heterogeneity.
1 Introduction

People in village economies face a large number of income shocks due to drought, flood, unemployment, illness, and crop or business failure. Households that are uninsured against these shocks experience consumption fluctuations detrimental to their welfare (Gertler and Gruber, 2002; De Weerdt and Dercon, 2006). Protection from such income shocks depends on the availability and effectiveness of institution that distribute and share risk. Asset accumulation \textit{ex ante} can help smooth consumption through precautionary saving (e.g., Zeldes 1989, Deaton 1991, ). Risk can also be pooled \textit{ex post} through various informal or formal agreements (e.g., Bold, Dercon on funeral societies; Fafchamps and Lund 2003; Udry 1996 on borrowing). Risk pooling is best at addressing idiosyncratic shocks that affect only some households at a time. But it offers little or no protection against aggregate shocks that affect the whole village. To self-protect against such shocks, some form of precautionary saving is required – either at the aggregate level (e.g., cereal bank; provident fund) or at the individual level (e.g., Fafchamps and Udry 1998).

In this paper we examine detailed panel data from thirty villages in India for evidence of risk pooling and precautionary saving. To the best of our knowledge, this is the first study that combines both aspects in an integrated and theoretically-based framework. In accordance to recent advances in testing for risk pooling, we correct for differences in risk and time preferences among households. We also test for differences in consumption smoothing across consumption categories, either resulting from risk pooling or precautionary savings. Finally, we replicate the analysis assuming aggregation of risk either at the village-level or the sub-caste level.

Many households in developing countries are engaged in inter-household insurance arrangements involving state-contingent transfers, as documented by Scott (1977), (Platteau, 1995, 1997), Udry (1990) and others. However, households are generally not completely insured: income and consumption are typically found to be positively correlated. The rejection of full insurance is documented by Rosenzweig (1988), Townsend (1994), Townsend (1995), Udry (1994) and others. Several explanations have been proposed for the failure of full insurance, including moral hazard, limited commitment, and hidden income Kinnan (2017). An emerging strand of literature suggests that ignoring heterogeneity in preferences may explain rejections of full risk pooling(Schulhofer-Wohl, 2011; Mazzocco and Saini, 2012; Chiappori et al., 2014).

This study examines whether households share risk efficiently within their village, using ICRISAT’s new wave of village data from 2010-2015. We propose a three methodological extensions to the standard test of risk pooling. First, we allow for precautionary savings and the accumulation of assets within that model. Second, we expand the standard model to allow testing for risk pooling for different categories of consumption.
expenditures while simultaneously allowing for non-homothetic consumption preferences. This method is based on the intuition, dating back to Wilson (1968), that efficient risk pooling allocates more risk to more risk-tolerant households, implying that a household whose consumption strongly co-moves with village consumption must be relatively more risk tolerant. Third, we implement an original methodology for estimating risk pooling tests that account for heterogeneity in risk and time preferences. These methodological improvements are applied to a rich panel dataset from a reliable source.

For total expenditures, we find evidence of less than perfect risk pooling at the village level. But the shortfall is quite limited in the sense that household consumption expenditures move nearly one-for-one with the village average. Even when year-to-year variation in household-level liquid wealth and earned income have a statistically significant coefficient, the magnitude of the correlation with household expenditures remains very small. From this we conclude that the study villages engage in a considerable pooling of idiosyncratic within-year risk. We are not saying, however, that risk pooling is the result of the explicit sharing of risk among villagers. Indeed, risk pooling tests do not identify the mechanism by which risk is being pooled.\footnote{Risk pooling can of course be achieved through an explicit or implicit agreement to share risk. However, as already noted in Sargent 1990 (chapter 3), a large amount of risk pooling can be achieved through individual precautionary saving. Sargent demonstrates this with the simple example of an island economy in which individual producers use their stock of currency to buy food when in deficit and sell food when in surplus. As long as they do not run out of currency, producers can achieve near perfect smoothing of consumption by using precautionary saving to pool risk. Only when they stock out of liquid wealth do they experience an individual fall in consumption (e.g., Deaton JAE 1991).} This reality, which is shared by all risk pooling test papers in the literature, is the reason why, throughout the paper, we have refrained from using the expression 'risk sharing' since it implicitly suggests some deliberate sharing intent.

We find that food and non-food expenditures do not vary with average village consumption in a way consistent with a within-year utility-maximizing allocation of total expenditures: households increase their food consumption less – and their non-food consumption more – than what the increase in average village expenditures would predict, based on estimated non-linear Euler curves. We also do not find that non-food expenditures respond more to household income and wealth than non-food expenditures, ruling out the idea that there is less risk pooling in non-food consumption than in food consumption. Instead, the results suggest that, in a good year for the village as a whole, people increase their non-food expenditures more than proportionally, thereby sheltering their average food consumption from aggregate shocks.

Our results confirm that there is substantial and significant heterogeneity in estimated risk and time preferences across households. We also find, as previous authors have argued theoretically, that the failure to correct for this heterogeneity biases coefficient estimates in any risk pooling test. In our data, however, this bias is empirically negligible and it does not affect the qualitative conclusions from the analysis.
Turning to consumption smoothing across years, we find a small but significant response of village consumption to aggregate village cash-in-hand. This finding is consistent with a high level of consumption smoothing achieved through precautionary saving – i.e., close to certainty equivalence – but it is partially negated by the larger coefficient on village earned income, which indicates a failure of asset integration: villages do not appear to optimally draw on liquid assets to smooth aggregate income shocks. Results also indicate that village food consumption, suitably corrected for non-homothetic preferences, responds little to cash-in-hand while village non-food expenditures respond significantly to cash-in-hand and display excess income sensitivity.

Similar findings are obtained when the same analysis is replicated at the sub-caste (Jati) level, instead of the village level. But they also suggest that, contrary to the existing literature (e.g., Townsend 1994 (Mazzocco and Saini, 2012; Shrinivas and Fafchamps, 2018)), risk pooling within sub-castes with each village is less strong – i.e., less responsive to aggregate consumption and more responsive to individual income and liquid assets – than pooling across all households in the village. Conclusions are also similar regarding precautionary saving: aggregate sensitivity to cash-in-hand is very small – probably smaller than it should be given the relatively low level of liquid wealth in the data: in a poor population such as the one we study, we would expect a stronger dependence of consumption to cash-in-hand in a precautionary savings optimum. The sub-caste evidence also suggests that the excess sensitivity to income found in the linear (CARA) model may be due to misspecification; a log model provides a better fit for the theory.

This paper makes several contributions to the literature. First, our empirical analysis of risk pooling in village economies combines both aspects of intra-temporal and inter-temporal aspects of smoothing in a theoretically consistent framework. Moreover, to the best of our knowledge, this is the first study that explicitly account for pooling of asset risk in risk pooling tests. Previous studies have mostly focused on either within period Townsend (1994) or across time . A closely related to this paper is Lim and Townsend, who assess each risk bearing institute independently one at a time. Consistent with the previous literature, we find substantial risk pooling in the villages, although full risk pooling is rejected.

Footnote: Several explanations have been proposed for the failure of full risk pooling. One is moral hazard, that one households actions are not observable to others, so shirking is possible (Rogerson, 1985; Golosov et al., 2003). Another is limited commitment, that households receiving high income draws may leave the insurance arrangement instead of contributing to the insurance pool (Kimball, 1988; Coate and Ravallion, 1993; Ligon et al., 2002; Laczó, 2015). A third possibility is hidden income, that households income realizations are unobservable, so that it is possible to claim lower income (Townsend, 1982). Kinnan (2017) cleanly documents all the three possibilities and supports the predictions of hidden income, but rejects limited commitment and moral hazard using panel data from rural Thailand. In this paper, we focus on testing for the benchmark of efficient risk pooling, and abstract away from mechanisms that may limit full risk pooling. We, however, explore one possible friction of risk sharing - the unit of risk pooling - whether at the village or caste level.
Our results using the new wave of ICRISAT’s panel data from 2010-2015 are broadly consistent with previous estimates that have used the old data from 1975-85. Using the new wave, we find that the marginal propensity to consume out of household’s own income is 0.02, which is substantially lower than the MPC of 0.14 estimated by Townsend using the old VDSA data. Similarly, Rosenzweig andBinswanger (1993) find that in the old sample, a 100 rupee decline in profits reduces food consumption by 7 rupees. In the new sample, for an equivalent decline in earned income, we find that food consumption reduces by 3.4 rupees. Overall, these results suggest that consumption smoothing has substantially improved in these villages over time.

Second, this paper contributes to the new strand of literature on tests of full risk sharing with heterogeneous preferences (Schulhofer-Wohl, 2011; Mazzocco and Saini, 2012; Chiappori et al., 2014). These studies show that omitted variable bias in standard tests under homogeneous preferences drives the income coefficient upwards, leading to spurious rejections of full insurance. These studies propose different parametric and semi-parametric testing methods to account for heterogeneous preferences. In accordance to these recent studies, we correct for the heterogeneity bias in risk pooling tests. Our testing approach is similar to Chiappori et al. (2014) who first impute risk preferences using the full risk sharing model, and then substitute the estimated risk preferences in the omnibus full insurance specification to control for preference heterogeneity. We propose a more straightforward and easily implementable method using a simple linear regression to account for preference heterogeneity.

In addition, our finding also corroborates with recent papers that find substantial heterogeneity in MPC across households (Lewis et. al. 2021)

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3These studies use different approaches. Schulhofer-Wohl (2011) and Chiappori et al. (2014) conduct a parametric test by estimating the benchmark risk sharing specification derived from the first order condition that household consumption depends only on aggregate shocks and not on idiosyncratic shocks. In deriving the econometric methods to test for full risk sharing, Schulhofer-Wohl (2011) treats risk preferences as nuisance parameters that must be eliminated from the full risk sharing equation, and uses quasi-fixed effects that controls for household specific trends and household specific effects of aggregate shocks, thereby removing any heterogeneity in preferences. Chiappori et al. (2014) measure each households preferences upto a scale by examining how much its consumption co-moves with aggregate consumption. The authors impute risk preferences for each household, based on the risk sharing model, by considering their pair-wise correlation of consumption. The estimated risk preferences for each household are then substituted in the omnibus full insurance specification to control for preference heterogeneity. Mazzocco and Saini (2012), on the other hand, use a non-parametric test that allows for a general class of utility functions. Efficient risk sharing is tested for household pairs. Instead of relying on the first order conditions, the authors use a household risk sharing function which is basically household expenditure as a function of aggregate resources (sum of expenditures for the household pair). The efficiency test for a household pair comprises of whether a households expenditure is monotonically increasing with the sum of expenditures for the pair. The test is repeated for all the possible household pairs in a group and the hypothesis of full risk sharing for the group is rejected if one of the pairs in the group fails to share risk efficiently. The use of risk sharing functions incorporates heterogeneity in risk preferences and non-separability between consumption and leisure. Actually, Townsend (1994) in part tests for full insurance that allows for heterogeneous preferences. Townsend runs separate time-series regressions for each household and tests whether the coefficient on the idiosyncratic income is
Lastly, we contribute to the recent literature on accounting for non-horizontal Engel curves (Atkin et. al. 2021; Ligon, 2019; Almas et.al 2019). We test for differences in consumption smoothing across consumption categories, and show that accounting for non-linear engel curves for different goods are important for risk pooling tests. More discussion.

Finally, we also replicate the analysis assuming aggregation of risk either at the village-level or the sub-caste level.

2 Risk pooling with Assets: A conceptual framework

Since we are interested in testing risk pooling within villages, we follow Townsend (1994), and many others and assume a closed village economy over time. In each period $t$ each individual $i$ in the village receives an earned income $y_{its}$ that varies with the state of nature $s$. We assume that the joint income distribution of all individuals in the village is stationary over time with known mean, variance, and covariance vectors. This allows correlation in outcomes across individuals within period but, for simplicity, we abstract from autocorrelation of incomes across time.\(^4\) The probability of state of the world $s$ is denoted $\pi_s$. Each individual starts the period with liquid wealth $(1 + r_s)w_{it}$ where $r_s$ is the return to assets, which is allowed to vary with the state of the world $s$. Each individual’s cash-in-hand at the beginning of the period is thus $x_{its} = y_{its} + (1 + r_s)w_{it}$.

We restrict our attention to cases where the total liquid wealth of the village must be non-negative. But the individual net liquid wealth of individuals can be negative.

The utility that an individual derives from consumption expenditures $c_{its}$ is given by a standard instantaneous utility function $U_i(c_{its})$ specific to individual $i$. This allows for heterogeneous risk preferences. Each individual discounts the future with constant discount factor $\rho_i$, which similarly allows for heterogeneous time preferences.

We identify the Pareto efficient allocation of consumption across individuals within equal to zero and if the aggregate consumption (or the village leave-out mean) is equal to one for each household. Kurosaki (2001) follows a similar procedure, using the same ICRISAT data, and estimates household by household regression with the inclusion of a time trend to account for heterogeneity in time preferences. But the power of these tests is very weak, given the short time dimension of panel data on consumption, only 10 periods for each household in a village. Furthermore, Dubois (2001) tests for full insurance allowing risk aversion to vary with observed household characteristics, but rules out unobserved heterogeneity.

\(^4\)Differences in the mean of income across individuals get subsumed in the welfare weights.
and across periods by solving a social planner problem of the form:

$$\text{Max} \left\{ \sum_{t=1}^{T} \sum_{i=1}^{N} \eta_i \rho_t^i \sum_{s=1}^{S} U_i(c_{its}) \pi_s \right\}$$

s.t. $$\sum_{i=1}^{N} c_{its} = \sum_{i=1}^{N} \left( (1 + r_s) w_{it} + y_{its} - w_{it+1,s} \right) \quad \forall t, s$$

where $$\eta_i$$ is a particular set of (time-invariant) welfare weights with $$\sum_{i=1}^{N} \eta_i = 1$$. The middle equation (1) denotes the aggregate feasibility constraint that must hold in each time period $$t$$ and state of the world $$s$$. To each particular set of welfare weights $$\{\eta_i\}$$ corresponds a different Pareto efficient solution.

We now characterize the solution to the social planner’s problem. We begin by noting that any income vector that has the same aggregate income $$y_{ts} = \sum_{i=1}^{N} y_{its}$$ produces the same optimal solution. The same can be said for $$w_{ist}$$: any distribution of assets across individuals that generates the same total wealth $$w_{ts} = \sum_{i=1}^{N} w_{its}$$ generates the same optimal solution. It follows that the allocation of consumption across individuals does not depend on individual incomes and wealth: only village aggregates $$y_{ts}$$ and $$w_{ts}$$ matter. Put differently, the social planner’s problem satisfies income and asset pooling: within each period, individual welfare does not depend on individual income or assets realizations; rather, it depends on welfare weights and individual preferences. Second, we note that since the return to wealth is linear and identical across individuals, the way assets are distributed across individuals is irrelevant and thus undetermined. This means that the solution to the social planner’s problem does not stipulate the distribution of liquid assets across individuals – only its aggregate.

Next we note that the social planner’s problem can be decoupled into an inner optimization problem – how to allocate consumption across individuals, conditional on a choice of future savings $$w_{t+1,s}$$ for each $$s$$ – and an outer optimization problem – how to allocate total consumption across periods by choosing the contingent path of $$\{w_{t+1,s}\}$$.

The inner optimization problem takes the familiar risk sharing form:

$$\text{Max} \left\{ \sum_{i=1}^{N} \eta_i \beta_t^i \sum_{s=1}^{S} U_i(c_{its}) \pi_s \right\}$$

s.t. $$\sum_{i=1}^{N} c_{its} = (1 + r_s) w_t + y_{ts} - w_{t+1,s} \equiv c_{ts} \quad \forall s$$

(2)
where \( w_{t+1,s} \) is taken as given. Since \((1+r_s)w_t + y_{ts}\) is predetermined by past savings and the state of the world \( s \), and \( w_{t+1,s} \) is taken as given for the purpose of this optimization, the above optimization boils down to an allocation problem: how a given \( c_{ts} \) is divided among individuals. To characterize the properties of the solution, let us denote \( \lambda_{ts} \pi_s \) as the Lagrange multiplier associated with the feasibility constraint. The first order conditions for the consumption levels \( c_{its} \) and \( c_{jts} \) of two arbitrary individuals in the same village are:

\[
\eta_i \rho^t_i U'_i(c_{its}) = \lambda_{ts} \eta_j \rho^t_j U'_j(c_{jts})
\]

which implies the usual condition for optimal risk pooling: since all individuals face the same realization of the aggregate resource constraint \( \lambda_{ts} \), weighted marginal utilities of consumption are equated across individuals in each state of the world \( s \). Since \( \lambda_{ts} \) is a deterministic function of \( c_{ts} \), this leads to the standard testable prediction: individual consumption \( c_{its} \) varies with aggregate village consumption \( c_{ts} \), not with individual income \( y_{ist} \) or wealth \( w_{ist} \). This theoretical result forms the basis for all tests of efficient risk pooling.

We now turn to the outer optimization problem that selects the contingent aggregate level of savings \( w_{t+1,s} \). Let \( W_t(c_{ts}) \) denote the value, to the social planner, of the optimal solution to the inner optimization problem for a total consumption level \( c_{ts} \). Function \( W_t(\cdot) \) is indexed with \( t \) because, as we just discussed, when time preferences vary across individuals, the way the social planner divides the same amount of aggregate consumption \( c_{ts} \) across individuals varies over time. For clarity of exposition, let us define \( R(t) \equiv \sum_{i=1}^{N} \eta_i \rho^t_i \). Since \( \sum_{i=1}^{N} \eta_i = 1 \) by construction, \( R(t) \) is nothing but an average of individual discount factors weighted by the welfare weights.\(^5\) Further, let us normalize individual discount factors as \( \hat{\rho}^t_i = \frac{\rho^t_i}{R(t)} \) such that \( \sum_{i=1}^{N} \eta_i \hat{\rho}^t_i = 1 \). With this normalization, the outer optimization can be written in the form of the following Belman equation:

\[
V_t(x_{ts}) = \max_{w_{t+1,s}} W_t(x_{ts} - w_{t+1,s}) + R(t)EV_{t+1}((1+r_{s'})w_{t+1,s'} + y_{ts'})
\]

where \( s' \) denotes the (yet unrealized) state of nature in period \( t+1 \) and where we made use of the fact that \( c_{ts} = x_{ts} - w_{t+1,s} \). This is a standard optimization problem (Stokey and Lucas 1981). It yields as solution a policy function of the form \( w_{t+1,s} = S_t(x_{ts}) \). The case with homogenous time preferences has been extensively studied in the precautionary savings literature (e.g., Zeldes 1989, Deaton 1991). It is well know that \( c_{ts} = C_t(x_{ts}) \) is a concave function of \( x_{ts} \).

\(^5\)Note that, as \( t \to \infty \), \( R(t) \) converges to the largest discount factor in the village.
2.1 Accounting for heterogeneous preferences

The generalization to heterogeneous time preferences does not change this main prediction. But the shape of $C_t(x_{ts})$ changes over time. This is because the relative weights associated with ratios of marginal utility vary over time: if $i$ is more patient than $j$, then $\rho_i^t/\rho_j^t$ increases with $t$. This means that $i$’s expected share of aggregate consumption increases over time. This implies that early on, the social planner’s discount factor $R(t)$ puts more weight on impatient individuals. As time passes, however, their weight in the average $\sum_{i=1}^{N} \eta_i \rho_i^t$ falls and $R(t)$ gets dominated by the most patient individuals whose weight $\rho_i^t$ falls less fast. This means that as time passes, the marginal propensity to consume $\frac{\partial C(x_{ts})}{\partial x_{ts}}$ out of village assets falls. With infinitely lived agents, in the long run all village cash-in-hand $x_{ts}$ is consumed by the most patient individual(s) since the welfare weight $\eta_i \rho_i^t$ of all the others converge more rapidly to 0. These are stark, unrealistic predictions that we do not expect to observe in practice, but they serve to outline the gradual unequalizing role that heterogeneous time preferences play in a risk pooling social optimum with assets.

Next we turn to the behavior of the model when individuals differ in their risk preferences. To this effect, we parameterize the utility function to have the constant-absolute-risk-aversion (CARA) form $U_i(c) = -\frac{e^{-\gamma_i c}}{\gamma_i}$ where parameter $\gamma_i$ is the coefficient of absolute risk aversion of individual $i$.\footnote{Assuming constant relative risk aversion (CRRA) instead yields a similar result, except that estimating equations are expressed in logs rather than levels. See, for instance, Mace (1991). The derivation is omitted here to save space.} With this functional form, the first order condition (3) simplifies to:

$$\eta_i \rho_i^t e^{-\gamma_i c_{its}} = \lambda_{ts}$$

Taking logs and rearranging yields, we get:

$$c_{its} = \frac{\log \eta_i}{\gamma_i} + \frac{\log \rho_i}{\gamma_i} t - \frac{1}{\gamma_i} \log \lambda_{ts}$$

(4)

Averaging over all $N$ individuals in the village and solving for $\log \lambda_{ts}$ yields an expression for average village consumption $\bar{c}_{ts} \equiv \frac{1}{N} \sum_{i=1}^{N} c_{its}$, which we use to replace the common Lagrange multiplier in equation (4). We obtain:

$$c_{its} = \frac{1}{\gamma_i} \left[ \log \eta_i - \frac{1}{N} \sum_{j=1}^{N} \frac{\log \rho_j}{\gamma_j} \right] + \frac{1}{\gamma_i} \left[ \log \rho_i - \frac{1}{N} \sum_{j=1}^{N} \frac{\log \rho_j}{\gamma_j} \right] t + \frac{1}{N} \sum_{j=1}^{N} \frac{1}{\gamma_j} \bar{c}_{ts}$$

(5)

which shows that the consumption of individual $i$ is a linear function of the average individual consumption $\bar{c}_{ts}$ and each parameter has been suitably normalized relative to its village average. Equation (5) shows that individual $i$’s consumption increases linearly in $1/\gamma_i$, which captures $i$’s willingness to bear risk. More risk averse individuals
consume, other thing being equal, a smaller fraction of village consumption but, thanks to the intercept, their consumption is, as we would expect, more stable. This means that individuals who are less risk averse than the rest of the village consume less in bad years, but make up for it in good years. We also confirm that $c_{its}$ increases in $i$’s relative welfare weight and relative discount factor, with the latter effect increasing over time as noted earlier.

2.2 Accounting for consumption categories

Finally, we examine the predictions that the model makes regarding specific components of consumption, e.g., food. If individuals have homothetic preferences, income elasticities are unity for all goods and consumption shares are constant. This implies that consumption of good $k$ is simply:

$$c_{itsk} = \alpha_k c_{its}$$

In this case, model (5) applies equally to all consumption goods, except that all coefficients are premultiplied by $\alpha_k$. This means that risk pooling can be tested with any component of consumption.

This is no longer the case when consumption preferences are not homothetic, i.e., when $c_{itsk} = \alpha_k(c_{its})$ where $\alpha_k(.)$ now denotes an Engel curve. If the shape of this Engle curve can be estimated separately, e.g., from an analysis of the relationship between consumption shares and total consumption expenditures in a cross-section, model (5) can still be fitted to specific consumption categories provided the dependent variable is suitable transformed as:

$$\hat{c}_{itsk} = \hat{\alpha}^{-1}_k(c_{itsk})$$

In an efficient risk pooling economy, applying model (5) to each $\hat{c}_{itsk}$ should yield the same coefficient estimates. This would indicate that all consumption categories move with total expenditures in a way consistent with preferences across goods. It is also conceivable that risk pooling focuses on specific categories of food, such as basic necessities like food and shelter, but ignore luxuries. In this case, the consumption share of luxuries would fall faster with a fall of total expenditures than predicted by the Engel curve. This can be investigated by comparing coefficient estimates of model (5) applied to consumption categories $\hat{c}_{itsk}$ with low and high income elasticities.

We now summarize the main predictions of our model for efficient risk pooling:

1. Individual consumption $c_{its}$ is independent of individual liquid assets $x_{its}$ and individual income $y_{its}$.

\footnote{For this transformation to yield a usable $\hat{c}_{itsk}$ in our test, function $\hat{\alpha}_k(.)$ must be monotonic over the relevant range.}
2. Individual consumption \(c_{ts}\) is a function of village aggregate consumption expenditures \(c_{ts}\).

3. Average village consumption \(\overline{c}_{ts}\) is a concave function of aggregate village cash-in-hand \(x_{ts}\) – i.e., the village smoothes consumption over time using all village liquid assets as pooled precautionary savings.

4. The share of village consumption that individuals receive falls over time if they are more impatient than the (suitably weighted) village average.

5. Individuals who are more risk averse than the (suitably weighted) village average receive, other things being equal, a smaller share of average village consumption. As a result their consumption is smoother than that of less risk averse individuals in the village.

6. The consumption of goods with a low income elasticity is smoothed more than the consumption of goods with a high income elasticity. Once transformed by the inverse of the Euler curve, expenditure shares on specific goods all respond identically to aggregate village expenditures \(c_{ts}\).

3 Testing strategy

Before we present our testing strategy in detail, we must first recognize that, while the model presented in Section 1 applies at the individual level, in our data, as in most, consumption, assets and income are all measured at the household level. As a result, we cannot estimate the extent to which risk is pooled within households (e.g., Dercon and Krishan 2000, Lewbel et al. 2013, Dizon-Ross et al. 2020). We can only test whether it is pooled across households.

To do so in a way consistent with theory, we need to normalize the data in such a way that, if risk were perfectly pooled within and across households, our methodology would conclude that it is. In order to obtain a correct village average \(\overline{c}_{ts}\), we must weigh each household’s per-capita consumption by the number of its members. The same reasoning applies to income and assets, as well as to the risk sharing tests themselves. For this reason, all regressions presented in the paper are weighted by household size, so as to ensure that our tests aggregate individuals in a way that is consistent with theory. In

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8 This is best illustrated with a simple example. Imagine two households 1 and 2, respectively with 1 and 2 members. Total consumption in household 1 is 100, which is also the consumption per head. In household 2, total consumption is also 100, which means that consumption per head is 50. If we take the simple average of consumption per head across the two households we obtain average village consumption of \(75 = \frac{1}{2}100 + \frac{1}{2}50\). If, however, we average across individuals, the average village consumption is \(66.67 = \frac{1}{3}100 + \frac{2}{3}50\).

9 To the best of our knowledge, however, this easy correction is not implemented by Mace (1991), Cochrane (1991), Townsend (1994), and those that followed in their footsteps (e.g., XXXXX).
practice, we measure the size of each household by its number of adult-equivalents to reflect the fact that minimal consumption needs vary by age and gender.

3.1 Homogeneous risk and time preferences

We start by testing the predictions of the model under the assumption of homogeneous risk and time preferences. Since there is only one realized state of the world per time period, equation (5) simplifies to a perfect risk pooling relationship of the form:

\[ c_{it} = \beta_i + \beta_1 t + \beta_2 \bar{c}_t \]  

with \( \beta_1 = 0 \) when all \( \rho_i \) are identical. It is important to note that assets are absent from this equation. This is because, thanks to predictions 2 and 3 above, \( \bar{c}_t \) is a sufficient statistic about the social planner’s choice of future savings for the village. It follows that standard tests of risk pooling that use village average also work when the village saves.

As in the rest of the literature (e.g., Mace 1991, Cochrane 1991, Ravallion and XXX 1997), we first-difference equation (7) to eliminate the individual specific welfare weight term \( \beta_i \). We also add two regressors, income \( y_{its} \) and assets \( w_{its} \). This is one regressor more than the standard risk pooling test, which ignores assets and precautionary savings either at the individual or village level. The estimated CARA model has the form:

\[ \Delta c_{it} = \beta_1 + \beta_2 \Delta \bar{c}_t + \beta_3 \Delta y_{it} + \beta_4 \Delta w_{it} + \epsilon_{it} \]  

Given the relatively small number of households within each village, the mechanical correlation between \( c_{it} \) and \( \bar{c}_t \) generates a bias in \( \beta_i \) when the null of perfect risk pooling is false (see Appendix A for illustration).\(^{10}\) To correct for this bias, we estimate (10) by replacing the village mean \( \bar{c}_t \) by the leave-out-mean \( \bar{c}_{-i,t} \equiv \frac{1}{N-1} \sum_{j \neq i} c_{jt} \).\(^{11}\) We also estimate a similar CRRA model where all variables are expressed in logs – see the Appendix for a formal derivation.

Our main null hypothesis is that risk pooling is efficient, which implies that \( \beta_2 = 1 \) and \( \beta_1 = \beta_3 = \beta_4 = 0 \). Equation (8) also enables us to consider the following alternative hypotheses:

1. Hand-to-mouth: Each individual consumes his or her income \( y_{its} \), which implies \( \beta_3 = 1 \) and \( \beta_1 = \beta_2 = \beta_4 = 0 \)

2. Individual precautionary saving: Each individual consumes a concave fraction of his or her cash-in-hand \( x_{its} \equiv y_{its} + w_{its} \), which implies that \( \beta_3 = \beta_4 > 0 \) and \( \beta_2 = 0 \)

\(^{10}\)For instance, when the true \( \beta_i = 0 \) in equation (10), the OLS estimate has a bias equal to \( 1/N \).

\(^{11}\)It is easy to show that, under the null of perfect risk pooling, estimating (10) with the leave-out-mean still yields the correct estimate of \( \beta_i \) but multiplies \( \alpha_i \) by \( \frac{N}{N-1} \). See Appendix A for details.
3. Individual precautionary saving with excess sensitivity to income: \( \beta_3 > \beta_4 > 0 \) and \( \beta_2 = 0 \)

4. Partial pooling of income but full pooling of assets: \( 1 > \beta_2 > 0 \) and \( 1 > \beta_3 > 0 \) and \( \beta_4 = 0 \)

5. Partial pooling of income and assets: \( 1 > \beta_2 > 0 \) and \( \beta_3 > 0 \) and \( \beta_4 > 0 \)

This regression is complemented by a village level analysis to test whether the village collectively uses assets to smooth consumption. The estimated regression is the standard test of the precautionary saving developed by Zeldes (1989b). It takes the following form:

\[
\Delta c_t = \beta_1 + \beta_3 \Delta y_t + \beta_4 \Delta w_t + \epsilon_t
\] (9)

Efficient precautionary saving requires asset integration, which implies that liquid assets and income have the same effect on consumption: \( \beta_3 = \beta_4 \). If the village does not use assets to smooth consumption across periods, then \( \beta_1 = \beta_4 = 0 \) and \( \beta_3 = 1 \). It is also conceivable that the village achieves a modicum of intertemporal consumption smoothing from other sources that are not identified in the data (e.g., external transfers from migrants, government, or NGOs), in which case \( \beta_1 > 0 \) and \( 1 > \beta_3 \geq 0 \). We also estimate (9) in log form. In addition, we present a non-parametric regression of \( \Delta c_t \) on village cash-in-hand \( \Delta x_t \). We expect to find a concave relationship between consumption and cash-in-hand, as predicted by the precautionary savings model (e.g., Zeldes 1989a, Deaton 1991).

### 3.2 Consumption categories and Engel curves

Next we estimate inverse Engel curves (6) for various consumption goods. This is achieved by non-parametrically regressing total expenditures \( c_{its} \) on expenditures \( c_{itsk} \) on good \( k \).

We do this using cross-section data, which means that the income elasticities embedded in these inverse Engel curves are estimated using variation in expenditure shares across households with different total levels of expenditures. We then use the fitted model \( \hat{\alpha}_k^{-1}(c_{itsk}) \) to obtain a prediction of total expenditures \( \hat{c}_{its}^k \) for each household in each period. If households are unconstrained in the consumption choices they make after risk sharing, they should, on average, be on their Engel curve for each good. In contrast, if assistance from the village favors certain goods – e.g., food\(^{12}\) – then households should spend a higher proportion of their total expenditures on food when they receive assistance. This observation forms the basis of our test.\(^{13}\)

\(^{12}\)As the US Food Stamps welfare program used to do.

\(^{13}\)To illustrate with an example, imagine that a household optimally spends 700 Rps on food and 300 on non-food when its total expenditures is 1000 Rps, and 800 on food and 400 on non-food when its total expenditures is 1200. Then if this household is unconstrained and we observe it to spend 800 Rps...
To implement this idea in the simplest way, model (8) is estimated separately for each \( \Delta \hat{c}_{kt} \) dependent variable. We then test whether estimated coefficients \( \beta_2, \beta_3, \) and \( \beta_4 \) are identical across consumption goods. This constitutes an alternative test of the perfect risk pooling model. The alternative is that certain expenditures are better insured than others. This is a common occurrence in all societies: social safety nets typically seek to guarantee individuals a minimum consumption level, with a focus on necessities such as food, shelter, and basic clothing – but typically excludes luxuries. To verify whether this pattern is also present in our data, we test whether \( \beta_2 \) is larger – and \( \beta_3 \) and \( \beta_4 \) smaller – for goods with a low income elasticity and, vice-versa for goods with a high income elasticity.

### 3.3 Heterogenous risk and time preferences

We now introduce heterogeneity in risk and time preferences. It is indeed well known that tests of risk pooling are biased in the presence of heterogeneous risk preferences. Ignoring heterogeneous risk preferences leads to an upwards bias in \( \hat{\beta}_2 \), the coefficient of \( \bar{c}_t \) in equation (8). This is because \( \epsilon_{it}^{\text{homog}} = \left( \frac{1}{\gamma_i} - \frac{1}{\gamma} \right) \bar{c}_t + u_{it} \), which introduces a positive correlation between \( \bar{c}_t \) and the error term.

To address this issue, we proceed in two steps. In the first step, we obtain consistent estimates of the time and risk preference parameters \( \rho_i \) and \( \gamma_i \) for each individual in the data. This is achieved by using monthly observations on income and consumption under the null hypothesis of full risk pooling, an approach similar to Townsend (1994) and Kurosaki (2001). We then introduce these estimated parameters into equation (5) and redo the various tests 1-5 outlined above for the homogenous case.

In the first step, we estimate model (5) separately for each of the 1200 households in our data. Estimation is done under the null of perfect risk pooling. To achieve this, we first follow Chiappori et al. (2014) and normalize risk preferences up to a village-specific scale by setting \( \frac{1}{N} \sum_{i=1}^{N} \frac{1}{\gamma_i} = 1 \). With this normalization, equation (5) reduces to:

\[
c_{it} = \frac{1}{\gamma_i} \left[ \log \eta_i - \frac{1}{N} \sum_{i=1}^{N} \frac{1}{\gamma_i} \log \eta_i \right] + \frac{1}{\gamma_i} \left[ \log \rho_i - \frac{1}{N} \sum_{i=1}^{N} \frac{1}{\gamma_i} \log \rho_i \right] + \frac{1}{\gamma_i} c_{it}^{\text{non-food}} + \frac{1}{\gamma_i} \bar{c}_{it}^{\text{non-food}}
\]

on food, its total expenditures should be 1200. If, at the same time, we observe it consuming 300 on non-food, we would predict that its total expenditures is 1000. Hence a systematic discrepancy between the two predicted values of total expenditures \( c_{it}^{\text{food}} \) and \( c_{it}^{\text{non-food}} \) indicates that consumption choices are constrained.

The intuition behind Chiappori et al. (2014)’s approach comes from Wilson (1968), who showed that doubling every household’s coefficient of risk aversion does not change the set of Pareto-efficient allocations.
In order to recover all individual $\gamma_i$ and $\rho_i$, we estimate a model of the form:

$$c_{it} = \alpha_i + \theta_i t + \beta_i c_{i,t-1} + \epsilon_{it}$$

(10)

using monthly consumption data on household $i$. We then recover structural parameters using the following equalities:

$$\beta_i = \frac{1}{\gamma_i}$$

(10A)

$$\alpha_i = \frac{1}{\gamma_i} \left[ \log \eta_i - \frac{1}{N} \sum_{i=1}^{N} \log \eta_i \right]$$

(10B)

$$\theta_i = \frac{1}{\gamma_i} \left[ \log \rho_i - \frac{1}{N} \sum_{i=1}^{N} \log \rho_i \right]$$

(10C)

Coefficient $\beta_i$ represents the risk tolerance (i.e., inverse of risk aversion) of individual $i$ relative to the village mean. Since $\frac{1}{N} \sum_{i=1}^{N} \beta_i = 1$ by construction, $\beta_i > 1$ implies that $i$ is more risk tolerant than others in the village, and as a result has a consumption level that varies more than others with the village average. Welfare weights $\eta_i$ and time preference parameters $\rho_i$ can be recovered using the following formulas (see Appendix B for derivation):

$$\log \eta_i = \frac{\alpha_i}{\beta_i} + \frac{\bar{\alpha}}{1-\beta}$$

(10A)

$$\log \rho_i = \frac{\theta_i}{\beta_i} + \frac{\bar{\theta}}{1-\beta}$$

(10B)

where, $\bar{\alpha}$, $\bar{\beta}$ and $\bar{\theta}$ represent the village averages of $\alpha_i$, $\beta_i$ and $\theta_i$.

Equation (10) is estimated by OLS. From this exercise, we obtain household-specific estimates of $\hat{\beta}_i$, $\log \hat{\eta}_i$, and $\log \hat{\rho}_i$, up to a village-specific scale due to the $\frac{1}{N} \sum_{i=1}^{N} \beta_i = 1$ normalization.

The second step of our test of risk pooling proceeds as follows. The model to be estimated is an extension of (10) that includes additional regressors $y_{it}$ and $w_{it}$, both of which have zero coefficients under the null of risk pooling:

$$c_{it} = \alpha_i + \theta_i t + \beta_i \bar{e}_{i,t-1} + \epsilon_{it}$$

As discussed above, the main concern is the bias caused by heterogeneity in risk preferences. To eliminate this bias, we use the $\hat{\beta}_i$ and $\hat{\theta}_i$ estimates obtained in the first step to
create a bias-free estimable model of the form:

\[
\Delta \left( c_{it} - \hat{\beta}_i c_t \right) - \hat{\theta}_i = \xi \Delta y_{it} + \zeta \Delta w_{it} + \Delta \epsilon_{it}
\]  

(11)

Under perfect risk pooling, we should observe \( \xi = \zeta = 0 \).

4 Data

We use the new wave of ICRISAT’s VDSA Village Dynamics of South Asia (VDSA) panel data of about 1400 households observed over 60 consecutive months from June 2010 to July 2015. Households were randomly selected from 30 villages in eight Indian states, chosen to represent the agro-climatic conditions in India’s semi-arid and humid tropical regions. Households in each village were randomly selected to represent households in four landholding classes: large, medium, small, and landless. The data collection timeline follows the agricultural cycle in India, beginning from June to July. Attrition in the VDSA data is minimal - only about 10% of households have an unbalanced panel of less than 60 months of data. For our analysis, we use a balanced panel of 1,296 households that reported 60 months of consecutive monthly data.

To construct the main consumption outcomes, we use data on food expenditures, non-food expenditures and total expenditures collected every month for each household. Food consumption includes all food items sourced from home production and purchases. Non-food consumption includes expenses on services and utilities such as travel, education, medical, and energy.

Our measure of earned income includes all net earnings from crops, livestock and off-farm labor. Crop and livestock income is calculated as the revenue from sales of crop and livestock products, minus production costs that include the value of material inputs and the imputed cost of own labor. Off-farm labor income is the sum of earned wages for all household members and the net income earned from household businesses. The majority of individuals in the sample are at least partially employed in the casual labor market. A few individuals are employed in business or a salaried job in the formal sector.

In the analysis we use two measure of household assets: liquid wealth and cash-in-hand. Liquid wealth is defined as the sum of the household’s net credit position (savings,

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15ICRISAT’s new wave of VDSA panel data is a continuation of Village level studies (VLS) panel of household data collected between 1975 to 1985 in six villages in the semi-arid tropics of India. In the VDSA data, in addition to the 6 old VLS villages, 12 more villages in the semi-arid tropics and 10 more villages from East India were included, summing to a total of 30 villages across 8 states in India. The VDSA data collection started in 2009, however, the data for panel year 2009 has many gaps, especially in the consumption module. To maintain consistency, this paper uses data beginning from panel year 2010 until 2014.

16The eight states are Andhra Pradesh, Bihar, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, and Orissa). Four villages were selected from each state, except in Madhya Pradesh where only two were selected. See map A1 in Appendix for the precise location of the 30 villages.
minus borrowing plus lending) and the value of liquid assets such as livestock, consumer 
durables, and inventories of crops, inputs, and fuel. Cash-in-hand is constructed as the 
sum of liquid wealth and earned income.

Although the VDSA has rich monthly data on consumption and income, household 
assets are only measured annually at the beginning of each panel year, which coincides 
with the onset of the main agricultural season in June. Consequently, all regressions 
that require asset information are estimated by aggregating monthly data on household 
consumption and income to the beginning of the agricultural cycle. All values are deflated 
and expressed in 2010 Indian rupees. Income, consumption, and assets are expressed per 
capita by dividing them by their adult-equivalent weight. PROVIDE THESE WEIGHTS 
IN A FOOTNOTE. We also trim the top and bottom 1% of the data to remove outliers 
and large measurement errors. CLARIFY HOW MANY OBSERVATION WE LOSE BY 
TRIMMING. IS THE NUMBER OF 1296 HOUSEHOLDS AFTER TRIMMING?

Table 1 presents descriptive statistics for the main variables used in the analysis. 
Annual consumption expenditures per adult equivalent are on average Rs. 14,961 in 2010 
rupees. This is equivalent to 2.89 US$ per day and per adult-equivalent, based on a 
purchasing parity rate of 14.59 Rs. per US$ in 2010. PROVIDE SOURCE OF PPP 
RATE AND ALSO FOR INFLATION RATE IN INDIA.

5 Stylized Facts

Stylized Fact 1: Engel curves are non-linear

Figure 1 plots engel curves using a flexible polynomial fit where household budget shares 
are plotted against log total household expenditure per capita. The engle curve for food is 
non-linear and downward sloping, representing decreasing expenditures on food along the 
expenditure distribution from the poorest to richest households. For instance, the poorest 
quintile spend about 70% of their total budget on food, whereas the richest quintile spend 
about 40%. These estimations show strong evidence against linearity in engel curves.

Further, figures 2 and 3 plot engel curves for each consumption item corresponding to 
food and non-food categories, respectively. The budget shares for each consumption item 
are expressed as proportion of expenditures on the consumption category, corresponding 
to either food or non-food. Among food items, as depicted in figure 2, cereals and milk 
(and milk products) consumption show some degree of non-linearities. For instance, 
the budget shares for cereal consumption ranges from 40% to 20% from the poorest to 
richest quintiles of the expenditure distribution. Among the non-food items, expenditures 
on education, tobacco and alcohol, travel and energy show non-linearities in engel curves. 
These results indicate non-linearities in engel curves for individual consumption good 
even within food and non-categories.
Stylized Fact 2: Preferences are heterogeneous

As described in Section 3.3, we can recover structural parameters of $\beta_i$ and $\log \rho_i$ by estimating regression of 10 for each household. The risk tolerance measure $\beta_i$ is normalized to a village-specific scale (mean risk tolerance of each village is equalized to one). We estimate two versions of the parameters, based on the underlying CARA and CRRA models, and plot the distributions of the household-specific estimates. Further, we also account for the sampling error in the estimates and shrink the distribution of the parameters, based on the degree of sampling errors.

Figure 4 shows the distribution of household-specific estimates of risk tolerance and risk aversion co-efficients, for both the CARA and CRRA models. Under a CARA model, households have risk tolerance lower than the village average, and therefore a high degree of absolute risk aversion. However, under CRRA, a large proportion of households have a relatively higher degree of risk tolerance than the village average, with a relative aversion ranging between 0 and 1. Only a very small fraction of households have a negative relative risk aversion coefficient.

Next, figure 5 shows the distribution of estimated structural parameter $\log \rho_i$ in equation 10, that represents a combination of pure time preferences and life-cycle motives. Under CRRA model, one can recover the discount factor $\rho$ based on the estimated parameter $\log \rho_i$. Figure 6 shows the distribution of the imputed discount factors from the CRRA model. The figure suggest that households in our data have a high degree of impatience ranging between 0.94 to 1.03.

Overall, the figures show significant heterogeneity in risk and time preferences.

6 Results

6.1 CARA household model

Table 2 presents the test results for full risk pooling within a village under a CARA model. In particular, we estimate a CARA model in first difference in levels using a pooled panel of all the sample households. Standard errors for all estimations are clustered at the village-level. Panel A in Table 2 reports the test results under homogeneous preferences. As shown in Column (1) Panel A, for total expenditures, full risk pooling of income and assets is rejected. However the small magnitude of the co-efficients on income and wealth suggest substantial smoothing of consumption risk. A Rs.100 change in annual income is associated with Rs. 3.38 change in total annual consumption, all measured in real 2010 rupees per-adult equivalent. Similarly, a Rs.100 change in annual liquid wealth is associated with Rs. 1.1 change in annual consumption. The co-efficient on village expenditure (0.931) indicates a high degree of mutual risk pooling within the village.
Overall, while full risk pooling is rejected, the results seem suggestive of partial pooling of income and assets.

Next, we examine the implications of risk pooling for different consumption goods, under homothetic and non-homothetic preferences. As described in Section 3.2, under non-homothetic preferences or non-linear Engel curves, the dependent variable is transformed by taking the inverse of the Engel curve, and therefore represents the predicted expenditure value. For instance, the transformed food expenditure value represents the total expenditure value predicted by the food Engel curve based on level of food expenditure. On the other hand, under the assumption of homothetic preferences or linear Engel curves, the dependent variable is transformed by simply dividing the consumption good with the corresponding sample average budget share.

We examine the implication of risk pooling for homothetic and non-homothetic preferences by estimating the test of full risk pooling separately for food and non-food. These results are reported in Columns (2) to (5) in Table 2. Under homothetic preferences, as shown in Columns (2) and (3), while full risk pooling is rejected for food and non-food, the coefficients on income and wealth are relatively smaller for food. The test implications of full risk pooling remain similar when one accounts for non-homothetic preferences. As shown in Columns (4) and (5), full risk pooling is rejected for both food and non-food. However, the magnitude of the income coefficient for food is slightly larger than non-food under non-homothetic preferences. In addition, the magnitude of the coefficient on village expenditure for food is smaller (almost twice) as compared to non-food consumption. In other words, food consumption responds less to changes in village-level consumption risk, which implies that food consumption is smoothed to a greater degree than non-food consumption.

Lastly, we examine the implications of risk pooling under heterogeneous preferences. As described in Section 3.3, our method of accounting for heterogeneous preferences involves two steps. We first estimate households’ risk and time preferences and then incorporate the estimated preferences to test for full risk pooling. Panel B in Table 2 shows the test results after incorporating heterogeneity in risk and time preferences. As shown in Column (1) for total expenditures, correcting for the bias from heterogeneous preferences does reduce the magnitude of the coefficients on income and liquid wealth. However, the main implications on the test of risk pooling are unchanged, even for the case of non-homothetic preferences for food and non-food consumption goods, as shown in Columns (2)-(5). Overall, the results for full risk pooling under heterogeneity-robust tests are largely similar to the test results under homogeneous preferences.
6.2 CRRA household model

Table 3 presents the tests results for full risk pooling within a village under a CRRA model in first difference in logs. Standard errors for all estimations are clustered at the village-level. Under homogeneous preferences, as shown in Column (1) Panel A, full risk pooling of income and assets is rejected. The homogeneous test results for the CRRA model are largely similar to the CARA model in Table 2. While full risk pooling is rejected, the results suggest partial pooling of income and assets. According to the point estimates in Column (1), a 10% change in income is associated with a change in consumption of 0.15%. Similarly, a 10% change in wealth is associated with a 0.24% change in total consumption.

The estimates from CRRA model is amenable to be interpreted as the marginal propensity to consume (MPC) out of income or the elasticity of consumption with respect to income (Blundell, Pistaferri and Preston 2008). As shown in Table 3, the estimate of MPC is about 0.015, and is precisely estimated with a standard error of 0.006. The estimated MPC of 0.015 for households in VDSA villages is slightly lower than the MPC of 0.05 estimated by Blundell, Pistaferri and Preston (2008) for households in US using PSID data, and is on the lower end of the mean MPC of 0.21, estimated in a recent meta-analysis of 246 estimates of MPCs by Havranek and Sokolova (2020). A low MPC found in our study also indicates a low share of rule-of-thumb households, far lower from the original estimate of 0.5 by Campbell and Mankiw (1989), and implies that a very low proportion of households in the VDSA villages consume from their own income, and that most households engage in consumption smoothing strategies of mutual risk pooling or borrowing and savings.

Next, we examine the implications of full risk pooling for the CRRA model for different consumption categories. The results under homothetic preferences in Columns (2) and (3) in Table 3 show that full risk pooling is rejected for food and non-food. The test implications of full risk pooling remain largely similar when one accounts for non-homothetic preferences, as shown in Columns (4) and (5). Although the income co-efficient on non-food in Column (5) is marginally imprecise (with a p-value of 0.13) does not provide strong evidence against rejection of full risk pooling. The magnitudes of the co-efficients on income and wealth for food consumption is comparable with non-food consumption. More importantly, the magnitude of the co-efficient on village expenditure for food is much smaller (less than one-half) as compared to non-food consumption, and suggests that food consumption may respond less to changes in aggregate risk. Overall, the results for the CRRA model suggest that, while food consumption may be better insured against aggregate risk.

Lastly, Panel B in Table 3 presents the test results of full risk pooling after accounting for heterogeneous risk and time preferences. As shown in Column (1) the co-efficient on
income reduces to a large extent (relative to homogeneous preferences in Panel A), indicating a correction of the heterogeneity bias. We fail to reject full risk pooling for total expenditures under heterogeneous preferences. Moreover, for consumption-specific pooling, as shown in Panel B columns (2) to (5), we fail to reject full risk pooling particularly for food consumption, but not for non-food consumption.

Overall, the results under CRRA model indicate that accounting for heterogeneity and non-linear Engel curves are important for testing for risk pooling. Moreover, the results under heterogeneity-robust tests, suggest that food consumption is smoothed to a greater degree than non-food consumption. Results in Panel A and B, taken together suggest that food consumption may be better insured against aggregate risk as well as idiosyncratic risk. These results provide suggestive evidence on mutual risk pooling to smooth food-specific consumption, consistent with our initial hypothesis of institutional arrangements of consumption-specific pooling on necessary goods such as food.

6.3 Village precautionary savings

We also perform complementary analysis of testing for precautionary savings at the village level, by estimating $9$. In particular, we aggregate household consumption, income and assets to the village level, and estimate the response of total village consumption to village cash-in-hand and village income. As cash-in-hand includes income, the co-efficient on income can be interpreted as the excess sensitivity parameter. The theory implies that, under the null of efficient savings at the village level, excess sensitivity to income should not enter as a significant variable in the regression estimations. The estimated results are reported in Table 4, in Panels A and B respectively for first difference in levels (CARA) and first difference in log units (CRRA). In Panel A Column (1), while perfectly efficient village savings is rejected, the small magnitude of the co-efficient on income suggest substantial smoothing against income risk. Columns (2) to (5) report results for village food and non-food separately and show that village food consumption is smoothed to a greater degree than non-food village consumption. For the estimations in log differences, as shown in Panel B, we fail to reject perfect village savings for total expenditures, food and non-food.

More importantly, the results show minimal response of village consumption to village cash-in-hand, and suggest that village consumption does not co-move to a great degree with village CIH. Based on the co-efficient estimates in Column 1, Rs.100 change in village cash-in-hand is associated with Rs. 3.09 change in total village consumption. Similarly, a 10% change in village cash-in-hand is associated with 0.38% change in village consumption (although the estimate is imprecise). These results are quite striking, given the large fluctuations in village consumption over time, observed in the VDSA village data, and indicate an absence of institutional arrangements for aggregate village-level
savings or lack of aggregate savings technologies in village economies.

6.4 Caste-level risk pooling and precautionary savings

Our main analysis of risk pooling assumes the village as the level at which risk is pooled. However, studies have shown that villages may not be an appropriate unit of pooling risk in village economies, and risk pooling may take place within subgroups in a village (Ellsworth, 1988; Platteau, 1997; Fafchamps and Lund, 2003; Goldstein et al., 2005; De Weerdt and Dercon, 2006); factors such as size and social characteristics of risk sharing groups may be important aspects in determining the amount of risk-sharing that occurs. Recent studies have also shown that castes may be a more natural level at which risk is pooled (Mazzocco and Saini, 2012; Shrinivas and Fafchamps, 2018). In this section, we explore whether the unit of risk pooling matters, by considering pooling within castes in a village.

To examine the extent of risk pooling in castes, we employ a similar testing strategy as described in Section 3. In particular, for the homogeneous tests at the caste level, we use caste expenditure instead of village expenditure in the regression estimations. As before, for the heterogeneity tests, first we estimate risk and time preferences, normalized to the caste-level based on the household’s co-movement with the aggregate caste consumption, rather than the village, and then use the estimated preferences to transform the consumption outcomes.

Table 5 contains the results for both CARA and CRRA models, and shows that full risk pooling is rejected for most cases in CARA and for homogeneous case in CRRA. However, under CRRA, we fail to reject risk pooling once heterogeneity in preferences is accounted. Moreover, food consumption is smoothed to a greater extent than non-food even within caste groups. Overall, these results suggest that full risk pooling test implications at the caste-level remain similar to the village-level test results in Tables 2 and 3, and implies that in the new wave of the VDSA data, the extent of risk pooling at the caste-level may not be substantially different than at the village-level.

Further, we also examine precautionary savings at the caste-level. These results, reported in Table 6, show that perfectly efficient caste-level savings is rejected under CARA, but not under CRRA. Moreover, the co-movement of caste consumption with caste CIH is of modest magnitude - a 10% change in caste CIH is associated with a 0.26% change in caste consumption. These results at the caste-level are almost identical to the village-level precautionary savings in 4. Taken together, these results suggest that the extent of consumption smoothing based on precautionary savings is minimal at the caste-level.

To identify caste group, we use the available data in the VDSA on jaati/caste of each household. There are a total 251 unique caste groups in the data, and 168 castes groups with atleast 2 households. For our analysis, and use the 168 caste groups with atleast 2 households and drop the castes with only one household.
village or caste-level.

7 Welfare costs of volatility

8 Conclusion
Figure 1: Engle Curves for food

Figure 2: Engle Curves for food
Non-food Engel curves

Figure 3: Engel curves for non-food

Distribution of risk preferences

Figure 4: Normalized risk tolerance and risk aversion
Figure 5: Normalized time preferences

Figure 6: Normalized discount factor
Table 1: Summary statistics

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Notes: This table reports descriptive statistics - mean and standard deviation - for household consumption, income, assets and demographic characteristics. Consumption, Income and Asset variables represent annual values, adjusted to 2010 rupees per adult-equivalent. Total expenditures is the sum of food and non-food expenditures, and earned income is the sum of crop and livestock income and wage income. Wealth is sum of net credit position (saving-borrowing+lending) and total assets (liquid assets+capital assets); Liquid wealth is the sum of net credit position (saving-borrowing+lending) and liquid assets (livestock, consumer durables and inventory value of crops, inputs and fuel). Similarly, cash-in-hand is constructed as the sum of liquid wealth and income earned. For all values, top and bottom 1% is trimmed for measurement errors.
Table 2: First differences in levels - CARA model

<table>
<thead>
<tr>
<th></th>
<th>Total expenditure</th>
<th>Homothetic preferences</th>
<th>Non-homothetic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Village Expenditure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0396)</td>
<td>(0.0562)</td>
<td>(0.0616)</td>
</tr>
<tr>
<td>Liquid wealth</td>
<td>0.0110***</td>
<td>0.0070**</td>
<td>0.0137**</td>
</tr>
<tr>
<td></td>
<td>(0.0039)</td>
<td>(0.0029)</td>
<td>(0.0054)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0338***</td>
<td>0.0292***</td>
<td>0.0334***</td>
</tr>
<tr>
<td></td>
<td>(0.0094)</td>
<td>(0.0080)</td>
<td>(0.0118)</td>
</tr>
<tr>
<td>Observations</td>
<td>5012</td>
<td>5012</td>
<td>5012</td>
</tr>
</tbody>
</table>

Panel A: Homogeneous preferences

Panel B: Heterogeneous preferences

Notes: This table reports the results from household panel-pooled estimation of first differences in levels, based on CARA model. Estimates in each column comes from a separate regression, with column and row headings representing the dependent and regressor variables respectively. Unit of observation is household-year. Panel A reports the test results of full risk pooling under homogeneous preferences and Panel B reports the test results of full risk pooling after accounting for heterogeneity in risk and time preferences. All variables are in units of 2010 rupees per-adult equivalent per year. Village expenditure represents the village leave out mean. Liquid wealth is the sum of net credit position (saving-borrowing+lending) and liquid assets (livestock, consumer durables and inventory value of crops, inputs and fuel). Income earned is the sum of income from crop, livestock and wages. The results under column Homothetic preferences assumes linear engel cruves, the dependent variables - food and non-food - are transformed by simply dividing the consumption good with the corresponding sample average budget share. Under column Non-homothetic preferences, the dependent variables -food and non-food expenditures - are transformed by taking the inverse of the engel curve, and represents the predicted expenditure value. In Panel B, the consumption outcomes are further transformed to account for heterogeneity in risk and time preferences. Top and bottom 1% of all values are trimmed for measurement errors. Standard errors are clustered at the village level. * p<0.10 ** p<0.05 *** p<0.01.
Table 3: First differences in logs - CRRA model

<table>
<thead>
<tr>
<th>Panel</th>
<th>Homothetic preferences</th>
<th>Non-homothetic preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total expenditure</td>
<td>Food</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Village Expenditure</td>
<td>0.9229***</td>
<td>0.6029***</td>
</tr>
<tr>
<td></td>
<td>(0.0215)</td>
<td>(0.0610)</td>
</tr>
<tr>
<td>Liquid wealth</td>
<td>0.0239***</td>
<td>0.0193***</td>
</tr>
<tr>
<td></td>
<td>(0.0042)</td>
<td>(0.0063)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0151**</td>
<td>0.0190**</td>
</tr>
<tr>
<td></td>
<td>(0.0059)</td>
<td>(0.0076)</td>
</tr>
<tr>
<td>Observations</td>
<td>3199</td>
<td>3188</td>
</tr>
</tbody>
</table>

Panel B: Heterogeneous preferences

<table>
<thead>
<tr>
<th></th>
<th>Total expenditure</th>
<th>Food</th>
<th>Non-food</th>
<th>Food</th>
<th>Non-food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Liquid wealth</td>
<td>-0.0023</td>
<td>-0.0115</td>
<td>-0.0006</td>
<td>-0.0104</td>
<td>0.0032</td>
</tr>
<tr>
<td></td>
<td>(0.0082)</td>
<td>(0.0120)</td>
<td>(0.0092)</td>
<td>(0.0118)</td>
<td>(0.0082)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0096</td>
<td>0.0093</td>
<td>0.0181**</td>
<td>0.0102</td>
<td>0.0191*</td>
</tr>
<tr>
<td></td>
<td>(0.0072)</td>
<td>(0.0095)</td>
<td>(0.0088)</td>
<td>(0.0094)</td>
<td>(0.0104)</td>
</tr>
<tr>
<td>Observations</td>
<td>3199</td>
<td>3188</td>
<td>3195</td>
<td>3188</td>
<td>2885</td>
</tr>
</tbody>
</table>

Notes: This table reports the results from household panel-pooled estimation of first differences in logs, based on CRRA model. Estimates in each column comes from a separate regression, with column and row headings representing the dependent and regressor variables respectively. Unit of observation is household-year. Panel A reports the test results of full risk pooling under homogeneous preferences and Panel B reports the test results of full risk pooling after accounting for heterogeneity in risk and time preferences. All variables are in log units of 2010 rupees per-adult equivalent per year. Village expenditure represents the village leave out mean. Liquid wealth is the sum of net credit position (saving-borrowing+lending) and liquid assets (livestock, consumer durables and inventory value of crops, inputs and fuel). Income earned is the sum of income from crop, livestock and wages. The results under column Homothetic preferences assumes linear engel crues, the dependent variables - food and non-food - are transformed by simply dividing the consumption good with the corresponding sample average budget share. Under column Non-homothetic preferences, the dependent variables -food and non-food expenditures - are transformed by taking the inverse of the engel curve, and represents the predicted expenditure value. In Panel B, the consumption outcomes are further transformed to account for heterogeneity in risk and time preferences. Top and bottom 1% of all values are trimmed for measurement errors, before transforming into log units. Standard errors are clustered at the village level. * p<0.10 ** p<0.05 *** p<0.01.
### Table 4: Village precautionary savings

<table>
<thead>
<tr>
<th></th>
<th>Total expenditure</th>
<th>Homothetic pref</th>
<th>Non-homothetic pref</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Panel A: First differences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIH</td>
<td>0.0309**</td>
<td>0.0173</td>
<td>0.0433**</td>
</tr>
<tr>
<td></td>
<td>(0.0147)</td>
<td>(0.0132)</td>
<td>(0.0178)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0935**</td>
<td>0.0669</td>
<td>0.0977*</td>
</tr>
<tr>
<td></td>
<td>(0.0468)</td>
<td>(0.0418)</td>
<td>(0.0567)</td>
</tr>
<tr>
<td>Observations</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Total expenditure</th>
<th>Food</th>
<th>Non-food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel B: Log differences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIH</td>
<td>0.0379</td>
<td>0.0131</td>
<td>0.0576</td>
</tr>
<tr>
<td></td>
<td>(0.0257)</td>
<td>(0.0228)</td>
<td>(0.0480)</td>
</tr>
<tr>
<td>Income earned</td>
<td>-0.0058</td>
<td>-0.0008</td>
<td>-0.0170</td>
</tr>
<tr>
<td></td>
<td>(0.0319)</td>
<td>(0.0283)</td>
<td>(0.0598)</td>
</tr>
<tr>
<td>Observations</td>
<td>118</td>
<td>118</td>
<td>118</td>
</tr>
</tbody>
</table>

**Notes:** This table reports the test of precautionary savings at the village level. Estimates in each column come from a separate regression, with column and row headings representing the dependent and regressor variables respectively. Unit of observation is village-year. Panel A reports the test results for first differences in levels and Panel B reports the results for first difference in log. All variables are in units of 2010 rupees per-adult equivalent per year. Wealth is the sum of the value of liquid assets (inventory of livestock, consumer durables, crop and farm inputs) and net credit position (savings-borrowing+lending). Income earned is the sum of income from crop, livestock and wages. The results under column Homothetic preferences assumes linear engel cruves, the dependent variables - food and non-food - are transformed by simply dividing the consumption good with the corresponding sample average budget share. Under column Non-homothetic preferences, the dependent variables -food and non-food expenditures - are transformed by taking the inverse of the engel curve, and represents the predicted expenditure value. Standard errors are reported in parenthesis. * p<0.10 ** p<0.05 *** p<0.01.
Table 5: Risk pooling within castes

<table>
<thead>
<tr>
<th></th>
<th>CARA Model : First difference in levels</th>
<th>CRRA model : First difference in log units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Homothetic preferences</td>
<td>Non-homothetic</td>
</tr>
<tr>
<td></td>
<td>Total exp (1) Food (2) Non-food (3)</td>
<td>Total exp (6) Food (7) Non-food (8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-homothetic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Food (9) Non-food (10)</td>
</tr>
<tr>
<td>Caste Expenditure</td>
<td>0.7402*** (0.0442) 0.4890*** (0.0552)</td>
<td>0.8475*** (0.0284) 0.5615*** (0.0436)</td>
</tr>
<tr>
<td></td>
<td>0.7453*** (0.0714) 0.5217*** (0.0720)</td>
<td>1.0191*** (0.0804) 0.5533*** (0.0418)</td>
</tr>
<tr>
<td></td>
<td>0.7776*** (0.0692)</td>
<td>1.1103*** (0.1137)</td>
</tr>
<tr>
<td>Liquid wealth</td>
<td>0.0154** (0.0062) 0.0078** (0.0034)</td>
<td>0.0261*** (0.0056) 0.0237*** (0.0061)</td>
</tr>
<tr>
<td></td>
<td>0.0176** (0.0077) 0.0106** (0.0048)</td>
<td>0.0235*** (0.0089) 0.0256*** (0.0063)</td>
</tr>
<tr>
<td></td>
<td>0.0124*** (0.0041)</td>
<td>0.0247*** (0.0075)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0436*** (0.0147) 0.0304*** (0.0094)</td>
<td>0.0168*** (0.0060) 0.0194*** (0.0060)</td>
</tr>
<tr>
<td></td>
<td>0.0426** (0.0184) 0.0324*** (0.0119)</td>
<td>0.0224** (0.0100) 0.0207*** (0.0064)</td>
</tr>
<tr>
<td></td>
<td>0.0309*** (0.0105)</td>
<td>0.0101</td>
</tr>
<tr>
<td>Observations</td>
<td>4322 4322 4322 4322</td>
<td>2743 2734 2739 2734</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2466</td>
</tr>
</tbody>
</table>

Panel A: Homogeneous preferences

Panel B: Heterogeneous preferences

|                          | Homothetic preferences                 | Non-homothetic                             |
|                          |                                        | Food (9) Non-food (10)                     |
| Liquid wealth            | 0.0128** (0.0049)                      | 0.0135* (0.0077)                          |
|                          | 0.0048 (0.0037)                        | 0.0067 (0.0092)                           |
|                          | 0.0151** (0.0069)                      | 0.0135 (0.0097)                           |
|                          | 0.0077 (0.0050)                        | 0.0085 (0.0094)                           |
|                          | 0.0099*** (0.0033)                     | 0.0178** (0.0079)                         |
| Income earned            | 0.0403*** (0.0120)                     | 0.0092 (0.0077)                           |
|                          | 0.0258*** (0.0091)                     | 0.0093 (0.0090)                           |
|                          | 0.0393** (0.0162)                      | 0.0163 (0.0119)                           |
|                          | 0.0279** (0.0116)                      | 0.0106 (0.0092)                           |
|                          | 0.0278*** (0.0090)                     | 0.0129 (0.0100)                           |
| Observations             | 4322 4322 4322 4322                    | 2743 2734 2739 2734                       |
|                          |                                        | 2466                                       |

Notes: This table reports the results from household panel-pooled estimation of first differences in levels and logs, based on CARA and CRRA models respectively. Estimates in each column comes from a separate regression, with column and row headings representing the dependent and regressor variables respectively. Unit of observation is household-year. Panel A reports the test results of full risk pooling under homogeneous preferences and Panel B reports the test results of full risk pooling after accounting for heterogeneity in risk and time preferences. All variables are in log units of 2010 rupees per-adult equivalent per year. Caste expenditure represents the caste leave out mean. Liquid wealth is the sum of net credit position (saving-borrowing+lending) and liquid assets (livestock, consumer durables and inventory value of crops, inputs and fuel). Income earned is the sum of income from crop, livestock and wages. The results under column Homothetic preferences assumes linear engel curves, the dependent variables - food and non-food - are transformed by simply dividing the consumption good with the corresponding sample average budget share. Under column Non-homothetic preferences, the dependent variables -food and non-food expenditures - are transformed by taking the inverse of the engel curve, and represents the predicted expenditure value. In Panel B, the consumption outcomes are further transformed to account for heterogeneity in risk and time preferences. Top and bottom 1% of all values are trimmed for measurement errors, before transforming into log units. Standard errors are clustered at the caste level. * p<0.10 ** p<0.05 *** p<0.01.
Table 6: Caste-level precautionary savings

<table>
<thead>
<tr>
<th></th>
<th>Total expenditure (1)</th>
<th>Homothetic pref</th>
<th>Non-homothetic pref</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Food (2)</td>
<td>Non-food (3)</td>
</tr>
<tr>
<td>CIH</td>
<td>0.0245***</td>
<td>0.0147***</td>
<td>0.0342***</td>
</tr>
<tr>
<td></td>
<td>(0.0062)</td>
<td>(0.0052)</td>
<td>(0.0078)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0690***</td>
<td>0.0551***</td>
<td>0.0610***</td>
</tr>
<tr>
<td></td>
<td>(0.0174)</td>
<td>(0.0147)</td>
<td>(0.0219)</td>
</tr>
<tr>
<td>Observations</td>
<td>656</td>
<td>656</td>
<td>656</td>
</tr>
</tbody>
</table>

Panel A: First differences

Panel B: Log differences

<table>
<thead>
<tr>
<th></th>
<th>Total expenditure (1)</th>
<th>Homothetic pref</th>
<th>Non-homothetic pref</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Food (2)</td>
<td>Non-food (3)</td>
</tr>
<tr>
<td>CIH</td>
<td>0.0259**</td>
<td>0.0265**</td>
<td>0.0288</td>
</tr>
<tr>
<td></td>
<td>(0.0119)</td>
<td>(0.0105)</td>
<td>(0.0210)</td>
</tr>
<tr>
<td>Income earned</td>
<td>0.0123</td>
<td>0.0081</td>
<td>0.0126</td>
</tr>
<tr>
<td></td>
<td>(0.0148)</td>
<td>(0.0130)</td>
<td>(0.0262)</td>
</tr>
<tr>
<td>Observations</td>
<td>562</td>
<td>562</td>
<td>562</td>
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</tbody>
</table>

Notes: This table reports the test of precautionary savings at the caste level. Estimates in each column come from a separate regression, with column and row headings representing the dependent and regressor variables respectively. Unit of observation is caste-year. Panel A reports the test results for first differences in levels and Panel B reports the results for first difference in log. All variables are in units of 2010 rupees per-adult equivalent per year. Liquid wealth is the sum of the value of liquid assets (inventory of livestock, consumer durables, crop and farm inputs) and net credit position (savings-borrowing+lending). Income earned is the sum of income from crop, livestock and wages. The results under column Homothetic preferences assumes linear engel curves, the dependent variables - food and non-food - are transformed by simply dividing the consumption good with the corresponding sample average budget share. Under column Non-homothetic preferences, the dependent variables -food and non-food expenditures - are transformed by taking the inverse of the engel curve, and represents the predicted expenditure value. Standard errors are reported in parenthesis. * p<0.10 ** p<0.05 *** p<0.01.
References


Dubois, P. (2001). Consumption insurance with heterogeneous preferences. Can sharecropping help complete markets?


Appendix: Figures

Figure 7: Location of ICRISAT VDSA villages  30 villages across 8 states
Appendix: Testing strategy with CRRA preferences

Building on the work of Mace (1991) and Townsend (1994), our testing strategy can easily be extended to the case where individuals have CRRA preferences of the form $U_i(c) = \frac{1}{1-\gamma_i} c^{-\gamma_i}$ where parameter $\gamma_i$ is the coefficient of relative risk aversion of individual $i$. Under CRRA, the FOC for perfect risk sharing by the social planner simplifies to:

$$\eta_i \rho_i c^{-\gamma_i} = \lambda_{ts}$$

Taking logs and rearranging, we get:

$$\log c_{its} = \frac{\log \eta_i}{\gamma_i} + \frac{\log \rho_i}{\gamma_i} - \frac{1}{\gamma_i} \log \lambda_{ts}$$

(12)

Averaging over all $N$ individuals in the village and solving for $\log \lambda_{ts}$ yields an expression for average village log consumption $\bar{\log c}_{ts} \equiv \frac{1}{N} \sum_{i=1}^{N} \log c_{its}$, which we use to replace the common Lagrange multiplier in equation (12). We then obtain:

$$\log c_{its} = \frac{1}{\gamma_i} \left[ \log \eta_i - \frac{1}{N} \sum_{j=1}^{N} \frac{\log \eta_j}{\gamma_j} \right] + \frac{1}{\gamma_i} \left[ \log \rho_i - \frac{1}{N} \sum_{j=1}^{N} \frac{\log \rho_j}{\gamma_j} \right] t + \frac{1}{\gamma_i} \frac{1}{N} \sum_{j=1}^{N} \frac{1}{\gamma_j} \log c_{ts}$$

(13)

Under homogeneous risk preferences, the regression used to test efficient risk sharing becomes:

$$\Delta \log c_{it} = \beta_1 + \beta_2 \Delta \log c_{t} + \beta_3 \Delta \log y_{it} + \beta_4 \Delta \log w_{it} + \epsilon_{it}$$

(14)

where the two exclusion restrictions in levels present in equation (8) have been suitably replaced by their equivalent in logs.

Under heterogeneous preferences, we similarly start by normalizing risk preferences relative to their mean by imposing that $\frac{1}{N} \sum_{i=1}^{N} \frac{1}{\gamma_i} = 1$. With this normalization, we obtain:

$$\log c_{it} = \frac{1}{\gamma_i} \left[ \log \eta_i - \frac{1}{N} \sum_{j=1}^{N} \frac{\log \eta_j}{\gamma_j} \right] + \frac{1}{\gamma_i} \left[ \log \rho_i - \frac{1}{N} \sum_{j=1}^{N} \frac{\log \rho_j}{\gamma_j} \right] t + \frac{1}{\gamma_i} \frac{1}{N} \sum_{j=1}^{N} \frac{1}{\gamma_j} \log c_{t}$$

To estimate this model, we first need to obtain estimates of all individual $\gamma_i$ and $\rho_i$ by running a model of the form:

$$\log c_{it} = \alpha_i + \theta_i t + \beta_1 \log c_{t} + \epsilon_{it}$$

(15)

using, as before, monthly consumption data on household $i$. We then recover structural parameters using the following equalities:
\[ \beta_i = \frac{1}{\gamma_i} \]  
\[ \alpha_i = \frac{1}{\gamma_i} \left[ \log \eta_i - \frac{1}{N} \sum_{i=1}^{N} \frac{\log \eta_i}{\gamma_i} \right] \]  
\[ \theta_i = \frac{1}{\gamma_i} \left[ \log \rho_i - \frac{1}{N} \sum_{i=1}^{N} \frac{\log \rho_i}{\gamma_i} \right] \]

(15A) \hspace{1cm} (15B) \hspace{1cm} (15C)

In this case, the estimated \( \gamma_i \) can be interpreted as capturing the extent to which the coefficient of relative risk aversion of individual \( i \) differs from the average degree of relative risk aversion in the sample. It follows that, apart from this difference in normalization, the estimation of the CRRA and CARA household by household is very similar: in CARA we regress \( c_{it} \) on village average consumption \( \bar{c} \) while in CRRA we regress \( \log c_{it} \) on village average log consumption \( \log \bar{c} \). Calculating welfare weights and time preference parameters is unchanged:

\[ \log \eta_i = \frac{\alpha_i}{\beta_i} + \frac{\bar{\pi}}{1 - \beta} \]  
\[ \log \rho_i = \frac{\theta_i}{\beta_i} + \frac{\bar{\theta}}{1 - \beta} \]

(15A) \hspace{1cm} (15B)

It follows that the equivalent of the regression model (10) for the CRRA case is:

\[ \log c_{it} - \hat{\beta}_i \log \bar{c}_t - \hat{\theta}_i t = \xi \log y_{it} + \zeta \log w_{it} + \epsilon_{it} \]

**Model in first differences in logs**

**Homogeneous case**

\[ \Delta \log c_{it} = \theta_i + \beta_i \Delta \log \bar{c}_t + \xi \Delta \log y_{it} + \zeta \Delta \log w_{it} + \epsilon_{it} \]

Accounting for heterogeneous risk preferences,

\[ (\Delta \log c_{it} - \hat{\beta}_i \Delta \log \bar{c}_t) = \theta_i + \xi \Delta \log y_{it} + \zeta \Delta \log w_{it} + \epsilon_{it} \]

Accounting for heterogeneous time preferences,

\[ (\Delta \log c_{it} - \hat{\beta}_i \Delta \log \bar{c}_t - \hat{\theta}_i) = \xi \Delta \log y_{it} + \zeta \Delta \log w_{it} + \epsilon_{it} \]
Appendix B: Estimation of Pareto-weight

From (??A) we have

\[
\frac{\alpha_i}{\beta_i} = \log \eta_i - \frac{1}{N} \sum_{i=1}^{N} \beta_i \log \eta_i \tag{16}
\]

For any household \( i = 1 \) and \( i = 2 \), we have

\[
\frac{\alpha_1}{\beta_1} = \log \eta_1 - \frac{1}{N} \sum_{i=1}^{N} \beta_i \log \eta_i \\
\frac{\alpha_2}{\beta_1} = \log \eta_2 - \frac{1}{N} \sum_{i=1}^{N} \beta_i \log \eta_i
\]

Substituting for \( \frac{1}{N} \sum_{i=1}^{N} \beta_i \log \eta_i \) we have

\[
\frac{\alpha_1}{\beta_1} = \log \eta_1 - \left[ \log \eta_2 - \frac{\alpha_2}{\beta_2} \right] \\
\log \eta_2 = \log \eta_1 - \frac{\alpha_1}{\beta_1} + \frac{\alpha_2}{\beta_2}
\]

Hence we can express for any household \( j \) in terms of \( i \), where \( j \neq i \)

\[
\log \eta_j = \log \eta_i - \frac{\alpha_i}{\beta_i} + \frac{\alpha_j}{\beta_j} \tag{17}
\]

Substituting (17) in (16) we get,
\[
\frac{\alpha_i}{\beta_i} = \log \eta_i - \frac{1}{N} \left[ \beta_i \log \eta_i + \beta_j \left( \log \eta_i - \frac{\alpha_i}{\beta_i} + \frac{\alpha_j}{\beta_j} \right) + \ldots + \beta_n \left( \log \eta_i - \frac{\alpha_i}{\beta_i} + \frac{\alpha_n}{\beta_n} \right) \right]
\]

\[
N \frac{\alpha_i}{\beta_i} = N \log \eta_i - \left[ \beta_i \log \eta_i + \log \eta_i (\beta_j + \ldots + \beta_n) - \frac{\alpha_i}{\beta_i} (\beta_j + \ldots + \beta_n) + (\alpha_j + \ldots + \alpha_n) \right]
\]

\[
= N \log \eta_i - \left[ \Sigma \beta \log \eta_i - \frac{\alpha_i}{\beta_i} (\Sigma \beta - \beta_i) + (\Sigma \alpha - \alpha_i) \right]
\]

\[
= (N - \Sigma \beta) \log \eta_i + \frac{\alpha_i}{\beta_i} (\Sigma \beta - \beta_i) - (\Sigma \alpha - \alpha_i)
\]

\[
= (N - N\overline{\beta}) \log \eta_i + \frac{\alpha_i}{\beta_i} \overline{\beta} - N\overline{\alpha}
\]

\[
\frac{\alpha_i}{\beta_i} = (1 - \overline{\beta}) \log \eta_i + \frac{\alpha_i}{\beta_i} \overline{\beta} - \overline{\alpha}
\]

\[
(1 - \overline{\beta}) \log \eta_i = (1 - \overline{\beta}) \frac{\alpha_i}{\beta_i} \overline{\beta} - \overline{\alpha}
\]

\[
\log \eta_i = \frac{\alpha_i}{\beta_i} + \frac{\overline{\alpha}}{1 - \overline{\beta}}
\]

Similarly, from (??A) we can derive,

\[
\log \rho_i = \frac{\theta_i}{\beta_i} + \frac{\overline{\theta}}{1 - \overline{\beta}}
\]