Distinguishing barriers to insurance in Thai villages[*]

Cynthia Kinnan[†]

January 2010

Abstract

A large body of evidence shows that informal insurance is an important risk-smoothing mechanism in developing countries but that this risk sharing is incomplete. Models of limited commitment, moral hazard, and hidden income have been proposed to explain the incomplete nature of informal insurance. Using the first-order conditions characterizing optimal insurance subject to each type of constraint, I show that the way history matters in forecasting consumption can be used to distinguish hidden income from limited commitment and moral hazard. This implication does not rely on a particular specification of the production technology or utility function. In a seven-year panel from rural Thailand, I show that neither limited commitment nor moral hazard can fully explain the relationship between income and consumption. In contrast, the predictions of the hidden income model are supported by the data.

JEL codes: D82, D91, O12

1 Introduction

Risk to households' incomes is widespread in developing countries—crops and businesses fail, jobs are lost, livestock die, prices fluctuate, family members become ill, etc. If perfect insurance were available, such income risk would not translate into fluctuations in household per capita consumption. In fact, poor households in many developing countries are insured against short-term, idiosyncratic income shocks to a surprising degree, despite absent or imperfect markets for formal insurance, credit, and assets (Rosenzweig 1988), (Townsend 1994), (Townsend 1995), (Udry 1994), (Morduch 1995), (Suri 2005). However, households are generally not completely insured—income and consumption are typically found to be positively correlated, and serious income shocks like severe illness translate into reduced household consumption (Gertler and Gruber 2002). Households neither seem to live "hand to mouth," with shocks to income translating one-for-one to fluctuations in consumption, nor to be fully insured, with consumption completely buffered against shocks to income.

[†]Email: ckinnan@mit.edu

Furthermore, households do not smooth consumption only with a borrowing-savings technology. There is direct evidence that households make state-contingent transfers to others in their village (Scott 1976), (Cashdan 1985), (Platteau and Abraham 1987), (Platteau 1991), (Udry 1994), (Collins et. al 2009). Transfers which depend on current states—loans forgiven when the borrower's crops fail, money given when a neighbor is ill, etc.—are the hallmark of insurance, since in a pure credit system transfers would depend only on past states (the amount borrowed, etc.). The incidence of state-contingent transfers demonstrates that households obtain insurance from others in their village. A natural question is then, why is this insurance not complete? Among the reasons proposed for the failure of full insurance are: moral hazard—one household's actions are not observable to others; imperfect information about income realizations—households' income realizations are unobservable by others; and limited commitment—households with high incomes, who would be required by full insurance to make transfers to others, may leave the insurance arrangement instead.

Knowing what barrier to full informal risk-sharing is most important in a given community is important for evaluation of policies that may affect the sustainability of informal insurance. Policies that interact with existing informal risk-sharing mechanisms may have very different impacts depending on the nature of incomplete informal insurance. For instance, a work-guarantee program such as India's National Rural Employment Guarantee Act could crowd out insurance constrained by moral hazard (by reducing the penalty for exerting low effort) or limited commitment (by making exclusion from the informal insurance network less painful), but could "crowd in" insurance constrained by imperfect information about households' incomes (which I will refer to as "hidden income"), by ruling out the possibility that a household received a very low income, since households have recourse to the work-guarantee program.

If binding, the participation constraints of the limited commitment model, the truth-telling constraints of the hidden income model and the incentive-compatibility constraints of the moral hazard model all preclude the village from achieving full insurance. All three models predict a positive correlation between income and consumption changes[1], as well as predicting that one household's income realizations will affect the consumption of other households in the village. Therefore, finding such a positive correlation is not sufficient to distinguish between these models. Most of the existing literature on barriers to informal insurance, which I briefly review below, tests one model of incomplete insurance against one or both of the benchmark cases— full insurance and borrowing-saving only. Such tests, while they can reject full insurance, are not able to reject models of incomplete insurance other than the particular insurance friction they consider. It is possible that tests of a particular insurance friction versus borrowing-saving or full insurance will conclude in favor of that incomplete insurance model if the true data-generating process is in fact another insurance friction. The contribution of this paper is to develop and empirically implement a set of testable predictions which distinguishes *between* the hidden income-, limited commitment- and moral hazard-constrained insurance.

I show that, when insurance is constrained by limited commitment or moral hazard, a household's

---

[1] The relationship between income and consumption need not be everywhere positive under a moral hazard model, even if the likelihood ratio is monotone (Milgrom 1981), (Grossman and Hart 1983). However, incentive compatibility requires that consumption be increasing in output on average. Moreover, if agents can costlessly "burn output," monotonicity may be required (Bolton and Dewatripont 2005).

"history" matters in a specific way in predicting that household's current consumption: conditional on the village's shadow price of resources (a measure of the aggregate shock faced by the village), a household's lagged inverse marginal utility ("LIMU") is a sufficient statistic for forecasting the household's consumption: no other past information should improve the forecast of current consumption made using LIMU. Allowing the distribution of household income to depend on actions taken by the household in the past (investment, for instance) does not overturn the sufficiency result.

On the other hand, when household income is unobserved, a household's LIMU is no longer a sufficient statistic in forecasting consumption. Because low-income households are optimally assigned low consumption, hence high marginal utility, their temptation to claim *even lower* income (resulting in a higher transfer), is highest for these households. Because truthful households value current consumption more than misreporting households, while truthful and misreporting households value promised future consumption equally, incentive compatibility is attained by reducing the expected future surplus promised to low-income households relative to their current consumption.

The tests of limited commitment and moral hazard I derive generalize existing results from the contract economics literature (Kocherlakota 1996), (Rogerson 1985), while the hidden income test is a new result. The second contribution of this paper is to empirically implement these tests, examining the relationship between LIMU and current consumption in rural Thailand using 84 months (7 years, 1999-2005) of the Townsend Thai Monthly Survey. Sufficiency of LIMU is rejected: lagged income has predictive power in forecasting current inverse marginal utility. Moreover, the prediction errors generated with LIMU alone display a significant, positive correlation with lagged income, as predicted by the hidden income model. This suggests that the need to give households incentives to truthfully reveal their income plays a role in generating the observed comovement between income and consumption.

An important consideration in implementing these tests is the concern that consumption is measured with error. Measurement error in right-hand variables is usually seen as a threat to power, causing under-rejection of the null, but in tests of the type used here, measurement error can distort the size of the test, causing over-rejection of the null. Accounting for measurement error in lagged consumption using instrumental variables techniques and by testing over-identifying restrictions on the reduced form equations for current and lagged consumption does not overturn the rejection of sufficiency of LIMU. That is, measurement error does not appear to drive the conclusion that neither limited commitment nor moral hazard can explain the relationship between current consumption, past consumption and past income.

The rest of the paper is organized as follows: Section 2 provides a brief overview of related literature. Section 3 outlines the benchmarks of full insurance and pure borrowing-saving, discusses the three barriers to insurance (moral hazard, limited commitment and hidden income), and explains the theoretical approach for distinguishing among these barriers. Section 4 explains how these theoretical predictions can be empirically tested, accounting for measurement error in consumption and uncertainty about the form of households' utility functions. Section 5 discusses the data used to implement these tests, Section 6 presents the results

and Section 7 concludes. Proofs are contained in Appendix A. Tables appear in Appendix B, and figures are in Appendix C.

2 Related literature

Several papers have examined whether limited commitment- or moral hazard-constrained insurance explain consumption and income data better than pure borrowing-saving or full insurance models. The contribution of this paper, relative to the existing literature is, first, to propose and implement a test of the hidden income model, which to my knowledge, has not previously been empirically tested. Another novel contribution of this testing procedure is that it can distinguish the hidden income model not only from full insurance and borrowing-lending, but also from limited commitment- and moral hazard-constrained insurance. The third contribution of this paper relative to existing literature is that, unlike maximum likelihood and GMM approaches, the tests proposed here do not rely on a particular specification of the production technology or the utility function.

Ligon (1998) uses a generalized method of moments (GMM) approach to test moral hazard-constrained insurance against full insurance and borrowing-saving (i.e., the permanent income hypothesis) in India using ICRISAT village data, and finds that moral hazard best explains consumption data in 2 of 3 villages; in the third some households' consumptions are better explained by the PIH. Ligon, Thomas and Worrall (2002) use a maximum likelihood approach to test full insurance against limited commitment, also in the ICRISAT villages. They find that limited commitment explains consumption dynamics, but not why high-income households consume as little as they do relative to low-income households. Lim and Townsend (1998) incorporate capital assets and livestock into a moral hazard-constrained insurance model, and find that it fits the ICRISAT consumption data better than the PIH or full insurance using a maximum likelihood approach. Cox et al. (1998) argue that qualitative features of lending in Peruvian villages are inconsistent with full insurance or the PIH, but consistent with limited commitment. Albarran and Attanasio (2003) show that the comparative statics of a limited commitment model are matched by data from Mexico following the introduction of Progresa. Dubois et al. (2008) develop a model with limited commitment and incomplete formal contracts and find, using a maximum likelihood approach, that its predictions are matched in Pakistani data. Kocherlakota and Pistaferri (2009) review the literature which uses the asset-pricing implications of incomplete markets (borrowing-lending only) and private information (moral hazard/adverse selection) economies; they find that the asset-pricing implications of the moral hazard/adverse selection model fit US, UK and Italian data with a "reasonable" coefficient of relative risk aversion (estimated using a GMM approach), while the implications of the borrowing-lending model are rejected. Hayashi et al. (1996) review the literature on full consumption smoothing in the US and find that neither endogeneity of labor nor nonseparability between labor and consumption explains the rejection of full smoothing of food consumption in the PSID. Blundell et al. (2008) document that persistent income shocks are partially insured in the US,

and even transitory shocks are not fully insured for low-wealth households.

Several papers have examined whether private information about households' productivity (a Mirrlees-style adverse selection model) can explain incomplete insurance in developed economies. Kaplan (2006) derives quantitative predictions about the amount of risk sharing that would arise, for a given wage distribution, under limited commitment versus a setting with observed income but unobserved productivity. Ai and Yang (2007) find that a model with limited commitment and private information about productivity (but observed income) better fits quantitative features US data than a model with limited commitment alone.

The implications of full consumption insurance have been characterized by Wilson (1968), Cochrane (1991), Mace (1991) and Townsend (1994). The inverse Euler equation implication of moral hazard-constrained insurance was first characterized by Rogerson (1985), and Phelan (1998) developed a recursive formulation of the moral hazard problem. The limited commitment model was first characterized by Kimball (1988) and Coate and Ravallion (1993). The hidden income model was first characterized by Townsend (1982) and Green (1987). The method used in this paper, distinguishing hidden income from limited commitment and moral hazard using the first-order conditions of the social planner's problem, draws on the characterization of efficient limited commitment-constrained insurance in Kocherlakota (1996) (which is described in section 3), and on the recursive formulation of the hidden income problem developed in Thomas and Worrall (1990).

The next section presents the benchmark cases of full consumption insurance and pure borrowing-saving, and then shows how the full insurance benchmark is altered by the presence of limited commitment, moral hazard and hidden income.

3 Models of optimal consumption smoothing: full insurance, borrowing-saving, moral hazard, limited commitment, hidden income

3.1 Setting

As a simplified approximation to the environment in a village, consider N risk-averse households who interact over an infinite time horizon in a mutual insurance network. Let i index households and t index time. Each household evaluates per capita consumption and effort plans according to:

$$U(\mathbf{c}_i, \mathbf{e}_i) = \mathbb{E} \sum_{t=0}^{\infty} \beta^t \left[v(c_{it}) - z(e_{it}) \right]$$

The specification of $U(\mathbf{c}_i, \mathbf{e}_i)$ embodies the assumption of no *ex ante* heterogeneity among households:

Assumption 1 *All households have a common discount factor β, and common, additively separable utility of per capita consumption and disutility of effort functions $v(c)$ and $z(e)$. Utility is increasing and concave in per capita consumption: $v' > 0$ and $v'' < 0$.*

Following Thomas and Worrall (1990), I also make the following assumption:

Assumption 2 *Absolute risk aversion is non-increasing:*

$$d\left(\frac{-v''(c_{it})}{v'(c_{it})}\right)/dc_{it} \leq 0$$

This assumption guarantees the concavity of the value function in the hidden income model (Thomas and Worrall 1990); it is satisfied by the commonly-used constant relative risk aversion and constant absolute risk aversion utility functions. It seems to be a natural assumption since, as pointed out by Arrow (1971), increasing absolute risk aversion implies that higher-wealth individuals would be more averse to a given absolute gamble than lower-wealth individuals; that is, risky assets would be inferior goods.

A key assumption is:

Assumption 3 *As long as any household is participating in the village insurance network, the household's borrowing and savings decisions are contractible.* (As described below, if a household leaves the village insurance network they may have access to a borrowing-savings technology with a weakly lower return.) As a result, savings and borrowing by network member households are determined as if chosen by a welfare-maximizing planner, not to maximize the household's own expected payoff. This may appear to be a strong assumption, but given the prevalence of joint savings groups (ROSCAs) in rural Thailand, and of borrowing from and saving with "village funds," where accounts are overseen by a committee of village members, this assumption is not implausible. Contractibility of borrowing and saving can be implemented as long as other households can observe a household's asset position, since transfers and future utility can be conditioned on the household choosing the recommended level of assets.[2]

Moreover, when insurance is limited by hidden income, if households can privately save at the same interest rate available to the community, no interpersonal insurance is possible, because the household will always find it in their incentive to report whatever income realization yields the highest present discounted value of current and future transfers (Allen 1985), (Cole and Kocherlakota 2001). Therefore, to the extent that the predictions of the pure borrowing-saving (PIH) model are rejected in the data in favor of the hidden income model, the joint hypothesis of hidden income and hidden savings (at the same interest rate as the community) is also rejected.[3]

I assume that the community-controlled borrowing-saving technology has gross return $R \geq 1$. There is an autarkic technology with gross return $R' < R$. (If no savings is possible in autarky, $R' = 0$.) Because the

---

[2] Collins et al. (2009) document that in samples of Indian, Bangladeshi and South African households, ROSCAs and other types of group savings arrangements (saving-up clubs and accumulating savings and credit associations, or ASCAs) are the primary means by which households accumulate sums of savings equal to one month's income or more. A key feature of these clubs and associations is that members know how much one another have contributed and borrowed.

[3] Doepke and Townsend (2006) show that when income is hidden, if households can privately borrow and save at a sufficiently different interest rate than the community, some insurance is possible. Although the optimal contract is then difficult to characterize analytically, Doepke and Townsend show numerically that access to private storage at a very low gross return does not distort insurance very much, relative to the no-private-savings case, because the low return dampens the temptation to privately save. This suggests that "saving under the mattress," which likely carries a negative net return due to inflation and risk of theft, may not pose too great a threat to the characterization of the optimal contract derived below. Formally introducing the possibility of hidden savings to the model is left to future work.

community-controlled borrowing-saving technology is assumed to have a strictly higher rate of return, the contractibility of savings implies that any net borrowing or saving by agents in the network (such that (21) does not hold with equality) will take place via the community-controlled technology.

When specifying the value of autarky below, I will make the following assumption:

Assumption 4 *Agents cannot take savings accumulated while in the insurance network with them into autarky.* Even in this case, potential access to the autarkic borrowing-saving technology after leaving the insurance agreement will reduce the amount of insurance attainable in a limited commitment insurance relationship (Ligon, Thomas, and Worrall 2000). Allowing households to take their savings with them into autarky will further reduce the amount of feasible insurance, but does not change the properties of efficient insurance derived below, because the effect of such savings, which is to raise the value of autarky, will be fully captured in the consumption allocation to households tempted to leave the insurance network.

Finally, the following assumptions are made on the production technology:

Assumption 5a *Output can take on S values, $\{y_1, ..., y_S\}$.* Indices are chosen so that a higher index means more output: $r > q \Rightarrow y_r > y_q$. The number of possible output realizations is restricted to be finite (although potentially very large).[4] This assumption is required for the approaches of Grossman and Hart (1983) characterizing the optimal contract under moral hazard, and the approach of Thomas and Worrall (1990) characterizing the optimal contract under hidden income, to be valid.

Assumption 5b *Effort can take on two values in each period, working ($e_t = 1$) or shirking ($e_t = 0$).* This assumption is made for simplicity and allowing for additional levels of effort, including a continuum of effort levels, would not substantially change the results. Effort costs are normalized as:

$$
\begin{aligned}
z(1) &= 1 \\
z(0) &= 0
\end{aligned}
$$

Like the assumption of a finite number of income levels, the following assumption is required for Grossman and Hart's approach to the moral hazard to be valid:

Assumption 5c *For every feasible level of promised utility u, there exists a feasible transfer schedule $\{\tau_{r1}(u)\}$ that that delivers, in expectation, exactly $u + z(1)$, gross of effort costs, when high effort is exerted, and a feasible transfer schedule $\{\tau_{r0}(u)\}$ that delivers exactly $u + z(0)$ in expectation when low effort is exerted. The first schedule satisfies the "promise-keeping" constraint for an agent with promised utility u who is assigned high effort ($e = 1$), and the second satisfies the promise-keeping constraint for an agent with promised utility u who is assigned low effort ($e = 0$).*

Since the main result for the moral hazard and limited commitment models is that a single lag of inverse marginal utility is sufficient to capture the extent to which history has influenced what the household is promised, a natural question is whether this relies on a "memoryless" production process, with income *i.i.d.*

---

[4]For instance, in the context of Thailand, income could take any one-baht increment from zero to one million baht.

across time. In fact, allowing the distribution of income to depend on actions taken by the household in the past does not overturn this result. To make this point, I make the following assumption:

Assumption 5d *The distribution of income at time t is affected by household's effort at time t and at time $t-1$:*[5]

$$\Pr(y_t = y_r) = \Pr(y_r | e_t, e_{t-1})$$

Define $p_{ree'} \equiv \Pr(y_r | e_t = e, e_{t-1} = e')$, the probability of income realization y_r when an effort level e is exerted in the current period and e' was exerted in the last period. So, p_{r11} is the probability of output level y_r if high effort was exerted in the current period the and previous period, etc. The next assumption (full support of output under high or low effort) rules out schemes that achieve full insurance by punishing the household severely if a level of output occurs that is impossible when the recommended effort is followed:

Assumption 5e *Each of the S income realizations occurs with positive probability under either high or low effort:*

$$p_{ree'} \in (0,1), \forall e, e', r$$

Finally, so that there may be a nontrivial moral hazard problem if effort is not observable, I make the assumption that surplus (expected output less effort costs) is higher when households exert effort than when they do not:

Assumption 5f *Effort raises expected surplus:*

$$\sum_{r=1}^{S} \left[p_{r11} - p_{r01} \right] y_r > \sum_{r=1}^{S} \left[p_{r10} - p_{r00} \right] y_r \geq z(1) - z(0)$$

Having set out the environment, I will briefly characterize the benchmark cases full insurance and pure borrowing-saving before introducing the constraints which may lead to incomplete interpersonal insurance.

3.2   Full insurance

We can find the set of first-best allocations by considering the problem of a hypothetical risk-neutral planner who maximizes the utility of villager N such that each villager 1 to $N-1$ gets at least a value u_{it} in period t. Let $\mathbf{u}_t \equiv \{u_{it}\}_{i=1}^{N-1}$ be the vector of time t utility promises and $\mathbf{e}\prime \equiv \{e_{i,t-1}\}_{i=1}^{N-1}$ be the vector efforts that were exerted at time $t-1$. The state variables of the planner's problem are $\mathbf{u}_t, \mathbf{e}', a_t$. The planner chooses effort recommendations e_{it}, transfers τ_{irt}, and future promises $u_{ir,t+1}$ for each villager. Transfers, which are equal to the difference between a household's income and its consumption, $\tau_{irt} \equiv c_{irt} - y_r$; and future promises, which summarize the utility the household can expect from next period onward (Spear and Srivastava 1987); are indexed by r because they may be income-contingent (though the dependence of promised utility $u_{ir,t+1}$ on the income realization y_r will be degenerate in the case of full insurance

---

[5] Allowing more than one lag of effort to influence the distribution of output would further complicate the notation, but would not change the results. Golosov et al. (2003) show that an Inverse Euler equation relationship is obtained in a wide variety of adverse selection economies with very general production functions.

while the dependence of the transfer τ_{irt} on the income realization will be degenerate in the case of pure borrowing-saving). The planner's value function is:

$$u_N(\mathbf{u}_t, a_t, \mathbf{e}') \equiv \max_{\mathbf{e}, \{\boldsymbol{\tau}_{rt}\}, \{\mathbf{u}_{r,t+1}\}} \tag{1}$$

$$\sum_{r=1}^{S} p_{ree'} v(y_r + \tau_{Nrt}) - z(e_N) + \beta \mathbb{E}_{\{y\}} u_N(\mathbf{u}_{t+1}, a_{t+1}, \mathbf{e})$$

subject to the promise-keeping constraints that each household 1 to $N-1$ must get their promised utility u_{it} (in expectation):

$$\sum_{r=1}^{S} p_{ree'} [v(y_r + \tau_{irt}) - z(e_i) + \beta u_{ir,t+1}] = u_{it}, \forall i < N \tag{2}$$

and the law of motion for assets:

$$a_{t+1} = R \left[a_t - \sum_{i=1}^{N} \tau_{irt} \right] \tag{3}$$

Let the multiplier on household i's time t promise-keeping constraint be λ_{it} and the multiplier on the village's time t budget constraint be η_{it}.

As is well known, absent problems of commitment or information, every village member's consumption is independent of their own income realization, given aggregate village resources. Therefore we have

Proposition 1 *Under full insurance, (a) realized household income has no effect on household consumption, given village aggregate consumption, and (b) with no preference heterogeneity and a common discount factor, households never change place in the village consumption distribution.*

Proof. *In Appendix A.* ■

In summary, full insurance predicts a complete decoupling of idiosyncratic income shocks and consumption changes. Since this implication fails to hold in virtually every dataset where it has been tested, the next question is how to distinguish among models that do predict a correlation between income shocks and consumption changes. I will first discuss the other benchmark case of no interpersonal insurance (borrowing and saving only) and then the moral hazard, limited commitment and hidden income models.

3.3 Borrowing-saving only (PIH)

Hall (1978) showed that, when households discount the future at rate β and can save and borrow at rate R, but have access to no interpersonal or state-contingent assets, marginal utility follows a random walk (even if income is correlated over time):

$$\mathbb{E}_{t-1} u'(c_t) = \beta R u'(c_{t-1}) \tag{4}$$

An implication of the Euler equation (4) characterizing the path of consumption under a pure borrowing-saving model is that, once lagged marginal utility $u'(c_{t-1})$ is controlled for, no other information dated $t-1$

or before should predict current marginal utility. Borrowing and saving allows the household to smooth its path of consumption independent of the timing of receipt of expected income (appropriately discounted). Unanticipated innovations to income are smoothed optimally over time (but not across households), starting from the time they are realized, so there is no tendency for consumption to revert to its pre-innovation mean: a household that receives a negative income shock with have lower expected consumption (higher expected marginal utility) permanently thereafter.

As discussed below, optimal moral hazard- and limited commitment-constrained insurance lead to the implication that, conditional on last period's *inverse* marginal utility, no other lagged information should predict current inverse marginal utility. These implications (sufficiency of marginal utility vs. sufficiency of inverse marginal utility) will not be distinguishable with isoelastic or nonparametrically estimated utility. With isoelastic utility, in a log specification sufficiency of the proposed statistic under limited commitment and moral hazard, $\ln\left(\frac{1}{u'(c_{i,t-1})}\right) = \rho \ln c_{i,t-1}$, cannot be distinguished from sufficiency of the proposed statistic under under borrowing-saving, $\ln u'(c_{i,t-1}) = -\rho \ln c_{i,t-1}$. With nonparametrically estimated utility, both implications reduce to the requirement that there exists a function $f(c_{i,t-1})$ conditional on which no other lagged information predicts $f(c_{it})$. However, if sufficiency of (inverse) marginal utility is not rejected, it is possible to test among borrowing-saving, moral hazard and limited commitment using other implications, discussed below.

3.4 Moral hazard

The moral hazard model has been widely used to explain imperfect insurance in developing and developed countries. Under a moral hazard model, the agent must be given incentives to do something—such as exert effort or invest—which cannot be directly observed or contracted on. The action occurs before output is realized and affects the expected level of output. Introducing incentive compatibility constraints to the optimal insurance setup implies that Proposition 1 no longer necessarily holds. With two effort levels, and a utility function separable in consumption and effort, the incentive-compatibilty constraint will be binding at the optimum (Grossman and Hart 1983). The constraint is:

$$\sum_{r=1}^{S} p_{r11}[v\left(y_r + \tau_{irt}\right) + \beta u_{ir,t+1}] - z(1) = \sum_{r=1}^{S} p_{r01}[v\left(y_r + \tau_{irt}\right) + \beta \hat{u}_{ir,t+1}]$$

i.e. the household must expect the same level of surplus (net of effort costs $z(1)$) if it exerts effort in the current period as the household expects if it shirks (and pays no effort cost).[6]

The inverse Euler equation implication[7] of moral hazard-constrained insurance (Rogerson 1985) has been

---

[6] The constraint is written for a household that exerted effort in the previous period (i.e., the household compares the probabilities p_{r11} with the probabilities p_{r01}, both of which reflect having exerted effort in the previous period) since by Assumption 5f effort raises expected surplus and so households will exert effort along the equilibrium path; the constraints which ensure this are discussed below.

[7] The Inverse Euler equation implies that inverse marginal utility follows a random walk: $\frac{1}{v'(c_{i,t-1})} = \beta R \mathbb{E}_{t-1}\left(\frac{1}{v'(c_{it})}\right)$.

used to test the moral hazard model against the PIH, which predicts a standard Euler equation. The moral hazard model considered by Rogerson assumed that the distribution of time t output was affected only by the agent's effort at time t. However, Fernandes and Phelan (2000) show that when the distribution of income depends on past as well as current effort, the moral hazard problem still has a recursive formulation, with two[8] additional "threat-keeping" constraints added to the planner's problem. These constraints enforce an upper bound on a household's expected utility from today on if the household disobeyed yesterday's effort recommendation, whether they obey or disobey today. The constraint requiring that, if the household disobeyed (shirked) yesterday but obeys (works) today (so that the relevant probabilities are p_{r10}), it does not expect higher utility than $\hat{u}_{it}$, is:

$$\sum_{r=1}^{S} p_{r10}[v(y_r + \tau_{irt}) - z(1) + \beta u_{ir,t+1}] \leq \hat{u}_{it}$$

The constraint requiring that, if the household disobeyed yesterday *and* disobeys today (shirking in both periods, so that the relevant probabilities are p_{r00}), it does not expect higher utility than $\hat{u}_{it}$, is:

$$\sum_{r=1}^{S} p_{r00}[v(y_r + \tau_{irt}) - z(0) + \beta \hat{u}_{ir,t+1}] \leq \hat{u}_{it}$$

Using Fernandes and Phelan's recursive setup, I show in Appendix A that the inverse Euler equation also holds under moral hazard even if the distribution of output depends on actions taken in past periods as well as the current period.[9] Therefore, a single lag of inverse marginal utility (LIMU) is a sufficient statistic in forecasting current inverse marginal utility, even with such technological linkages between periods:

Proposition 2 *When insurance is constrained only by moral hazard, conditional on the time t shadow price of resources η_t, LIMU $\left(\frac{1}{u'(c_{i,t-1})}\right)$ is a sufficient statistic for household i's time t inverse marginal utility.*
Proof. *In Appendix A.* ■

We obtain the result that, conditional on η_t, time $t-1$ inverse marginal utility is a sufficient statistic for all $t-1$ information for forecasting time t consumption because in the moral hazard-constrained model (and in the limited commitment model discussed below), income is observed. As a result, the planner or community directly controls consumption and marginal utility. Moreover, the temptation preventing full insurance (in this case, the temptation to shirk) is evaluated at the same levels of consumption and marginal utility that the household actually realizes in equilibrium. Therefore, expected marginal utility can be expressed as a function of the past only via lagged inverse marginal utility. It will turn out that this property also holds under limited commitment, another workhorse model of incomplete informal insurance.

---

[8] If there are N effort levels instead of 2, there are $N(N-1)$ threat-keeping constraints, but the solution method is unchanged.
[9] Golosov et al. (2003) show a similar result for adverse selection economies with very general production functions; see note 5.

3.5 Limited commitment

If an agent can walk away from the insurance network at any time if he can do better in autarky, Proposition 1 no longer necessarily holds (Coate and Ravallion 1993). Limited commitment imposes further constraints on the planner's problem (1), which is now subject to the promise-keeping constraints (whose multipliers are λ_{it}), the budget constraint (with multiplier η_{it}) and the participation constraints that the expected utility an agent gets in the insurance network be at least as great as the expected utility he could achieve in autarky, choosing his own savings and effort optimally. That is, a household will only remain in the network if

$$v(y_r + \tau_{irt}) + \beta u_{ir,t+1} \geq u_{aut}(y_r, e), \forall i, r \tag{5}$$

where

$$
\begin{aligned}
u_{aut}(y_r, e) \quad \equiv \quad & \max_{s_t, e_{t+1}} v(y_r - s_t) - \beta z(e_{t+1}) \\
& + \beta \mathbb{E}\left[u_{aut}(y_{t+1} + R's_t)|e_{t+1}, e\right]
\end{aligned}
$$

3.5.1 Sufficiency of lagged inverse marginal utility

Kocherlakota (1996) showed that, under limited commitment, the vector of lagged marginal utility ratios for every member of the insurance group,

$$\left\{ \frac{v'(c_{N,t-1})}{v'(c_{i,t-1})} \right\}_{i=1}^{N-1}$$

is a sufficient statistic for history when forecasting any household's consumption. This vector specifies a unique point on the Pareto frontier and therefore captures all relevant information in forecasting any households' future consumption. However, Kocherlakota's result is not directly testable if the econometrician does not have information on all the members of the insurance group. Since consumption and income data generally come from surveys, rather than censuses, the test has limited empirical applicability. In Kocherlakota's setting, the need to keep track of the past consumption of every member of the insurance network in order to forecast any member's current consumption arises due to the assumption that the village as a whole cannot borrow or save. If the village can borrow and save, the shadow price of resources at time t serves as a summary measure of how much consumption must be given to other households in the village. In this case, we have the following result, which is testable with panel data for only a sample of households in a network.

Proposition 3 *With village-level credit access, conditional on the time t shadow price of resources η_t, household i's LIMU $\left(\frac{1}{v'(c_{i,t-1})}\right)$ is a sufficient statistic for household i's time t inverse marginal utility under limited commitment. When i's participation constraint binds, i's current and expected future consumption are increasing in i's income.*

Proof. *In Appendix A.* ∎

The intuition for this result is that, when the only barrier to full insurance is the fact that the household can walk away when income is high, the principal can allocate consumption to a household who is tempted to walk away without affecting the incentive of any other household to stay in the network, except through the tightness of the village's budget constraint. The constrained household gets current consumption and a future promise that make it exactly indifferent between staying in or leaving the network. At the optimum, providing a household with utility in the current period (through current consumption c_{it}) should be exactly as effective as providing promised utility in the future (through the utility promise $u_{i,t+1}$). Therefore, the Lagrange multiplier on the household's promise-keeping constraint uniquely describes the efficient combination of $c_{it}, u_{i,t+1}$. Moreover, under limited commitment the household's lagged inverse marginal utility fully captures the Lagrange multiplier on the promise-keeping constraint. So LIMU $\left(\frac{1}{v'(c_{i,t-1})}\right)$ captures all the information from time $t-1$ and earlier that is relevant in predicting household i's time t consumption, c_{it}. The need to control for the time t shadow price of resources, η_t, arises because η_t captures the "size of the pie" at time t, while $\frac{1}{v'(c_{i,t-1})}$ captures the share of that pie that will, in expectation, go to household i.

Since, as discussed above, the same sufficiency result is obtained under moral hazard (with the additional, stronger implication of an Inverse Euler equation), and with isoelastic or nonparametrically estimated utility an indistinguishable result holds under the PIH[10], if we are unable to reject sufficiency of LIMU in a given setting, this does not tell us whether limited commitment, moral hazard, or borrowing-saving is a more plausible alternative. Thus, before moving on to discuss hidden income, I discuss a stronger implication of limited commitment that would allow a researcher to distinguish limited commitment from moral hazard and borrowing-saving in the case that sufficiency of LIMU is not rejected.

3.5.2 Amnesia

A stronger implication of limited commitment, which does not hold under moral hazard or borrowing-saving, is what Kocherlakota calls "amnesia." As noted above, when limited commitment binds for household i, consumption c_{irt} and promised future utility $u_{ir,t+1}$ are pinned down by the requirement that the household be just indifferent between staying in and leaving the network, and that the utility value of current and future consumption be equated at the margin:

$$v(y_r + \tau_{irt}) + \beta u_{ir,t+1} = u_{aut}^t(y_r)$$

$$v'(y_r + \tau_{irt}) = -\left(\frac{\partial u_N(\mathbf{u}_{r,t+1})}{\partial u_{ir,t+1}}\right)^{-1}$$

independent of the time t promised value u_{it}. Thus the household's old promised value, u_{it}, is "forgotten" when limited commitment binds. Kocherlakota suggests the following procedure to test for amnesia: find the

---

[10] As discussed in section 3.3, in a log specification with isoelastic utility sufficiency of the proposed statistic under limited commitment and moral hazard, $\ln\left(\frac{1}{u'(c_{i,t-1})}\right) = \rho \ln c_{i,t-1}$, cannot be distinguished from sufficiency of the proposed statistic under under borrowing-saving, $\ln u'(c_{i,t-1}) = -\rho \ln c_{i,t-1}$. With nonparametrically estimated utility, both implications reduce to that there exists a function $f(c_{i,t-1})$ conditional on which no other lagged information predicts $f(c_{it})$.

network member(s) with the lowest growth in consumption between periods $t-1$ and t. Ignoring measurement error in consumption for now (see Section 6), define

$$B_t \equiv \min_{i=1,\ldots,N} v'(c_{i,t-1})/v'(c_{it})$$

Those for whom $v'(c_{i,t-1})/v'(c_{it}) > B_t$, by construction, had binding limited commitment constraints— otherwise their consumption would have been fully smoothed between periods $t-1$ and t. Those with $v'(c_{i,t-1})/v'(c_{it}) = B_t$ were not constrained, and therefore did achieve full intertemporal consumption smoothing. Define the sets of constrained and unconstrained households

$$
\begin{aligned}
C_t &\equiv \{i : v'(c_{i,t-1})/v'(c_{it}) > B_t\} \\
U_t &\equiv \{i : v'(c_{i,t-1})/v'(c_{it}) = B_t\}
\end{aligned}
$$

Amnesia implies that, for any constrained household $i \in C_t$, LIMU $\left(\frac{1}{v'(c_{i,t-1})}\right)$ should not predict current consumption c_{it}, given current income y_{jt}. That is, if we estimate the regression

$$\ln c_{it} = \alpha_1 \ln c_{i,t-1} + \alpha_2 \ln y_{it} + \delta_v + \varepsilon_{it} \tag{6}$$

for those households $i \in C_t$, limited commitment implies, since the households are constrained, $\alpha_1 = 0$: the old promises are forgotten. This test is implemented, and the results discussed, in Section 6.

The result that, when insurance is constrained by either limited commitment or moral hazard, the village's current shadow cost of resources and a household's LIMU should together be a sufficient statistic for the past in forecasting the household's current inverse marginal utility, arises because in these models (unlike the hidden income model) income is observed, so the community can effectively control consumption by controlling income-contingent transfers. As a result, there is no deviation from the optimal division of promised utility across periods—utility in the current period (via transfers) and utility in future periods (via promised utility) are equally valuable to the household.

3.6   Hidden income

As well as issues of *ex ante* information (moral hazard) and of limited commitment, *ex post* informational asymmetries may also restrict the type of (implicit or explicit) contracts that agents can enter into, and thereby restrict insurance. Namely, it may be that income is not observable by the community, and households must be given incentives to report it (Townsend 1982). It turns out that such *ex post* informational asymmetries cause the sufficiency result of limited commitment and moral hazard to break down.

Assume now that agents can commit to the insurance arrangement and that effort is observable. However, household income is not observable by other households. Potentially $S(S-1)$ incentive-compatibility

constraints are added to the planner's problem:

$$v(y_r + \tau_{irt}) + \beta u_{ir,t+1} \geq v(y_r + \tau_{ir',t}) + \beta u_{ir',t+1}$$

$$r' \in \mathcal{S} \backslash y_r$$

These constraints require that a household realizing any of the S income levels must not gain by claiming any of the $S - 1$ other possible levels. However, Thomas and Worrall (1990) show that only the $S - 1$ local downward constraints, which require that an agent getting income y_r not prefer to claim the slightly lower income y_{r-1}, will be binding at the optimum. These constraints are:

$$v(y_r + \tau_{irt}) + \beta u_{ir,t+1} = v(y_r + \tau_{i,r-1,t}) + \beta u_{i,r-1,t+1},$$

$$r = 2, ..., S$$

The first-order conditions of the problem imply:

Proposition 4 *When agents can commit to the insurance agreement, and effort is contractible, but output is hidden, forecasts using only $\frac{1}{v'(c_{i,t-1})}$ and η_t will over-predict consumption for households with the lowest time $t-1$ income realizations, and the degree of overprediction will decline with the level of time $t-1$ income (controlling for an interaction between time $t-1$ income and the aggregate shock η_t).*

Proof. *In Appendix A.* ∎

The intuition for this difference between hidden income on one hand, and limited commitment and moral hazard on the other is that, in the limited commitment and moral hazard cases, the temptation of a household with high output to claim a lower level of output is not a relevant constraint, and as a result there is no deviation from the optimal division of promised utility across periods–utility in the current period (via transfers) and utility in future periods (via promised utility) are equally valuable to the household. As a result, all past information relevant to forecasting current consumption is encoded in last period's consumption. When income is private information, in contrast, consumption is not effectively controlled by the community, and the constrained-optimal schedule of transfers and promised utilities distorts the tradeoff between current consumption and future expected utility, with households announcing low incomes being penalized more in terms of future utility, which is equally valuable to truthful and misreporting households, than current consumption, which is more valuable to truthful households, who have lower income than households who are tempted to falsely claim the same level of income.

Aggregate risk may matter because if the network receives a positive income shock, there is a potentially countervailing effect: all agents consume more than would have been predicted using past marginal utility, and the aggregate shock is divided unequally between high- and low-past income households. (In the limited commitment and moral hazard cases, on the other hand, lagged inverse marginal utility is the only past information which determines how the aggregate shock is divided among households. Scheuer (2009) discusses

the implications of aggregate risk in the moral hazard case.)

Therefore, under hidden income, estimating (10) should lead to $\hat{\zeta} \neq 0$, since $\ln y_{i,t-1}$ has predictive power in forecasting current inverse marginal utility not captured in LIMU. A further implication of the hidden income model is that, if the residuals defined in (11) are regressed on lagged income:

$$\hat{\varepsilon}_{it} = \alpha + \beta \ln y_{i,t-1} + u_{it} \tag{7}$$

we should find $\alpha < 0, \beta > 0$, because the residuals will be negative at the lowest levels of past income ($\alpha < 0$) and the residuals will be increasing in past income ($\beta > 0$). On the other hand, if we are unable to reject $\alpha = \beta = 0$, this is evidence for either limited commitment, moral hazard or borrowing-saving, which can then be distinguished based on the amnesia test discussed above, the inverse Euler equation implication of moral hazard, and the Euler equation implication of the PIH. The results of this test are discussed in Section 6.

3.6.1 An additional implication of hidden income: insufficiency of LIMU is less when income is less variable

An additional prediction of the hidden income model is that a reduction in the variability of a household's income process will have the effect of making truth-telling constraints less binding, which in turn implies a reduced wedge between LIMU and expected promised utility:

Proposition 5 *A decrease in variability of the income process (in the sense of that the new distribution is second-order stochastically dominated by the old distribution, keeping the probability of each income realization the same) reduces the degree to which LIMU over-predicts current inverse marginal utility for low-lagged income households.*

Proof. *In Appendix A.* ∎

The intuition for this result is that, the less uncertainty about a household's income, the less binding are truth-telling constraints. Since the truth-telling constraints are the cause of the wedge between LIMU and expected promised utility, relaxing the constraints reduces the wedge. Therefore, if one household's income process is more predictable than another's, the household with more predictable income should exhibit a reduced degree of overprediction at the bottom. The results of this test are also discussed in Section 6.

4 Distinguishing barriers to insurance

4.1 Testable implication of limited commitment or moral hazard

The fact that, under either limited commitment or moral hazard, all past information relevant to forecasting current consumption is encoded in last period's consumption implies that the prediction errors

$$\hat{\varepsilon}_{it}^* \equiv \frac{1}{v'(c_{it})} - \mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{\eta_t}{v'(c_{i,t-1})}\right) \tag{8}$$

should be uncorrelated with past income, a finding that contrasts with the prediction of the hidden income model discussed below. Of course, implementing this test requires assuming or estimating a functional form for $v()$. A natural starting point is the constant relative risk aversion (CRRA) function. There is some empirical evidence that the CRRA function provides a good fit for actual behavior (Szpiro 1986); moreover Schulhofer-Wohl (2006) shows that CRRA can be viewed as a local approximation to any concave utility function. With CRRA utility with coefficient of relative risk aversion ρ, the utility function is:

$$v(c_{it}) = \begin{cases} \frac{c_{it}^{1-\rho}}{1-\rho} \text{ if } \rho \neq 1 \\ \ln(c_{it}) \text{ if } \rho = 1 \end{cases}.$$

Since the coefficient of relative risk aversion ρ is unknown, ideally the test would be implemented in a way that did not depend on assuming a particular value of ρ. One implication of no correlation between the prediction errors (8) and $y_{i,t-1}$ is that the prediction errors are not systematically high for high (low) values of $y_{i,t-1}$ and systematically low for low (high) values of $y_{i,t-1}$, an implication that is preserved by taking a monotonic transformation of (8). That is, we can test whether the transformed prediction errors

$$\hat{\varepsilon}_{it}^{**} \equiv \ln \frac{1}{v'(c_{it})} - \mathbb{E}\left(\ln \frac{1}{v'(c_{it})}\Big|\ln \frac{1}{v'(c_{i,t-1})}, \ln \eta_t\right)$$

are uncorrelated with past log income.

When utility is CRRA,

$$\ln\left(\frac{1}{v'(c_{i,t-1})}\right) = \rho \ln c_{i,t-1}$$

so the value of $\rho > 0$ will not affect the sign of $\hat{\varepsilon}_{it}^{**}$. Since $\ln \eta_t$ enters additively, it can be controlled for by adding a village-year effect δ_{vt}. Then, expected inverse marginal utility $\mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{1}{v'(c_{i,t-1})}, \eta_t\right)$ is proportional to the predicted value from the regression

$$\ln c_{ivt} = \gamma \ln c_{iv,t-1} + \delta_{vt} + \varepsilon_{ivt}. \tag{9}$$

Sufficiency of LIMU implies that if we add $\ln y_{i,t-1}$ (or any other variable dated $t-1$ or earlier) to (9) and

estimate

$$\ln c_{ivt} = \gamma \ln c_{iv,t-1} + \zeta \ln y_{i,t-1} + \delta_{vt} + \varepsilon_{ivt} \tag{10}$$

we should be unable to reject $\hat{\zeta} = 0$. Another way to test the sufficiency implication is to test whether the residuals

$$\hat{\varepsilon}_{it} \equiv \ln c_{ivt} - \hat{\gamma} \ln c_{iv,t-1} - \hat{\delta}_{vt} \tag{11}$$

are uncorrelated with $\ln y_{i,t-1}$ or any other variable dated $t-1$ or earlier. The results of the regression-based test using (10) and the results of the residuals-based test using (11) are discussed in Section 6.[11]

However, two further empirical issues must be considered in distinguishing among different insurance regimes: agents' utility functions are not known, and consumption is measured with error. Both of these, if not accounted for, can result in biased inference about the nature of the barrier to full insurance.

4.2 Measurement Error in Expenditure

4.2.1 Classical measurement error

If expenditure is measured with classical error, the estimated coefficient on LIMU in (7) will be attenuated toward zero. This will result in biased predictions of consumption using LIMU. To see what form the bias will take, note that we want to estimate the part of consumption that is unexplained by LIMU and village-year effect:

$$\varepsilon_{ivt} = \ln c_{ivt} - \delta_{vt} - \gamma \ln c_{iv,t-1} \tag{12}$$

Assume an error-ridden measure of consumption is observed,

$$\tilde{c}_{iv,t-1} = c_{iv,t-1} \cdot \nu_{iv,t-1}$$

where the measurement error $\nu_{iv,t-1}$ is uncorrelated with true time $t-1$ consumption, $c_{iv,t-1}$, or true time t consumption, c_{ivt}. The estimated prediction error is constructed using observed lagged consumption $\tilde{c}_{iv,t-1}$, and the estimates of γ and δ:

$$\hat{\varepsilon}_{ivt} = \ln c_{ivt} - \hat{\delta}_{vt} - \hat{\gamma} \ln \tilde{c}_{iv,t-1}$$

Assume the true data-generating process is insurance constrained by limited commitment or moral hazard, so that LIMU is in fact a sufficient statistic for forecasting current inverse marginal utility. Then, the forecast error (12) will be uncorrelated with lagged income:

$$\mathbb{E} \underbrace{(\ln c_{ivt} - \gamma \ln c_{iv,t-1} - \delta_{vt})}_{\text{"true" residual } \varepsilon_{ivt}} y_{iv,t-1} = 0 \tag{13}$$

---

[11]Estimating (8) for various values of ρ leads to similar conclusions as tests using (11); results available on request.

However, if γ is estimated by OLS, the null hypothesis (13) may potentially be incorrectly rejected, because $\hat{\gamma}$ is biased downward:

$$p\lim \hat{\gamma} = \gamma \left(1 - \frac{\sigma_\nu^2}{\sigma_c^2 + \sigma_\nu^2} \right)$$

The estimated residual is then positively correlated with lagged income, because fraction $\frac{\sigma_\nu^2}{\sigma_c^2 + \sigma_\nu^2}$ of current log consumption is incorrectly not projected onto lagged log consumption, and this term is correlated with lagged income (because under either limited commitment or moral hazard, contemporaneous income and consumption are positively correlated):

$$
\begin{aligned}
\hat{\varepsilon}_{ivt} &= \ln c_{ivt} - \hat{\delta}_{vt} - \hat{\gamma} \ln \tilde{c}_{iv,t-1} \\
p\lim \hat{\varepsilon}_{ivt} &= \ln c_{ivt} - \hat{\delta}_{vt} - \gamma \left(1 - \frac{\sigma_\nu^2}{\sigma_c^2 + \sigma_\nu^2} \right) \ln \tilde{c}_{iv,t-1} \\
&= \underbrace{\ln c_{ivt} - \hat{\delta}_{vt} - \gamma \ln \tilde{c}_{iv,t-1}}_{\text{uncorrelated w/ } y_{iv,t-1}} + \underbrace{\frac{\sigma_\nu^2}{\sigma_c^2 + \sigma_\nu^2} \gamma \ln \tilde{c}_{iv,t-1}}_{+ \text{ correlated w/ } y_{iv,t-1}}
\end{aligned}
$$

That is, we may conclude wrongly that $corr(\hat{\varepsilon}_{ivt}, y_{iv,t-1}) > 0$, that is, that LIMU is not a sufficient statistic, when consumption is measured with classical error, because lagged income is then in effect a second proxy for true LIMU.

However, for classical error, there is a straightforward solution. If γ is estimated using the second lag of consumption as an instrument for the first lag, we obtain a consistent estimate of γ:

$$
\begin{aligned}
p\lim \hat{\gamma}^{IV} &= \frac{cov(\ln \tilde{c}_{iv,t-2}, \ln \tilde{c}_{ivt})}{cov(\ln \tilde{c}_{iv,t-2}, \ln \tilde{c}_{iv,t-1})} \\
&= \gamma \left(1 - \underbrace{\frac{cov(\nu_{t-2}, \nu_{t-1})}{cov(\ln \tilde{c}_{iv,t-2}, \ln \tilde{c}_{iv,t-1})}}_{=0} \right)
\end{aligned}
$$

Then, the probability limit of the residual is

$$
\begin{aligned}
p\lim \hat{\varepsilon}_{ivt}^{IV} &= \ln \tilde{c}_{ivt} - \hat{\delta}_{vt} - \gamma \ln \tilde{c}_{iv,t-1} \\
&= \ln c_{ivt} + \ln \nu_{ivt} - \hat{\delta}_{vt} - \gamma \left(\ln c_{iv,t-1} + \ln \nu_{iv,t-1} \right)
\end{aligned}
$$

Rearranging,

$$p\lim \hat{\varepsilon}_{ivt}^{IV} = \underbrace{\ln c_{ivt} - \gamma \ln c_{iv,t-1} - \delta_{vt}}_{\text{``true'' residual}} + \underbrace{\ln \nu_{ivt}}_{\text{meas. error in } c_{ivt}} - \underbrace{\gamma \ln \nu_{iv,t-1}}_{\text{meas. error in } c_{iv,t-1}}$$

Under the hypothesis that true lagged inverse marginal utility ($\ln c_{iv,t-1}$) is a sufficient statistic, the "true" residual (12) is uncorrelated with lagged income. Moreover, if the measurement error in (log) consumption

is classical, $\ln \nu_{ivt}$ and $\ln \nu_{iv,t-1}$ are also uncorrelated with lagged income:

$$corr(\ln \nu_{ivt}, y_{iv,t-1}) = corr(\ln \nu_{iv,t-1}, y_{iv,t-1}) = 0$$

Therefore, with classical measurement error and a true data-generating process of limited commitment or moral hazard, instrumenting the first lag of consumption with the second lag of consumption will lead to the correct conclusion:

$$p \lim \hat{\varepsilon}_{ivt}^{IV} y_{iv,t-1} = 0.$$

4.2.2 Non-classical measurement error

Using the second (or longer) lag of consumption as an instrument will not address non-classical measurement error which is correlated over time. A possible solution in this case is to move lagged consumption from the right- to the left-hand side of the equation of interest, and test overidentifying restrictions on the reduced form equations for $\ln c_{it}$ and $\ln c_{i,t-1}$. If lagged income affects current consumption only through lagged consumption, then all components of lagged income, or any other lagged information $x_{i,t-s}$ which predicts lagged income, should satisfy the restriction

$$\frac{d \ln c_{it}}{dx_{i,t-s}} \Big/ \frac{d \ln c_{i,t-1}}{dx_{i,t-s}} = K, \forall x_{i,t-s}$$

That is, a unit change in an instrument $x_{i,t-s}$ should have the same relative effect on current versus lagged consumption as a unit change in another instrument $x'_{i,t-s}$.

Under the null of limited commitment/moral hazard, consumption depends on a household's initial Pareto weight and its subsequent income realizations. (Under limited commitment or moral hazard, lagged income does not belong in the structural equation for consumption, but it appears in the reduced form because y_{is} depends on c_{is}.) Three lags of income are significant predictors of c_{it}, so write

$$\ln c_{it} = \sum_{s=1}^{3} \alpha_s y_{i,t-s} + \hat{\lambda}_0 + \varepsilon_{it}$$

where $\hat{\lambda}_0$ is a measure of the household's Pareto weight as of 1999: the household's rank in the 1999 per-capita consumption distribution for the village.

Since lagged income appears in the reduced form for consumption, lags of total income cannot be used to generate overidentifying restrictions. Instead, I test whether the *composition* of lagged income matters for predicting current consumption, beyond its effect on lagged consumption. In particular, I test whether income from crop cultivation matters differently than income from raising livestock or fish and shrimp. If crops are more homogenous than animals, less susceptible to difficult-to-verify disease, or simply easier to observe by virtue of growing in a fixed location rather than being mobile, reporting low income from animal cultivation may result in a greater wedge between current and future utility than reporting low income

from crop cultivation. That is, animal cultivation income would be associated with high contemporaneous consumption relative to future consumption, while crop cultivation income would be associated with lower contemporaneous consumption relative to future consumption. This would not be the case under the other models of incomplete insurance. While different types of income may convey different information about effort, or different information about the household's prospects in autarky, under limited commitment or moral hazard that information will be completely encoded in consumption. Under hidden income, in contrast, the components of income will also matter through the direct effect of lagged income on current consumption. So in the reduced-form regressions

$$\ln c_{it} = \sum_{s=1}^{3} [\pi_{1Cs} y_{i,t-s}^{crops} + \pi_{1Ls} y_{i,t-s}^{livestock}] + \hat{\lambda}_{i0} + \varepsilon_{it}$$

$$\ln c_{i,t-1} = \sum_{s=1}^{3} [\pi_{2Cs} y_{i,t-s}^{crops} + \pi_{2Ls} y_{i,t-s}^{livestock}] + \hat{\lambda}_{i0} + \varepsilon_{i,t-1}$$

and

$$\ln c_{it} = \sum_{s=1}^{3} [\pi_{1Cs} y_{i,t-s}^{crops} + \pi_{1Fs} y_{i,t-s}^{fish}] + \hat{\lambda}_{i0} + \varepsilon_{it}$$

$$\ln c_{i,t-1} = \sum_{s=1}^{3} [\pi_{2Cs} y_{i,t-s}^{crops} + \pi_{2Fs} y_{i,t-s}^{fish}] + \hat{\lambda}_{i0} + \varepsilon_{i,t-1}$$

if the first lag of income does not directly affect current consumption, we should find

$$\frac{\pi_{1C1}}{\pi_{2C1}} = \frac{\pi_{1L1}}{\pi_{2L1}}$$

and

$$\frac{\pi_{1C1}}{\pi_{2C1}} = \frac{\pi_{1F1}}{\pi_{2F1}}$$

These overidentifying restrictions can be used to test whether the rejection of limited commitment is only due to measurement error.

4.3 Specification of u()

The test of hidden income proposed above is to test whether $\varepsilon_t \perp y_{t-1}$ in

$$\ln\left(\frac{1}{v'(c_t)}\right) = \delta_t + \ln\left(\frac{1}{v'(c_t)}\right) + \varepsilon_t \tag{14}$$

However, since the form of $v()$ is unknown, the approach above was to approximate it with the isolelastic function

$$v(c_{it}) = \frac{c^{1-\rho}}{1-\rho}$$

$$\ln\left(\frac{1}{v'(c_t)}\right) = \rho \ln(c_{it})$$

and test $\hat{\varepsilon}_t \perp y_{t-1}$ in

$$\ln(c_{it}) = \delta_{vt} + \ln(c_{t-1}) + \hat{\varepsilon}_t \tag{15}$$

This raises the question, if the true error ε_t satisfies $\varepsilon_t \perp y_{t-1}$ in (14), will testing $\hat{\varepsilon}_t \perp y_{t-1}$ in (15) yield the correct conclusion? Nonparametrically estimating $\frac{1}{v'(c)}$ avoids the need to make an assumption about the form of the utility function. In order to correct for measurement error as well, a nonparametric IV approach seems most appropriate.

One possible approach would be to use the nonparametric 2SLS approach of Newey and Powell (2003) to estimate

$$f(c_{it}) = f(\tilde{c}_{t-1}) + \delta_{vt} + \hat{\varepsilon}_t$$

where $\tilde{c}_{t-1}$ is estimated using a nonparametric first stage with c_{t-2} as an instrument. However, consistency of this estimator requires that $f()$ and its derivatives are bounded in the tails, if $\tilde{c}_{t-1}$ is not bounded. Since in this context $f()$ is an inverse marginal utility function which may tend to infinity as consumption tends to infinity, this is an unappealing assumption in this context. Newey and Powell's approach also requires the conditional mean zero assumption:

$$\mathbb{E}(\varepsilon_t|\tilde{c}_{t-2}) = 0$$

which is stronger than the assumption needed for linear IV:

$$corr(\varepsilon_t, \tilde{c}_{t-2}) = 0$$

Fortunately, inspection of the nonparametric first stage between $\ln(\tilde{c}_{t-1})$ and $\ln(\tilde{c}_{t-2})$ shows it to be nearly linear (see Figure 2), suggesting that linear IV may be a suitable approach. Therefore, I nonparametrically estimate $f()$, using a 5-knot spline,[12] in

$$\ln(\tilde{c}_t) = f(\hat{c}_{t-1}) + \delta_{vt} + \tilde{\varepsilon}_t$$

Then, $f(\hat{c}_{t-1})$ is linearly instrumented with $f(\hat{c}_{t-2})$. The fitted relationship $f(\hat{c}_{t-1})$, graphed in Figure 3, is quite similar to the log form implied by CRRA, which is also shown. This is consistent with other empirical evidence suggesting that the CRRA utility function is, in fact, a reasonable approximation to actual utility

---

[12] Results are not sensitive to the number of knots used. (Results using a 7-knot spline available on request.)

functions (Szpiro 1986).

4.4 Summary: Distinguishing barriers to insurance

The preceding discussion suggests four tests that, in combination, can be used to distinguish among limited commitment, moral hazard, hidden income, and borrowing-saving (PIH):

1. Sufficiency of $\frac{1}{v'(c_{i,t-1})}$: under limited commitment, moral hazard, or borrowing-saving (PIH):

$$\mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{1}{v'(c_{i,t-1})}, \eta_t, x_{i,t-s}\right) = \mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{1}{v'(c_{i,t-1})}, \eta_t\right), \forall x_{i,t-s}, s > 0$$

.

2. Amnesia: under limited commitment, if household i is constrained at t:

$$\mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{1}{v'(c_{i,t-1})}, \eta_t, y_{it}\right) = \mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\eta_t, y_{it}\right)$$

3. Overprediction at the bottom: under hidden income:

$$\mathbb{E}\left(\left[\frac{1}{v'(c_{it})} - \mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{1}{u'(c_{i,t-1})}, \eta_t\right)\right]\Big| y_{i,t-1} = 0\right) \quad < \quad 0$$

$$\text{and}$$

$$\frac{d}{dy_{i,t-1}}\left(\frac{1}{v'(c_{it})} - \mathbb{E}\left(\frac{1}{v'(c_{it})}\Big|\frac{1}{u'(c_{i,t-1})}, \eta_t\right)\right) \quad > \quad 0$$

4. Inverse Euler equation: under moral hazard:

$$\frac{1}{v'(c_{i,t-1})} = \mathbb{E}_{t-1}\left(\frac{1}{v'(c_{it})}\right)$$

These tests are summarized in the following table:

	Autarky/PIH	Limited com.	Moral hazard	Hidden inc.
Sufficiency of $\ln c_{t-1}$	✓	✓	✓	
Amnesia		✓		
Overprediction at the bottom				✓
Inverse Euler			✓	

Ligon (1998) and Attanasio and Pavoni (2009) test for asymmetric information regarding agents' choice of actions (moral hazard) using GMM approaches, while Karaivanov and Townsend (2008) test across several moral hazard models as well as the PIH using an MLE approach. The test proposed here has the advantage of accommodating nonparametric estimates of the utility function, rather than requiring the specification of

a parametric form, and requiring no assumptions on the form of the production function. Of course, in the event that the assumptions imposed by GMM/MLE methods are correct, they may provide more powerful tests, but such assumptions are difficult to test and may result in incorrect conclusions if the assumptions are incorrect.

5 Data

Data are from the 1999-2005 waves of the Townsend Thai Monthly Survey, which covers 16 villages in central and northeastern Thailand, 4 each in four provinces, two in the central region near Bangkok and two in the northeast. In each village, 45 households were initially selected at random and reinterviewed each month. (See Townsend et al. (1997) for details.) Detailed data were collected on households' demographic composition and their income, including farms, businesses, and wage employment. Information was also collected on household expenditure, using detailed bi-weekly and monthly surveys. Thus expenditure is likely to be quite well-measured in this dataset, relative to datasets which measure expenditure over a longer recall period and/or which collect information on only a subset of expenditures, such as only food (as in the Panel Survey of Income Dynamics in the US).

A total of 531 households appear in all 84 months of the survey period used here, out of an original 670 who were interviewed in January 1999. I focus on the continuously-observed sample so that changes in a household's rank in the PCE distribution are not due to migration in and out of the survey. Differences between the continuously-observed sample and the initial sample are reported in Table 3. Smaller households and those whose head is engaged in rice farming or construction are most likely not to be continuously observed, while corn and livestock farmers are more likely to be continuously observed. This degree of missing data is a concern; however, residuals of income and consumption (partialing out demographic, village, year and occupation variables) do not differ across the two samples. Imputing income and expenditure data for missing household-months based on village, year, occupation and baseline demographic variables and running the analysis on this sample, yields results similar to the results for the continuously-observed sample.[13]

Summary statistics are reported in Table 1. Average household size is 4.5, or 3.8 adult equivalents. Average reported monthly per capita expenditure was 5,213 2002 baht (approximately 124 2002 US dollars.[14]). Average reported monthly income per capita is higher than expenditure at 8,981 baht, due to investment.

Households are classified into occupations based on the primary occupation reported by the household head in the initial wave of the survey. The most common occupation in the sample is rice farming (35% of household heads), followed by non-agricultural labor (including owning a non-agricultural business) (12% of household heads), growing corn (10%), raising livestock (9%), and agricultural wage labor (5%). Growing other crops, raising fish or shrimp, growing orchard crops, and construction each account for less than 5%. Seven percent report an occupation classified as "other."

---

[13] Results available on request.

[14] The exchange rate in 2002 was approximately 42 baht=$1. All following references to baht refer to 2002 baht.

Another strength of the Townsend Thai Monthly Survey data is that households are asked separately about gifts and transfers (both in money and in-kind) from organizations, from households in the village, and from households outside of the village. All of these types of transfers are prevalent: gifts given to other households in the same village equal 5.4% of average expenditure, while gifts from others in the same village equal 9% of average expenditure. Gifts/remittances given to those outside the household's village equal 17.5% of average expenditure, and gifts/remittances received from those outside the village equal 27.7% of average expenditure. Moreover, these numbers exclude transfers embodied in interest-free, low-cost and flexible loans, which are prevalent in these villages, as well as in other settings ((Platteau and Abraham 1987), (Udry 1994), (Fafchamps and Lund 2003)) The significant magnitude of intra-village transfers is direct evidence that within-village insurance is important, while transfers made with those outside the village may constitute a source of unobserved income.

Finally, using data from rain gauges located in each village, yielding a measure of total rainfall in each village in each month between 1999 and 2003, quarterly rainfall variables (deviations from the provincial average in that quarter over the entire period) were constructed following Paxson (1992):

$$R_{qvt} - \bar{R}_{qp}, \left(R_{qvt} - \bar{R}_{qp}\right)^2, \tag{16}$$
$$q = 1, 2, 3, 4$$

The rainfall variables are used to construct instruments for income in the tests of full insurance, and for tests of the hidden income model. The next section presents the empirical results.

6   Results

6.1   Insurance is imperfect...

If households were perfectly insured, there would be no need to look for evidence of a particular insurance friction—if household consumption did not move with contemporaneous household income, and all villagers' consumptions moved one-for-one with average village consumption, this would mean that none of hidden income, moral hazard, or limited commitment was a significant impediment to full insurance. This is not the case for rural Thailand. To see this, I estimate the standard omnibus test of full insurance (Townsend 1994) using the January 1999-December 2005 waves of the Townsend Thai Monthly Survey:[15]

$$\ln c_{it} = \alpha \ln y_{it} + \beta_i + \varepsilon_{it} \tag{17}$$

---

[15] As detailed in Section 4, income and expenditure data are collected monthly. However, throughout the paper I aggregate the 84 months of data to the annual level because the correspondence between expenditure and consumption is likely to be higher at annual frequencies than monthly frequencies. Aggregating to the annual level will also reduce the importance of measurement error if recall errors are uncorrelated across months.

where c_{it} is household i's per-capita consumption at time t, y_{ivt} is household i's income at time t and β_i is a household-fixed effect, yields $\hat{\alpha} = .078$ ($t = 10.5$). (See Table 2, column 1.) That is, a 10% change in household income is associated with a .78% change in contemporaneous per capita consumption.[16]

Adding village-year dummy variables δ_{vt} to capture common changes in villagers' consumption due to change in aggregate resources (indexing households by v to denote their village) and estimating

$$\ln c_{ivt} = \alpha \ln y_{ivt} + \beta_{iv} + \delta_{vt} + \varepsilon_{ivt} \tag{18}$$

reduces the correlation between income and consumption deviations (from the household means) to $\hat{\alpha} = .067$ ($t = 9.2$). (See Table 2, column 2.[17]) The significance of the village-year indicators is direct evidence that village-level networks are providing insurance, as discussed below, but the continued significant correlation between income and consumption changes demonstrates that this insurance is incomplete.[18]

Measurement error in income is a concern in interpreting the individual and village results. Classical measurement error in income (uncorrelated with the true values of income changes and with the error terms ε), will attenuate $\hat{\alpha}$ toward zero. This would make the extent to which income changes predict consumption changes in the data a lower bound on the true sensitivity of consumption to income. In this case, instrumenting income with variables correlated with true income but uncorrelated with the measurement error should then result in a higher estimate of α. Because many households in these villages work in agriculture, rainfall is a possible instrument. As discussed above, village-level monthly rainfall data is available for the years 1999-2003. Following the strategy of Paxson (1992), I instrument income changes with the interactions between occupation indicators[19] and deviations of quarterly income from the province-wide quarterly average defined in (16), and occupation interactions with squared deviations:

$$\mathbf{1}(occ_i = o) \times R_{qvt} - \bar{R}_{qp},$$
$$\mathbf{1}(occ_i = o) \times \left(R_{qvt} - \bar{R}_{qp} \right)^2,$$
$$q = 1, 2, 3, 4; o \in \{1, 10\}$$

Using the occupation-rainfall variables as instruments for income raises the coefficient on income changes significantly, to $\hat{\alpha}^{IV} = .21$ ($t = 5.4$) without the inclusion of village-year dummy variables (Table 2, column 4), and $\hat{\alpha}^{IV} = .17$ ($t = 3.9$) when the village-year dummies are added. Once measurement error in income

---

[16] Consumption is measured as expenditure and converted to per capita terms using the equivalence scale used by Townsend (1994) for Indian villages. The weights are: for adult males, 1.0; for adult females, 0.9. For males and females aged 13-18, 0.94, and 0.83, respectively; for children aged 7-12, 0.67 regardless of gender; for children 4-6, 0.52; for toddlers 1-3, 0.32; and for infants 0.05. Using an equivalence scale that accounts for within-household economies of scale (Olken 2005) does not significantly affect any reported results (results available on request).

[17] A first-differenced specification with a village-year effect yields a correlation of .04 ($t = 4.30$), the same point estimate found by Chiappori et al. (2008) for the same dataset.

[18] Townsend (1995) also finds imperfect insurance in northern Thai villages in the years 1989-1991.

[19] Households were asked in the initial wave of the survey about the primary occupation of each adult household member. The response of the household head was used to classify the household, with responses grouped into 10 categories: farm rice, farm corn, farm orchard crops, farm other crops, raise livestock, raise fish/shrimp, agricultural wage labor, non-agricultural wage labor, construction, and other.

is addressed, the evidence is even stronger that households bear a substantial fraction of their idiosyncratic income risk, although village-level insurance does smooth a significant portion of income risk, as discussed below.

Another telling feature of the data is a large amount of movement in the village per capita expenditure (PCE) distribution: the correlations between household PCE rankings in adjacent years range from .824 (1999-2000) to .539 (2000-2001). (See Table 3, Panel A.) Moreover, PCE rank changes are not random, as they would be if driven by classical error in expenditure, but are predicted by income changes, with a +10% change in income associated with an increase in the PCE distribution of about one-half of a ranking. An ordered probit regression shows that, at the mean income level, a +10% change in income is associated with a 5.9% increase in the probability of moving up in the consumption distribution. (See Table 3, Panel B.)

Absent taste shocks and with no heterogeneity in risk aversion, churn in the consumption distribution is incompatible with full insurance, as discussed above, as is $\alpha \neq 0$ in (17). However, insurance constrained by either limited commitment, hidden income, or moral hazard would predict both $\alpha > 0$ and $corr(rank_{it}, rank_{it'}) < 1$.

6.2   ...but villages do provide insurance

Finding $\alpha < 1$ in equation (17) does not establish that villages provide insurance: households could smooth consumption using borrowing and saving (Hall 1978), (Deaton 1991), or the relevant risk-sharing network might be a different group, such as kinship groups. The presence of intravillage insurance can be established by testing the hypothesis that the village-year effects in (17) are jointly insignificant in explaining household consumption changes. If these village-year effects play a significant role in explaining consumption changes, this implies that villagers' consumptions move together, evidence of the spillover implied by inter-village insurance. The hypothesis of no common component to within-village consumption changes is strongly rejected: $F(111, 3210) = 5.256, p = 0.000$ in the OLS regression (table 1, column 2) and $F(63, 1814) = 3.471, p = 0.000$ in the IV regression (table 2, column 5), indicating that there is a highly significant tendency for the consumption of households in the same village to move together.

To get a quantitative estimate of the extent of within-village insurance, Suri (2005) notes that an additional implication of a set of households belonging to an insurance group is that household consumption is less correlated with household income, conditional on total group consumption, than group average consumption is correlated with group average income. If we estimate the village-fixed effects specification

$$\ln c_{PCvt} = \alpha^W \ln y_{ivt} + \beta_i + \delta_{vt} + \varepsilon_{ivt} \tag{19}$$

and the between-village (or village average) specification

$$\overline{\ln c}_{vt} = \overline{\ln y}_{vt} \alpha^B + \bar{\varepsilon}_{vt} \tag{20}$$

27

where $\ln c_{ivt}$ and $\ln y_{ivt}$ are the log-per capita consumption and log-income of household i in village v at time t, and $\overline{\ln c}_{vt}$ and $\overline{\ln y}_{vt}$, are the time t averages of log-consumption and log-income for village v, insurance at the village level implies $\frac{\alpha^W}{\alpha^B} < 1$. Suri (2005) shows that the "contrast estimator"

$$\hat{\beta} = 1 - \frac{\alpha^W}{\alpha^B}$$

is a measure of the extent of insurance provided by village-level networks. (Under the null hypothesis that villages do not provide insurance, household consumption would be no less correlated with household income, conditional on total group consumption, than group average consumption is correlated with group average income, implying $\alpha^W = \alpha^B$ and $\hat{\beta} = 0$.)

Estimating (20) by OLS yields $\alpha^{B,OLS} = .172$, while $\alpha^{W,OLS} = .0669$. (See table 2, columns 2 and 3.) This implies $\hat{\beta}^{OLS} = .61$. Estimating (20) by IV, using quarterly rainfall deviations and squared deviations as instruments for average village income yields $\alpha^{B,IV} = .300$, while $\alpha^{W,IV} = .174$ (see table 2, columns 5 and 6), implying $\hat{\beta}^{IV} = .421$.

Whether estimated by OLS or IV, $\hat{\beta}$ is well below one: belonging to a village network does not remove all idiosyncratic risk, but village networks do manage to reduce dependence of household consumption on household income by between 40 and 60 percent. Section 3 discussed three models that attempt to rationalize this finding of partial insurance: limited commitment, hidden income, and moral hazard.

6.3   Credit is available

The form of the contract that the hypothetical village social planner can offer to a household depends on whether the village's budget must balance each period. If so, a constraint on the planner's problem is that, at each date and state of the world, total consumption among the villagers ($i \in V$) cannot exceed their total income:

$$\sum_{i \in V} c_{it} \leq \sum_{i \in V} y_{it}, \forall t. \tag{21}$$

Alternatively, if borrowing and savings are possible, subject only to a terminal condition,[20] village assets a_{vt} evolve according to

$$a_{v,t+1} = R \left[a_{vt} + \sum_{i \in V} (y_{it} - c_{it}^T) \right] \tag{22}$$

where R is the gross interest rate and y_{it} and c_{it}^T are the income and total (not per capita) consumption of household $i \in V$.

Dependence of village consumption at time t on village income at t can be tested with with between-village estimator (20). As noted above, $\alpha^{B,OLS} = .172$ (table 1, col 3) and $\alpha^{B,IV} = .300$ (table 2, col 6). Therefore, even correcting for measurement error in income, villages are far from living "hand to mouth," consuming

---

[20] $a_{v,T+1} = 0$ if T is finite or, if T is infinite, $\sum_{t=1}^{\infty} R^{-t}(y_{it} - c_{it}^T) \leq a_{v0}$.

total village income period-by-period. This suggests that village institutions (banks, moneylenders, local government, etc.) have access to a national-level credit market or a set of equivalent institutions.

6.4 Testing sufficiency of lagged inverse marginal utility

Under limited commitment, moral hazard, or autarky, current inverse marginal utility should only depend on the past through $\frac{1}{v'(c_{i,t-1})}$. If households' consumptions are described by efficient insurance constrained by limited commitment or moral hazard, we should find $\gamma \neq 0, \zeta = 0$ in

$$\ln c_{it} = \gamma \ln c_{i,t-1} + \zeta' X_{i,t-1} + \delta_{vt} + \varepsilon_{it} \tag{23}$$

where $X_{i,t-s}$ is any information dated $t-1$ or before. Table 4 presents the results of this test. While lagged inverse marginal utility is significantly predictive of current inverse marginal utility (column 1), lagged log income is also a significant predictor of current inverse marginal utility ($p < .001$) in the full sample (column 2). The result is unchanged when the top and bottom 5% of per capita expenditure (by year) are dropped, to address the concern that very high or low observed consumption may be due to measurement error. (See columns 3 and 4.) This suggests that neither limited commitment or moral hazard alone can explain the failure of full insurance in these villages.

6.5 Testing amnesia

Table 5 presents tests of the amnesia prediction of the limited commitment model. If there is measurement error in expenditure, exactly following Kocherlakota's proposed procedure for implementing this test—classifying as constrained every household in a village who had consumption growth above the village minimum—would result in every household but one in each village appearing constrained. In fact, many of these households will be unconstrained, and including them in the set of households for whom amnesia is predicted will introduce bias toward rejecting the predictions of limited commitment. To address this, in columns 1 through 4, interaction terms between $\ln \frac{1}{v'(c_{i,t-1})}$ and indicators for the quartile of the village distribution of consumption growth between $t-1$ and t into which the household fell ($\mathbf{1}_q$); and similar interaction terms with $\ln(y_{i,t})$ are added to (6). That is, estimate

$$\ln c_{it} = \alpha + \beta_1 \ln c_{i,t-1} + \sum_{q=2}^{4} \beta_q \ln c_{i,t-1} \times \mathbf{1}_q + \gamma_1 \ln y_{it} + \sum_{q=2}^{4} \gamma_q \ln y_{i,t} \times \mathbf{1}_q + \delta_{vt} + \varepsilon_{it}$$

If past promises are forgotten, conditional on current income, for those who had highest consumption growth due to binding participation constraints, the sum of the coefficients on the LIMU terms $\beta_1 + \beta_q$ should be low and insignificant for higher quartiles of consumption growth and, since the main effect of $\ln \frac{1}{v'(c_{i,t-1})}$ is positive and significant, β_4 should be negative. In fact, these predictions are rejected. The pattern of coefficients β_q is the opposite of that predicted by amnesia—LIMU is *more* strongly (positively), predictive

of current consumption, conditional on current income, for households with higher consumption growth: β_4 is larger than β_3, which in turn is larger than β_2 ($\beta_4 = .201 > \beta_3 = .152 > \beta_2 = .134$). For those in the highest quartile of consumption growth, the hypothesis that $\beta_1 + \beta_4$ equals zero is overwhelmingly rejected (point estimate $.057, p < .001$), suggesting again that limited commitment is not the (entire) explanation for incomplete insurance in these villages.

As a second test, columns 5 and 6 estimate (6) for households with above-median consumption growth, separately for villages where the variability of rainfall from year to year is high and villages where rainfall variability is low, based on monthly rainfall data from 1999-2003. Villages with high rainfall variance also had higher average income variance in every year but 2004, when the opposite is true—see Figure 1. If measurement error in expenditure is independent of the variance in incomes, then when high consumption growth is observed in high-rainfall-variance (HRV) villages, it is more likely to be due to a high income realization resulting in a binding participation constraint. In low-rainfall-variance (LRV) villages, high consumption growth is more likely to be due to measurement error. This suggests that, if limited commitment is the true model, the amnesia prediction should do better in HRV villages, i.e. the coefficient on $\ln \frac{1}{v'(c_{i,t-1})}$ in column 6 should be less than in column 5. Indeed, the point estimate for HRV villages is lower than for LRV villages, but the two estimates are not statistically different ($p = .66$). Therefore, both the sufficiency and amnesia predictions of the limited commitment model are strongly rejected.

6.6 Testing hidden income: insufficiency of LIMU and predictive power of lagged income

Table 6, Panel A presents the results of the tests that under hidden income LIMU will overpredict consumption for those households whose promises decreased, i.e. who had low income in the previous period, while under moral hazard or limited commitment, the prediction errors will be uncorrelated with last-period income because LIMU is a sufficient statistic for history, hence no additional lagged information will contain predictive power. Consistent with the hidden income prediction, when the prediction errors (11) are regressed on lagged income (and lagged income and lagged income squared interacted with the aggregate shock measure η_t) the slope is positive and significant while the intercept is significantly negative (column 1). Since the dependent variable is a regression residual, which has mean zero by construction, the slope and intercept are not independent. The joint hypothesis that $\alpha = 0, \beta = 0$ is rejected at the .0001 level. Column 2 repeats this test without the aggregate shock interaction terms, showing that the overprediction result holds unconditionally; i.e., the potential countervailing effect of increased aggregate resources does not undo the overprediction result. Again, the joint hypothesis that $\alpha = 0, \beta = 0$ is rejected at the .0001 level.

Columns 3 and 4 of table 6 show that instrumenting $\ln c_{iv,t-1}$ with $\ln c_{iv,t-2}$ does not overturn the finding that the prediction residuals are negative at low levels of lagged income: the null that the slope and the intercept in (7) are both 0 is rejected at the 1% level. This suggests that the rejection of sufficiency of LIMU is not driven by classical measurement error.

To check the robustness of the insufficiency of LIMU to non-classical measurement error, the tests of overidentifying restrictions on the reduced forms for current consumption and lagged consumptions are presented in Table 7. Columns 1 and 2 present the results of comparing the reduced forms of $\ln c_{it}$ and $\ln c_{i,t-1}$ using crop and livestock income as "instruments" for consumption. Time $t-1$ crop income is associated with higher consumption at time t than at $t-1$, while the opposite is true for time $t-1$ livestock income, consistent with what would be expected if crop income were easier to observe than livestock income. The hypothesis that $\frac{\pi_{1C1}}{\pi_{2C1}} = \frac{\pi_{1L1}}{\pi_{2L1}}$ is rejected at the 5% level (p=.0422). Columns 3 and 4 present the results of comparing the reduced forms of $\ln c_{it}$ and $\ln c_{i,t-1}$ using crop and fish income as instruments, and the results are similar, again consistent with what would be expected if crop income were easier to observe than income from aquaculture, although in this case the hypothesis that $\frac{\pi_{1C1}}{\pi_{2C1}} = \frac{\pi_{1F1}}{\pi_{2F1}}$ is rejected at the 10% level (p=.0535). This suggests that the rejection of sufficiency of LIMU is not due to measurement error in lagged consumption, but in fact arises because reporting low levels of difficult-to-observe income is associated with a greater penalty in terms of future consumption than contemporaneous consumption.

Finally, to check the robustness of this finding to allowing for a utility function that is not CRRA, table 8 shows that when $\frac{1}{v'(c)}$ is estimated nonparametrically, sufficiency of LIMU is still rejected. Panel A shows that there is still a significant positive association between the prediction errors $\hat{\varepsilon}_t$ (formed using a nonparametric estimate of LIMU) and lagged income. When the forecast of inverse marginal utility based on LIMU is estimated by OLS, sufficiency of LIMU is once again rejected, at the 1% level (column 1). Because measurement error is still a concern, column 2 presents results instrumenting nonparametrically estimated LIMU with the second lag of nonparametric inverse marginal utility. Sufficiency of LIMU is still rejected, now at the 5% level. Table 8, Panel B presents the results of an alternative specification of the test of sufficiency of LIMU. Analogously to equation (23), results for which are shown in table 4, Panel B estimates

$$\ln c_{it} = f(c_{i,t-1}) + \zeta \ln y_{i,t-1} + \delta_{vt} + \varepsilon_{it}$$

where $f(c_{i,t-1})$ is the nonparametric estimate of LIMU. Sufficiency of LIMU implies $\zeta = 0$—lagged income should contain no additional information relevant to forecasting current inverse marginal utility once $f(c_{i,t-1})$ is controlled for. The hidden income model, in contrast, predicts $\zeta > 0$, since higher lagged income implies a higher forecast of current inverse marginal utility. In fact, as in the CRRA formulation in table 4, ζ is significantly positive, significant at the 1% level in the OLS specification and at the 5% level in the IV specification. Given that the nonparametric estimate of $f(\hat{c}_{t-1})$ is quite similar to the CRRA form, it is not surprising that the two methods yield similar conclusions about the (in)sufficiency of LIMU.

To summarize, a wide variety of evidence suggests that hidden income constraints cause those with low past income to receive less current consumption (i.e. lower current inverse marginal utility) than predicted by LIMU, while those with high past income receive more consumption and higher current inverse marginal utility. This suggests that insurance is constrained by the need to provide incentives to high-income house-

holds to truthfully reveal that income. This finding does not appear to be driven by measurement error or misspecification of the utility function. Next, I present two tests of the prediction that households with easier-to-predict income processes should display less departure from sufficiency of LIMU.

6.7 Testing hidden income: departure from sufficiency and predictive power of rainfall

If the primary barrier to insurance is the inability of the community to directly observe households' incomes, and this barrier is manifested through insufficiency of LIMU, households whose income processes are less uncertain, because they are predicted by observed factors, or are unconditionally less variable, should display less insufficiency of LIMU.

As a first test of this prediction, I regress income on the rainfall variables $R_{qvt} - \bar{R}_{qp}$ and $\left(R_{qvt} - \bar{R}_{qp} \right)^2$ separately for households in each of 10 occupational categories. The R^2 from this regression was interacted with lagged income. (The R^2s are shown in Table 10.) Table 9a shows the results of regressing the prediction errors (11) on lagged income, separately for the occupations with above- and below-median R^2s of income on the rainfall variables:

$$\hat{\varepsilon}_{it} = \alpha + \beta y_{i,t-1} + u_{it}$$

If insufficiency of LIMU is reduced when a household's income is easier to forecast, we should find $\alpha^{high R^2} > \alpha^{low R^2}, \beta^{high R^2} > \beta^{low}$, and $\chi^2_{high R^2} < \chi^2_{low R^2}$. In fact, this is the case: there is less insufficiency of LIMU (in the sense of a less significant correlation of the residuals with lagged income), when rainfall R^2 is high than when it is low.

As a second test, for each household, I calculate variance of income, after removing the component of income predicted by the rainfall variables and occupation-year dummies; i.e. that part which should be difficult to forecast. I split the sample according to whether this variance is above or below the median. The prediction of the hidden income model is that there should be less insufficiency of LIMU for the low-variance sample. Table 9b shows the results. Both in terms of the point estimates and the chi-squared test of joint significance, the high-variance sample displays greater insufficiency of LIMU: $\alpha^{high} < \alpha^{low}, \beta^{high} < \beta^{low}$, and $\chi^2_{high} > \chi^2_{low}$.

7 Conclusion

Knowing what barrier to full informal risk-sharing is most important in a given community is important for evaluation of policies that may affect the sustainability of informal insurance. One such group of policies is those that aim to increase individuals' access to savings, such as rural bank expansion, cell phone banking and microsavings accounts. Access to savings can crowd out limited commitment-constrained insurance if savings can be used after individuals renege on their informal insurance obligations (Ligon, Thomas, and

Worrall 2000). On the other hand, savings access may crowd out insurance subject to hidden income if individuals' savings are not observable by the community, and the degree of crowdout will be complete if hidden savings offers the same rate of return as community-controlled savings (Cole and Kocherlakota 2001), (Doepke and Townsend 2006). Technologies that make observing others' incomes easier (such as crop price information dissemination) or harder (such as taking individual deposits rather than collecting savings at a group meeting; or access to larger, more anonymous markets) may affect informal insurance constrained by hidden income, but not if the only barrier to insurance is limited commitment or moral hazard.[21] Weather insurance which makes leaving community insurance more palatable will crowd out insurance under limited commitment (Attanasio and Rios-Rull 2000), but not under hidden income or moral hazard. Policies that expand communities' sanctioning ability (such as community-allocated aid; see Olken (2005)), or restrict it (such as road access; see Townsend 1995) will also affect limited commitment constraints, while community-allocated aid may reduce problems of hidden income, since the community knows the amount of aid each household is getting. Conditional cash transfer programs may also have differing effects on insurance constrained by limited commitment, moral hazard or hidden income.[22]

This paper suggested a set of tests that can be used to determine whether any of three models of endogenously incomplete insurance—limited commitment, moral hazard or hidden income—is consistent with the relationship between current consumption, lagged consumption and other lagged information. If information from "the past" helps to forecast current consumption, conditional on one lag of inverse marginal utility, neither limited commitment or moral hazard can fully explain incomplete insurance. However, if a household's past income helps to forecast current consumption, in the particular sense that prediction errors ignoring past income are positive when past income was low, this is consistent with a model in which households cannot directly observe one another's income and must be given incentives to truthfully report it.

Measurement error in right-hand side variables, which is commonly seen as a threat to power (causing underrejection of the null), is a particular concern with tests of this type, because mismeasurement of the proposed sufficient statistic (here, lagged inverse marginal utility) can distort the size of the test, causing *over*rejection of the null, if those variables which are excluded under the null hypothesis are correlated with the true value of the proposed sufficient statistic. This concern is addressed here with instrumental variables and by testing overidentifying restrictions on the reduced forms for the left- and right-hand-side variables.

Results from an 84-month (7-year) panel of households in rural Thailand are inconsistent with pure moral hazard or limited commitment, and suggest that hidden income plays a role in constraining households from achieving full risk sharing. This suggests that policies which make it easier (harder) for villagers to infer one another's incomes may improve (worsen) risk sharing. Changes that improve observability of income could include dissemination of crop or other price information; changes that worsen observability could include

---

[21] Of course, a technology that made observing others' incomes harder could also *create* a hidden income problem where none had existed previously.

[22] Angelucci and De Giorgi (2009) discuss partial insurance of income transfers under Mexico's Progresa program.

access to larger, anonymous markets; diversification of occupations within a village; electronic payments of remittances or for business transactions; seasonal migration; and private rather than group banking. Since policies that have the potential to worsen observability of income may also raise the average *level* of income, this is not to suggest that such policies be avoided. However, when possible they should be designed with consideration of the consequences for informal insurance.

References

Ai, H. and F. Yang (2007, August). Private information, limited commitment, and risk sharing. Duke University working paper.

Allen, F. (1985). Repeated principal-agent relationship with lending and borrowing. *Economic Letters 17*, 27–31.

Angelucci, M. and G. DeGiorgi (2009). Indirect effects of an aid program: How do cash transfers affect ineligibles' consumption? *American Economic Review 99*, 486–508.

Arrow, K. (1971). *Essays in the Theory of Risk Bearing*, Chapter Aspects of a Theory of Risk Bearing. Markham Publishing.

Attanasio, O. and N. Pavoni (2007, March). Risk sharing in private information models with asset accumulation: Explaining the excess smoothness of consumption. NBER Working Paper 12994.

Attanasio, O. and J.-V. Rios-Rull (2000). Consumption smoothing in island economies: Can public insurance reduce welfare? *European Economic Review 44*, 1225–1258.

Blundell, R., L. Pistaferri, and I. Preston (2008, February). Consumption inequality and partial insurance. *American Economic Review 98*, 1887–1921.

Bolton, P. and M. Dewatripont (2005). *Contract Theory*. MIT Press.

Cashdan, E. A. (1985). Coping with risk: Reciprocity among the Basarwa of Northern Botswana. *Man 20*, 454–474.

Chiappori, P. A., K. Samphantharak, S. Schulhofer-Wohl, and R. M. Townsend (2008, January). Heterogeneity and risk sharing in thai villages. MIT working paper.

Coate, S. and M. Ravallion (1993). Reciprocity without commitment: Characterization and performance of informal insurance arrangements. *Journal of Development Economics 40*, 1–24.

Cochrane, J. H. (1991). A simple test of consumption insurance. *Journal of Political Economy 99*, 957–976.

Cole, H. and N. Kocherlakota (2001). Effcient allocations with hidden income and hidden storage. *Restud 68*, 523–42.

Collins, D., J. Morduch, S. Rutherford, and O. Ruthven (2009). *Portfolios of the poor: how the world's poor live on two dollars a day*. Princeton University Press.

Cox, D., Z. Eser, and E. Jimenez (1998). Motives for private transfers over the life cycle: An analytical framework and evidence for Peru. *Journal of Development Economics 55*, 57–80.

Deaton, A. (1991). Saving and liquidity constraints. *Econometrica 59*, 1221–1248.

Doepke, M. and R. Townsend (2006). Dynamic mechanism design with hidden income and hidden actions. *JET 126*, 235–285.

Dubois, P., B. Jullien, and T. Magnac (2008). Formal and informal risk sharing in LDCs: Theory and empirical evidence. *Econometrica 76*, 679 – 725.

Fafchamps, M. and S. Lund (2003). Risk-sharing networks in rural Phillipines. *Journal of Development Economics 71*, 261–287.

Fernandes, A. and C. Phelan (2000). A recursive formulation for repeated agency with history dependence. *Journal of Economic Theory 91*, 223–247.

Gertler, P. and J. Gruber (2002). Insuring consumption against illness. *American Economic Review 92*, 51–70.

Golosov, M., N. Kocherlakota, and A. Tsyvinski (2003). Optimal indirect and capital taxation. *Review of Economic Studies 70*, 569–587.

Green, E. J. (1987). *Contractual arrangements for intertemporal trade*, Chapter Lending and the Smoothing of Uninsurable Income, pp. 3–25. University of Minnesota Press.

Grossman, S. J. and O. D. Hart (1983). An analysis of the principal-agent problem. *Econometrica 51*, 7–45.

Hall, R. E. (1978). Stochastic implications of the life cycle-permanent income hypothesis: Theory and evidence. *Journal of Political Economy 86*, 971–987.

Hayashi, F., J. Altonji, and L. Kotlikoff (1996). Risk-sharing between and within families. *Econometrica 64*, 261–294.

Kaplan, G. (2006). The cross-sectional implications of incomplete markets: Private information or limited enforcement? NYU Working Paper.

Karaivanov, A. and R. M. Townsend (2008, September). Firm dynamics and finance: Distinguishing information regimes. Manuscript.

Kimball, M. S. (1988). Farmers' cooperatives as behavior toward risk. *American Economic Review 78*, 224–232.

Kocherlakota, N. and L. Pistaferri (2009). Asset pricing implications of pareto optimality with private information. *Journal of Political Economy 117*(3), 555–590.

Kocherlakota, N. R. (1996). Implications of efficient risk sharing without commitment. *Review of Economic Studies 63*, 595–609.

Koeppl, T. V. . (2006). Differentiability of the efficient frontier when commitment to risk sharing is limited. *Topics in Macroeconomics 6*, 1–8.

Ligon, E. (1998). Risk sharing and information in village economies. *Review of Economic Studies 65*, 847–864.

Ligon, E., J. P. Thomas, and T. Worrall (2000). Mutual insurance, individual savings, and limited commitment. *Review of Economic Dynamics 3*, 216–246.

Ligon, E., J. P. Thomas, and T. Worrall (2002). Informal insurance arrangements with limited commitment: Theory and evidence from village economies. *Review of Economic Studies 69*, 209–244.

Lim, Y. and R. M. Townsend (1998). General equilibrium models of financial systems: Theory and measurement in village economies. *Review of Economic Dynamics 1*, 59–118.

Mace, B. J. (1991). Full insurance in the presence of aggregate uncertainty. *Journal of Political Economy 99*, 928–956.

Milgrom, P. (1981). Good news and bad news: Representation theorems and applications. *The Bell Journal of Economics 12*, 380–391.

Morduch, J. (1995). Income smoothing and consumption smoothing. *Journal of Economic Perspectives 9*, 103–114.

Newey, W. K. and J. L. Powell (2003). Instrumental variable estimation of nonparametric models. *Econometrica 71*, 1565–1578.

Olken, B. A. (2005). Revealed community equivalence scales. *Journal of Public Economics 89*, 545–566.

Paxson, C. H. (1992). Using weather variability to estimate the response of savings to transitory income in thailand. *American Economic Review 82*, 15–33.

Phelan, C. (1998). On the long run implications of repeated moral hazard. *Journal of Economic Theory 79*, 174–191.

Platteau, J.-P. (1991). *Social security in developing countries*, Chapter Traditional Systems of Social Security and Hunger Insurance: past achievements and modern challenges, pp. 112–163. Oxford: Clarendon Press.

Platteau, J.-P. and A. Abraham (1987). An inquiry into quasi-credit contracts: The role of reciprocal credit and interlinked deals in small-scale fishing communities. *Journal of Development Studies 23*, 461–490.

Rogerson, W. P. (1985). Repeated moral hazard. *Econometrica 53*, 69–76.

Rosenzweig, M. (1988). Risk, implicit contracts and the family in rural areas of low-income countries. *The Economic Journal 98*, 1148–1170.

Scheuer, F. (2009, January). Pareto-optimal taxation with aggregate uncertainty and financial markets. MIT working paper.

Schulhofer-Wohl, S. (2006). *A Test of Consumption Insurance with Heterogeneous Preferences*. Ph. D. thesis, University of Chicago.

Scott, J. C. (1976). *The Moral Economy of the Peasant*. Oxford: Basil Blackwell.

Spear, S. E. and S. Srivastava (1987). On repeated moral hazard with discounting. *Review of Economic Studies 54*, 599–617.

Suri, T. (2005, September). Spillovers in village consumption: Testing the extent of partial insurance.

Szpiro, G. G. (1986). Measuring risk aversion: An alternative approach. *Review of Economics and Statistics 68*, 156–159.

Thomas, J. and T. Worrall (1990). Income fluctuation and asymmetric information: An example of a repeated principal-agent problem. *Journal of Economic Theory 51*, 367–390.

Townsend, R. M. (1982). Optimal multiperiod contracts and the gain from enduring relationships under private information. *Journal of Political Economy 90*, 1166–1186.

Townsend, R. M. (1994). Risk and insurance in village India. *Econometrica 62*, 539–591.

Townsend, R. M. (1995). Financial systems in northern Thai villages. *Quarterly Journal of Economics 110*, 1011–1046.

Townsend, R. M. (2007). Townsend Thai project initial household survey, 1997. [Computer file]. 2nd Release. Chicago, IL: Social Sciences Computing Services, the University of Chicago [Producer & distributor].

Townsend, R. M., A. L. Paulson, S. Sakuntasathien, T. J. Lee, and M. B. 1997. (1997). *Questionnaire Design and Data Collection for NICHD Grant 'Risk, Insurance and the Family' and NSF Grants.* Univ. Chicago.

Udry, C. (1994). Risk and insurance in a rural credit market: An empirical investigation in northern Nigeria. *The Review of Economic Studies 61*, 495–526.

Wilson, R. (1968). The theory of syndicates. *Econometrica 36*, 119–132.

A   Appendix: Proofs

Define the N-dimensional vector of household incomes at t, $h_t = \{y_{it}\}_{i=1}^N$, and the history $(h_1, ..., h_t) \equiv h^t$.

A.1   Proof of Proposition 1: Full insurance rules out rank-reversals and dependence of consumption on income

Let λ_{it} be the multiplier on household i's time t promise-keeping constraint, and η_t be the multiplier on the village's time t budget constraint. Solving (1) subject to the promise-keeping constraints (2) and the village's budget constraint (3) yields the following first-order conditions for transfers, promised utility, and assets:

Proof. The FOCs are ∎

$\tau_{it}(h^t)$:

$$\eta_t(h^t) = \lambda_{it} \Pr(h^t) v'(y_{it} + \tau_{it}(h^t)) \tag{24}$$

$u_{i,t+1}(h_t)$:

$$\Pr(h^t) \frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} = -\Pr(h^t)\lambda_{it}, \forall h^t, i < N \tag{25}$$

a_{t+1} :

$$\Pr(h^t) \frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial a_{t+1}(h^t)} = \eta_t(h^t) \tag{26}$$

and the envelope conditions:

$$\frac{\partial u_N(\mathbf{u}_t(h^{t-1}), a_t(h^{t-1}), \mathbf{e}')}{\partial u_{it}(h^{t-1})} = -\lambda_{it}, \forall i < N \tag{27}$$

$$\frac{\partial u_N(\mathbf{u}_t(h^{t-1}), a_t(h^{t-1}), \mathbf{e}')}{\partial a_t(h^{t-1})} = \eta_{t-1}(h^{t-1}) \tag{28}$$

The FOCs for transfers for households i and N imply

$$\frac{\lambda_{Nt}}{\lambda_{it}} = \frac{v'(y_{it} + \tau_{it}(h^t))}{v'(y_{Nt} + \tau_{Nt}(h^t))}$$

So that

$$c_{it} \equiv y_{it} + \tau_{it}(h^t) = v'^{-1}\left(\frac{\lambda_{Nt}}{\lambda_{it}} v'(y_{Nt} + \tau_{Nt}(h^t))\right) \tag{29}$$

Substituting into the law of motion for assets,

$$R^{-1}a_{t+1} = a_t + \sum_{i=1}^N y_{it} - \sum_{i=1}^N v'^{-1}\left(\frac{\lambda_{Nt}}{\lambda_{it}} v'(y_{Nt} + \tau_{Nt}(h^t))\right) \tag{30}$$

which is a single equation in c_{Nt}, i.e. c_{Nt} depends only on the aggregate endowment, and not on h^t or $\{y_{it}\}$. Then (29) implies that for all households, c_{it} depends only on the aggregate endowment.

Using (25) and (27), $\lambda_{it} = \lambda_{it+1} = \lambda_i, \forall i, t$.

Further, for all i, j in the network:

$$
\begin{aligned}
\frac{v'(y_r + \tau_{Nrt})}{v'(y_r + \tau_{irt})} &= \lambda_i, \forall r, t, i < N \\
\frac{v'(y_r + \tau_{jrt})}{v'(y_r + \tau_{irt})} &= \frac{\lambda_j}{\lambda_i}
\end{aligned}
$$

So if in the first period, household i consumes more than household j, this will be the case in all subsequent periods, and vice versa. Therefore under full insurance the ordering of initial multipliers λ_{i0} or equivalently initial promises u_{i0} will determine the ordering of household i in the consumption distribution in all periods.∎

A.2 Proof of Proposition 2: Under moral hazard, lagged inverse marginal utility is a sufficient statistic for current consumption

The proof proceeds in two steps. First, to show that the difference between the multipliers on the household's time t promise- and threat-keeping constraints equals expected time t inverse marginal utility. Second, that the expected difference between the multipliers on the household's time t promise- and threat-keeping constraints equals time t inverse marginal utility; the difference is a random walk (conditional on the time t budget multiplier, η_t).

Again let λ_{it} be the multiplier on household i's promise-keeping constraint, and η_t be the multiplier on the village's time t budget constraint. Let ζ_{it} be the multiplier on household i's incentive-compatibility constraint. (Since there are only two possible effort levels and utility is separable in consumption and effort, the incentive-compatibilty constraint will be binding at the optimum (Grossman and Hart 1983).)

The planner's problem is now

$$
u_N(\mathbf{u}_t, \hat{\mathbf{u}}_t, a_t | \mathbf{e}') \equiv \max_{\{\boldsymbol{\tau}_{rt}\}, \{\mathbf{u}_{r,t+1}\}, \{\hat{\mathbf{u}}_{r,t+1}\}}
$$

$$
\sum_{r=1}^{S} p_{r11} v(y_r + \tau_{Nrt}) - c(1) + \beta \mathbb{E}_{\{y\}} u_N(\mathbf{u}_{t+1}, \hat{\mathbf{u}}_{t+1}, a_{t+1} | \mathbf{e})
$$

subject to the promise-keeping constraints:

$$
\sum_{r=1}^{S} p_{r11}[v(y_r + \tau_{irt}) - c(1) + \beta u_{ir,t+1}] \geq u_{it}, i < N \qquad (\lambda_{it})
$$

the law of motion for assets:

$$
R^{-1} a_{t+1} = a_t - \sum_{i=1}^{N} \tau_{irt} \qquad (\eta_t)
$$

the incentive-compatibility constraints:

$$
\sum_{r=1}^{S} p_{r11}[v(y_r + \tau_{irt}) + \beta u_{ir,t+1}] - c(1) \qquad (\zeta_{it})
$$

$$
= \sum_{r=1}^{S} p_{r10}[v(y_r + \tau_{irt}) + \beta \hat{u}_{ir,t+1}] - c(0)
$$

threat-keeping 1: if the household disobeyed yesterday but obeys today, they don't get more than $\hat{u}_{it}$:

$$\sum_{r=1}^{S} p_{r10}[v(y_r + \tau_{irt}) - c(1) + \beta u_{ir,t+1}] \leq \hat{u}_{it}, i < N \qquad (\psi_{1it})$$

threat-keeping 2: if the household disobeyed yesterday and disobeys today, they don't get more than $\hat{u}_{it}$:

$$\sum_{r=1}^{S} p_{r00}[v(y_r + \tau_{irt}) - c(0) + \beta \hat{u}_{ir,t+1}] \leq \hat{u}_{it}, i < N \qquad (\psi_{2it})$$

The FOCs are:

τ_{irt} :

$$\frac{\eta_t p_{r11}^{-1}}{v'(y_r + \tau_{irt})} = \lambda_{it} + \frac{p_{r11} - p_{r01}}{p_{r11}} \zeta_{it} - \frac{p_{r10}}{p_{r11}} \psi_{1it} - \frac{p_{r00}}{p_{r11}} \psi_{2it}$$

$u_{ir,t+1}$:

$$-\mathbb{E}_{\{y_{-i}|y_i\}} \frac{\partial u_N(\cdot, \cdot, \cdot | \mathbf{e})}{\partial u_{ir,t+1}} = \lambda_{it} + \zeta_{it} - \frac{p_{r10}}{p_{r11}} \psi_{1it}$$

$\hat{u}_{ir,t+1}$:

$$-\mathbb{E}_{\{y_{-i}|y_i\}} \frac{\partial u_N(\cdot, \cdot, \cdot | \mathbf{e})}{\partial \hat{u}_{ir,t+1}} = -\frac{p_{r01}}{p_{r11}} \zeta_{it} - \frac{p_{r00}}{p_{r11}} \psi_{2it}$$

a_{t+1} :

$$\mathbb{E}_{\{y\}} \frac{\partial u_N(\cdot, \cdot, \cdot | \mathbf{e})}{\partial a_{t+1}} = \eta_t$$

and the envelope conditions:

$$-\frac{\partial u_{Nt}(\mathbf{u}_t, \hat{\mathbf{u}}_t, a_t | \mathbf{e'})}{\partial u_{irt}} = \lambda_{it}$$

$$-\frac{\partial u_{Nt}(\mathbf{u}_t, \hat{\mathbf{u}}_t, a_t | \mathbf{e'})}{\partial \hat{u}_{irt}} = \psi_{1it} + \psi_{2it}$$

$$\frac{\partial u_{Nt}(\mathbf{u}_t, \hat{\mathbf{u}}_t, a_t | \mathbf{e'})}{\partial a_t} = \eta_t$$

Multiplying the FOC for each τ_{irt} by p_{r11} and summing gives

$$\eta_t \mathbb{E}\left(\frac{1}{v'(y_r + \tau_{irt})} | \eta_t\right) = \lambda_{it} - (\psi_{1it} + \psi_{2it})$$

Expected inverse marginal utility at t equals the difference $\lambda_{it} - (\psi_{1it} + \psi_{2it})$ (Step 1)

Adding the FOCs for $u_{ir,t+1}$ and $\hat{u}_{ir,t+1}$ gives:

$$\mathbb{E}_{\{y_{-i}|y_i\}} \left(\frac{-\partial u_N(\mathbf{u}_{t+1}, \hat{\mathbf{u}}_{t+1}, a_{t+1}|\mathbf{e})}{\partial u_{ir,t+1}} - \frac{\partial u_N(\mathbf{u}_{t+1}, \hat{\mathbf{u}}_{t+1}, a_{t+1}|\mathbf{e})}{\partial \hat{u}_{ir,t+1}}\right)$$

$$= \underbrace{\lambda_{it} + \zeta_{it} - \frac{p_{r10}}{p_{r11}} \psi_{1it}}_{u_{ir,t+1}} + \underbrace{\left(-\frac{p_{r01}}{p_{r11}} \zeta_{it} - \frac{p_{r00}}{p_{r11}} \psi_{2it}\right)}_{\hat{u}_{ir,t+1}}$$

$$= \lambda_{it} + \frac{p_{r11} - p_{r01}}{p_{r11}} \zeta_{it} - \frac{p_{r10}}{p_{r11}} \psi_{1it} - \frac{p_{r00}}{p_{r11}} \psi_{2it}$$

$$= \frac{\eta_t}{v'(y_r + \tau_{irt})}$$

Lagging this by one period,

$$\frac{\eta_{t-1}}{v'(y_{i,t-1} + \tau_{i,t-1})} = \mathbb{E}_{\{y\}} \frac{-\partial u_N(\mathbf{u}_t, \hat{\mathbf{u}}_t, a_t | \mathbf{e}')}{\partial u_{it}} - \frac{\partial u_N(\mathbf{u}_t, \hat{\mathbf{u}}_t, a_t | \mathbf{e}')}{\partial \hat{u}_{it}}$$

So that, using the time t envelope conditions for u_{it} and $\hat{u}_{it}$:

$$\frac{\eta_{t-1}}{v'(y_{i,t-1} + \tau_{i,t-1})} = \lambda_{it} - (\psi_{1it} + \psi_{2it})$$

Using Step 1, this implies

$$\frac{1}{v'(y_{i,t-1} + \tau_{i,t-1})} = \frac{\eta_t}{\eta_{t-1}} \mathbb{E} \left(\frac{1}{v'(y_{it} + \tau_{it})} | \eta_t \right)$$

Inverse marginal utility times the budget multiplier is a random walk (given the time t budget multiplier). LIMU is a sufficient statistic for past information in forecasting consumption.∎

A.3   Proof of Proposition 3: Lagged inverse marginal utility is a sufficient statistic under limited commitment

Let $\frac{\lambda_{it}}{\Pr(h^t)}$ be the multiplier on household i's promise-keeping constraint, and $\frac{\eta_t(h^t)}{\Pr(h^t)}$ be the multiplier on the village's time t budget constraint after history h^t. Using the stationarity of the problem,

$$\Pr(h^t | \mathbf{u}(h^{t-1}), a(h^{t-1}), \mathbf{e}) = \Pr(h^t | h^{t-1}) = \Pr(h_t)$$

so probabilities are written conditional only on the time t realization h_t. Let $\phi_{it}(h^t)$ be the multiplier on household i's participation constraint after history h^t.

Assume that there is at least one realization h_t such that no household's participation constraint is binding: this guarantees differentiability of the planner's value function (Koeppl 2006). Solving (1) subject to the promise-keeping constraints (2), the participation constraints (5) and the village's budget constraint (3) yields the following first-order conditions for transfers, promised utility, and assets:

$\tau_{it}(h^t)$:

$$\eta_t(h^t) = (\lambda_{it} + \phi_{it}(h^t))v'(y_{it} + \tau_{it}(h^t)) \tag{31}$$

$u_{i,t+1}(h^t)$:

$$\Pr(h^t)\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} = -\Pr(h^t)\lambda_{it} - \phi_{it}(h^t), \forall h^t, i < N \tag{32}$$

$a_{t+1}(h^t)$:

$$\Pr(h^t)\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial a_{t+1}(h^t)} = \eta_t(h^t) \tag{33}$$

and the envelope conditions for current promises (27) and assets (28):

$$\frac{\partial u_N(\mathbf{u}_t(h^{t-1}), a_t(h^{t-1}), \mathbf{e}')}{\partial u_{it}(h^{t-1})} = -\lambda_{it}, \forall i < N$$

$$\frac{\partial u_N(\mathbf{u}_t(h^{t-1}), a_t(h^{t-1}), \mathbf{e}')}{\partial a_t(h^{t-1})} = \eta_{t-1}(h^{t-1})$$

It will be helpful to use the following result:

Lemma 6 *The double (y_{it}, η_t) is a sufficient statistic for the N-vector of income realizations h^t in determining household i's transfer: $\tau_{it}(h^t) = \tau_{it}(y_{it}, \eta_t)$*

Proof. Note that, when $\phi_{it}(h^t) > 0$, i.e. household i's participation constraint is binding, (31) and (27) imply that the household's transfer and future promise are set to make the household exactly indifferent between staying in the network or defaulting, and to equate the cost of providing the current transfer τ and future promise u, irrespective of the income realizations of other households in the network:

$$v(y_r + \tau_{it}(h^t)) + \beta u_{i,t+1}(h^t) = u_{aut}^t(y_r)$$

$$v'(y_r + \tau_{it}(h^t)) = -\left(\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)}\right)^{-1}$$

so $\tau_{it}(h^t | \phi_{it}(h^t) > 0) = \tau_{it}(y_{it}, \eta_t)$. And, when $\phi_{it}(h^t) = 0$, i.e. household i's participation constraint is not binding, (31) and (27) imply that $\frac{1}{v'(y_{it} + \tau_{it}(h^t))} = \frac{\eta_t(h^t)}{\lambda_{it}}$, so, again, $\tau_{it}(h^t | \phi_{it}(h^t) = 0) = \tau_{it}(y_{it}, \eta_t)$. $\blacksquare$

This lemma allows us to write $\tau_{it}(y_{it}, \eta_t)$ for $\tau_{it}(h^t)$. Using the FOCs for $\tau_{it}(y_{it}, \eta_t)$ and $u_{i,t+1}(h^t)$:

$$
\begin{aligned}
\eta_t(h^t) &= \Pr(h_t)\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} v'(y_{it} + \tau_{it}(y_{it}, \eta_t)) \\
&= \Pr(y_{it}, \eta_t) v'(y_{it} + \tau_{it}(y_{it}, \eta_t)) \Pr(h_t | y_{it}, \eta_t)\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)}
\end{aligned}
$$

since $\Pr(y_{it}, \eta_t) \Pr(h_t | y_{it}, \eta_t) = \Pr(h_t \cap (y_{it}, \eta_t)) = \Pr(h_t \cap (\eta_t(h^t)))$. This says that inverse marginal utility, weighted by the shadow price of resources scaled by the probability of (y_{it}, η_t), is equal to the gradient of the planner's value function with respect to household i's time $t+1$ promised utility weighted by the probability of the N-vector of income realizations h_t, given (y_{it}, η_t):

$$\frac{\eta_t(h^t)}{\Pr(y_{it}, \eta_t) v'(y_{it} + \tau_{it}(y_{it}, \eta_t))} = \Pr(h_t | y_{it}, \eta_t)\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} \tag{34}$$

Note that

$$\sum_{h_t | \Pr(h_t | y_{it}, \eta_t) > 0}\left(\frac{\eta_t(h^t)}{\Pr(y_{it}, \eta_t) v'(y_{it} + \tau_{it}(y_{it}, \eta_t))}\right) = \frac{\Pr(y_{it}, \eta_t)^{-1}}{v'(y_{it} + \tau_{it}(y_{it}, \eta_t))}\sum_{h_t | \Pr(h_t | y_{it}, \eta_t) > 0}\eta_t(h^t)$$

since the term $\frac{\Pr(y_{it}, \eta_t)^{-1}}{v'(y_{it} + \tau_{it}(y_{it}, \eta_t))}$ does not depend on h^t: $\Pr(y_{it}, \eta_t)$ is the unconditional probability that (y_{it}, η_t) occurs.

Summing (34) over all time t realizations h_t such that $\Pr(h_t|y_{it}, \eta_t) > 0$ gives

$$\frac{\Pr(y_{it}, \eta_t)^{-1}}{v'(y_{it} + \tau_{it}(y_{it}, \eta_t))} \sum_{h_t \mid \Pr(h_t|y_{it}, \eta_t) > 0} \eta_t(h^t)$$

$$= \sum_{h_t \mid \Pr(h_t|y_{it}, \eta_t) > 0} \Pr(h_t|y_{it}, \eta_t) \frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)}$$

$$= \mathbb{E}\left(\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} \middle| y_{it}, \eta_t\right)$$

So that

$$\frac{1}{v'(y_{it} + \tau_{it}(y_{it}, \eta_t))} \sum_{h_t \mid \Pr(h_t|y_{it}, \eta_t) > 0} \eta_t(h^t) = \Pr(y_{it}, \eta_t)\mathbb{E}\left(\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} \middle| y_{it}, \eta_t\right)$$

Summing over all realizations of (y_{it}, η_t) gives

$$\sum_{y_{it}, \eta_t} \frac{1}{v'(y_{it} + \tau_{it}(y_{it}, \eta_t))} \sum_{h_t \mid \Pr(h_t|y_{it}, \eta_t) > 0} \eta_t(h^t) = \mathbb{E}\left(\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)}\right)$$

or

$$\sum_{h_t} \left(\frac{\eta_t(h^t)}{v'(y_{it} + \tau_{it}(y_{it}, \eta_t))}\right) = \mathbb{E}\left(\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)}\right)$$

So, using the time $t+1$ envelope condition for $u_{i,t+1}(h^t)$, (27):

$$\frac{\eta_t(h^t)}{v'(y_{it} + \tau_{it}(h^t))} = \Pr(h_t)\frac{\partial u_N(\mathbf{u}_{t+1}(h^t), a_{t+1}(h^t), \mathbf{e})}{\partial u_{i,t+1}(h^t)} = \mathbb{E}_{h^{t+1}}\left(\lambda_{i,t+1}|h^t\right)$$

lagging by one period and using the FOC for $\tau_{it}(h^t) = \tau_{it}(y_{it}, \eta_t)$,

$$\mathbb{E}_{h^t}\left(\frac{\lambda_{it}}{\eta_t(h^t)}\middle| h^{t-1}, \eta_t(h^t)\right) = \frac{1}{v'(c_{i,t-1}(h^{t-1}))} = \frac{1}{\eta_t(h^t)}\left(\lambda_{i,t-1} + \frac{\phi_{ir,t-1}(y_{i,t-1})}{\Pr(h^t|h^{t-1})}\right).$$

Starting from the multiplier on the initial promise-keeping constraint, λ_{i0},

$$\mathbb{E}_{h^t}\left(\frac{1}{v'(c_{it}(h^t))}\middle| \eta_t(h^t)\right)$$

$$= \frac{\lambda_{i,t-1}(h^{t-1})}{\eta_t(h^t)} = \lambda_{i0} + \sum_{q=1}^{t-1} \frac{\phi_{ir,t-q}(y_{i,t-q})}{p(y_q)\eta_q}$$

Lagged inverse marginal utility, conditional on the current shadow price of resources $\eta_t(h^t)$, captures all past information relevant to forecasting current marginal utility of consumption.∎

A.4 Proof of proposition 4: With hidden income, lagged inverse marginal utility over-predicts consumption for low-lagged income households

Let λ_{it} be the multiplier on household i's promise-keeping constraint, η_t the multiplier on the budget constraint, and ζ_{irt} the multiplier on the truth-telling constraint when $y_t = y_r$. The FOCs are:

43

τ_{irt}:

$$\eta_t = \left(p_{ree'}\lambda_t + \xi_{irt}\right) v'(y_r + \tau_{rt}) - \xi_{i,r+1,t}v'(y_{r+1} + \tau_{irt})$$

$u_{ir,t+1}$:

$$p_{ree'}\mathbb{E}_{\{y_{-i}|y_i\}} \frac{-\partial u_N(\mathbf{u}_{t+1}, a_{t+1}, \mathbf{e})}{\partial u_{ir,t+1}} = p_{ree'}\lambda_t + \xi_{irt} - \xi_{i,r+1,t}$$

a_{t+1}:

$$-\mathbb{E}_{\{y\}} \frac{\partial u_N(\mathbf{u}_{t+1}, a_{t+1}, \mathbf{e})}{\partial a_{t+1}} = -\eta_t$$

envelope conditions:

$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e}')}{\partial u_{it}} = -\lambda_{it}$$
$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e}')}{\partial a_t} = \eta_t$$

The lagged promise-keeping multiplier, λ_{t-1}, is a sufficient statistic for history, since the FOC for $u_{ir,t+1}$ and the envelope condition for u_{it} imply

$$\mathbb{E}\left(\lambda_{i,t+1}|\eta_{t+1}\right) = \lambda_{it} + \frac{\xi_{irt} - \xi_{i,r+1,t}}{p(y_t)}$$

lagging one period,

$$\mathbb{E}\left(\lambda_{it}|\eta_t\right) = \lambda_{i,t-1} + \frac{\xi_{ir,t-1} - \xi_{i,r+1,t-1}}{p(y_{t-1})}.$$

The FOC for transfers at $t-1$ implies that

$$\lambda_{i,t-1} = \frac{1}{v'(y_r + \tau_{ir,t-1})} \times \qquad (35)$$
$$\left(1 - \frac{\xi_{ir,t-1}v'(y_r + \tau_{irt}) - \xi_{i,r+1,t-1}v'(y_{r+1} + \tau_{irt})}{\eta_{t-1}p(y_{t-1})}\right)$$

Since $\mathbb{E}(\lambda_{it}|\eta_t) = \lambda_{i,t-1}$,

$$\mathbb{E}(\lambda_{it}|\eta_t) = \frac{1}{v'(y_r + \tau_{r,t-1})} \times$$
$$\left(1 - \frac{\xi_{ir,t-1}v'(y_r + \tau_{rt}) - \xi_{i,r+1,t-1}v'(y_{r+1} + \tau_{rt})}{\eta_{t-1}p(y_{t-1})}\right)$$

Using the envelope condition for u_{it}, the time $t-1$ FOC for u_{it} can be written

$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it}} - \frac{\partial u_N(\mathbf{u}_{t-1}, a_{t-1}, \mathbf{e})}{\partial u_{i,t-1}} = \frac{\xi_{i,r,t-1} - \xi_{i,r+1,t-1}}{p_{ree'}}$$

First, assume no aggregate uncertainty: $a_t = a_{t-1}$

Since $u_N(\mathbf{u}_t, a_t, \mathbf{e})$ is concave in each u_{it}, when a household's promise decreases $(u_{it} < u_{i,t-1})$, then

$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it}} > \frac{\partial u_N(\mathbf{u}_{t-1}, a_t, \mathbf{e})}{\partial u_{i,t-1}},$$

so $\xi_{ir,t-1} > \xi_{i,r+1,t-1}$: truth-telling constraints bind more at lower than higher output levels. Then, since $v'(y_r + \tau_{rt}) > v'(y_{r+1} + \tau_{rt})$,

$$\xi_{ir,t-1}v'(y_{ir} + \tau_{ir,t-1}) > \xi_{i,r+1,t-1}v'(y_{ir+1} + \tau_{ir,t-1})$$

so

$$\mathbb{E}(\lambda_{it}|h^{t-1}) < \frac{1}{v'(y_{ir} + \tau_{ir,t-1})}$$

LIMU over-predicts λ_{it} when the household's promise decreased between $t-1$ and t. Promises are unobserved, but truth-telling implies that promises are an increasing function of income, so low-y_{t-1} households will get less consumption at t than predicted using lagged inverse marginal utility.

However, if $a_t > a_{t-1}$, there is an offsetting effect:

$$\frac{\partial^2 u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it} \partial a_t} \neq 0 \Rightarrow$$
$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it}} \neq \frac{\partial u_N(\mathbf{u}_t, a_{t-1}, \mathbf{e})}{\partial u_{i,t-1}}$$

However, we can sign this effect: by the envelope condition for u_{it}:

$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it}} = -\lambda_{it}$$

So

$$\frac{\partial^2 u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it} \partial a_t} = -\frac{\partial \lambda_{it}}{\partial a_t}$$
$$sgn\left(-\frac{\partial \lambda_{it}}{\partial a_t}\right) = sgn\left(\frac{\partial \lambda_{it}}{\partial \eta_t}\right)$$

Using the formula for λ_{it}:

$$\frac{\partial \lambda_{it}}{\partial \eta_t} = \frac{1}{v'(y_r + \tau_{irt})} \times$$
$$\frac{\partial}{\partial \eta_t}\left(1 - \frac{\xi_{irt}v'(y_r + \tau_{irt}) - \xi_{i,r+1,t}v'(y_{r+1} + \tau_{irt})}{\eta_t p(y_r)}\right)$$

$$sgn\left(\frac{\partial \lambda_{it}}{\partial \eta_t}\right) = sgn\left(\xi_{irt}v'(y_r + \tau_{irt}) - \xi_{i,r+1,t}v'(y_{r+1} + \tau_{irt})\right)$$

That is, when $u_{it} < u_{i,t-1}$,
$$\frac{\partial^2 u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it} \partial a_t} > 0$$

so the extent of "overprediction at the bottom" is reduced the greater is $\Delta a_t \equiv a_t - a_{t-1}$.∎

A.5 Proof of proposition 5: Less variable income processes display a reduced wedge between LIMU and current inverse marginal utility:

Using (35):

$$\mathbb{E}(\lambda_{it}|\eta_t) = \frac{1}{v'(y_q + \tau_{iq,t-1})} \times$$
$$\left(1 - \frac{\xi_{iqt-1}v'(y_q + \tau_{iqt-1}) - \xi_{iq+1t-1}v'(y_{q+1} + \tau_{iqt+1})}{\eta_{t-1}p_{qee'}}\right)$$

Define

$$\theta(y_q) \equiv 1 - \frac{\xi_{iqt-1}v'(y_q + \tau_{iqt-1}) - \xi_{iq+1t-1}v'(y_{q+1} + \tau_{iqt+1})}{\eta_{t-1}p_{qee'}}.$$

$\theta(y_q)$ measures the "wedge" between λ_{it} and $\frac{1}{v'(y_q+\tau_{iq,t-1})}$. Take the expectation of $\theta(y_q)$, given that y_q was below the average level of income $\bar{y}$:

$$\mathbb{E}[\theta(y_q)|y_q < \bar{y}] =$$
$$\sum_{q:y_q<\bar{y}} p_{qee'}\left[1 - \frac{\xi_{iqt-1}v'(y_q + \tau_{iqt-1}) - \xi_{iq+1t-1}v'(y_{q+1} + \tau_{iqt+1})}{\eta_{t-1}p_{qee'}}\right]$$

Fixing the probability of each income realization, $p_{qee'}$, a SOSD reduction in variability will reduce

$$\mathbb{E}\left[v'(y_q + \tau_{iq,t-1}) - v'(y_{q+1} + \tau_{iq,t+1})\right]$$

since income levels are closer together (note these differences remain negative since $y_q < y_{q+1}$), and will reduce

$$\mathbb{E}\left|\xi_{ir,t-1} - \xi_{i,r+1,t-1}\right|$$

since

$$\frac{\partial u_N(\mathbf{u}_t, a_t, \mathbf{e})}{\partial u_{it}} - \frac{\partial u_N(\mathbf{u}_{t-1}, a_{t-1}, \mathbf{e})}{\partial u_{i,t-1}} = \frac{\xi_{i,r,t-1} - \xi_{i,r+1,t-1}}{p_{ree'}}$$

and a reduction in the amount of uncertainty about the household's income moves u_{it} and $u_{i,t-1}$ closer together, on average (insurance improves). By the concavity of the planner's value function, this in turn reduces the gap $\frac{\partial u_N(\mathbf{u}_t,a_t,\mathbf{e})}{\partial u_{it}} - \frac{\partial u_N(\mathbf{u}_{t-1},a_{t-1},\mathbf{e})}{\partial u_{i,t-1}}$ (which remains negative since the household's promise is falling).

Therefore, $\mathbb{E}[\theta(y_q)|y_q < \bar{y}] \to 1$ as the variability of y decreases, so that the amount of additional information contained in y_{t-1} falls.∎

B   Appendix: Tables

<div align="center">Table 1: Summary statistics</div>

		531-HH panel mean	Non-continuously observed HH difference	N
	Monthly income	8981.224	-2624.627	670
	Monthly expenditure	5213.472	-1108.721***	670
	Monthly income, resids	32.443	-163.756	670
	Monthly expenditure, resids	67.416	-570.84	670
	Household size	4.525	-0.663***	669
	Adult equivalents	3.786	-0.638***	669
	Adult men	1.382	-0.324***	669
	Adult women	1.552	-0.247***	669
Gifts given				
	Gifts to orgs in village	33.714	-9.813	670
	Gifts to orgs not in village	53.749	-29.063**	670
	Gifts given for events in village	103.219	-35.550***	670
	Gifts given for events not in village	220.117	-140.576***	670
	Other gifts to HHs in village	147.317	-29.854	670
	Other gifts to HHs not in village	637.198	-96.868	670
Gifts received				
	Gifts from orgs in village	36.105	-20.002**	670
	Gifts from orgs not in village	38.963	10.82	670
	Gifts rec'd for events in village	316.862	-213.653***	670
	Gifts rec'd for events not in village	80.068	9.976	670
	Other gifts from HHs in village	118.129	-20.575	670
	Other gifts from HHs not in village	1327.131	-253.376	670
Occupation	(household head, baseline)			
	Rice farmer	0.355	0.116*	667
	Non-ag labor	0.119	0.033	667
	Corn farmer	0.098	-0.062*	667
	Livestock farmer	0.089	-0.082***	667
	Ag wage labor	0.051	0.007	667
	Other crop farmer	0.043	-0.036*	667
	Shrimp/fish farmer	0.036	-0.021	667
	Orchard farmer	0.017	0.005	667
	Construction	0.015	0.036*	667
	Other	0.074	0.013	667

Notes: All baht-denominated variables were converted to 2002 baht using the Thai Ministry of Trade's Rural Consumer Price Index for Thailand. In 2002, approximately 42 Thai baht were equal to US$1. Income and expenditure resids are residuals from regression on village, year, occupation and demographic variables.

Table 2: Consumption smoothing at the individual and village level

	log household PCE	log household PCE	log avg household PCE	log household PCE	log household PCE	log avg household PCE
		OLS			IV	
	(1)	(2)	(3)	(4)	(5)	(6)
log household income	.0778***	.0669***		.2113***	.1737***	
	[.0074]	[.0073]		[.0394]	[.0444]	
avg log household income			.1722***			.3002***
			[.0499]			[.1164]
Village-year fixed effect?	No	Yes	No	No	Yes	No
Village-year F statistic	-	5.256	-	-	3.471	-
P value	-	0.0000	-	-	0.0000	-
Observations	3323	3323	112	1879	1879	64
R-squared	0.0318	0.1807	0.8763			

Notes: Household-level variables in columns (1), (2), (4) and (5) are deviations from individual means. Standard errors in brackets. All variables are in 2002 Thai baht. F-statistic tests the joint significance of the village-year effects. In columns (4) and (5) income is instrumented with quarterly rainfall deviations from average province-level quarterly rainfall, and deviations, and deviations and squared deviations interacted with 11 occupation dummies. In column (6) income is instrumented with quarterly rainfall deviations and squared deviations. Rainfall data is available for 1999-2003. *p<.1, ** p<.05, *** p<.01

Table 3: Movement in the consumption distribution

A: Correlations in per capita expenditure rank' over time

Rank in village PCE distribution

	2005	2004	2003	2002	2001	2000	1999
2005	1.000						
2004	0.643	1.000					
2003	0.645	0.658	1.000				
2002	0.565	0.681	0.680	1.000			
2001	0.453	0.549	0.591	0.589	1.000		
2000	0.354	0.409	0.436	0.437	0.539	1.000	
1999	0.375	0.442	0.466	0.459	0.525	0.824	1.000

B: Changes in PCE rank vs. changes in income

	OLS (LHS var: change in PCE rank)	Ordered probit* (LHS var: direction of change)
Change in ln(income)	.527	.0586
	[.1414]	[.0089]
	3.73	6.56
R-squared	0.0052	
N	2674	2674

Notes: In panel B, standard errors in brackets, t-statistics in italics.
*Marginal effect on probability of positive change in income rank,
evaluated at mean income.

Table 4: Testing sufficiency of lagged inverse marginal utility

	Full sample		Drop top and bottom 5% of PCE	
	(1)	(2)	(3)	(4)
ln(LIMU)	.7386***	.7126***	.6215***	.5952***
	[.0208]	[.023]	[.0212]	[.0233]
Lagged log income		.0424***		.0378***
		[.007]		[.0068]
Village-year fixed efftects?	Yes	Yes	Yes	Yes
R-squared	0.6645	0.6687	0.6200	0.6299
Observations	3186	2845	2874	2573

Notes: Robust standard errors in brackets. Ln(LIMU) is
proportional to $ln(c_{t-1})$. LIMU is lagged inverse marginal utility.

Table 5: Testing Amnesia

	Full Sample		Drop top and bottom 5% of PCE		Low rainfall variance	High rainfall variance
	(1)	(2)	(3)	(4)	(5)	(6)
ln(LIMU)	0.846***	0.756***	0.790***	0.714***	0.949***	0.933***
	[0.011]	[0.019]	[0.014]	[0.021]	[0.027]	[0.024]
ln(LIMU)X25	0.041***	0.134***	0.038***	0.120***		
	[0.001]	[0.015]	[0.001]	[0.016]		
ln(LIMU)X50	0.059***	0.152***	0.054***	0.139***		
	[0.001]	[0.015]	[0.001]	[0.015]		
ln(LIMU)X75	0.099***	0.201***	0.088***	0.166***		
	[0.002]	[0.022]	[0.002]	[0.020]		
ln(income)		0.093***		0.083***	0.030*	-0.004
		[0.013]		[0.013]	[0.012]	[0.012]
ln(income)X25		-0.084***		-0.074***		
		[0.013]		[0.013]		
ln(income)X50		-0.085***		-0.076***		
		[0.013]		[0.013]		
ln(income)X75		-0.092***		-0.071***		
		[0.018]		[0.017]		
ln(LIMU)+ln(LIMU)X75		0.957		0.880		
F-statistic		3576.2		2807.3		
p-value		0.000		0.000		
Chi-squared (High=Low)					0.20	
p-value					(0.658)	
Fixed effects	Village	Village	Village	Village	Village	Village
Sample	Full	Full	Middle 90% by PCE	Middle 90% by PCE	HHs w/ above median growth in PCE, low var. villages	HHs w/ above median growth in PCE, high var. villages
R-squared	0.85	0.86	0.82	0.83	0.70	0.74
N	3186	2860	2874	2589	665	811

Note: High-rainfall variance villages are those with above-median standard deviation of annual rainfall.
Robust standard errors in brackets (clustered at the household level). Ln(LIMU) is proportional to $ln(c_{t-1})$.
LIMU is lagged inverse marginal utility. *p<.1, ** p<.05, *** p<.01

Table 6: Testing the hidden income model (CRRA utility)

LHS=Prediction residuals from a regression of $ln(c_t)$ on $ln(c_{t-1})$ and a village-year effect.				
	OLS		IV	
	(1)	(2)	(3)	(4)
Constant (α)	-.5406	-.4839	-.2301	-.2123
	[.0691]	[.0694]	[.0668]	[.0576]
Lagged log income (β)	.0509	.0453	.0224	.0205
	[.0061]	[.0063]	[.0059]	[.0052]
Control for aggregate shock interactions?	Yes	No	Yes	No
Chi-square stat ($\alpha<0$, $\beta>0$)	81.47	54.84	19.11	19.40
p value	(0.000)	(0.000)	(0.000)	(0.000)
Observations	2781	2781	2322	2322

Notes: Bootstrapped standard errors in brackets. All regressions include a village-year fixed effect. Chi-square stat is the statistic for the test that the slope>0, intercept<0. P-value in parentheses.

Table 7: Test overidentifying restrictions on reduced form for consumption

| | (1) | (2) | | (3) | (4) | |
	$ln(c_t)$	$ln(c_{t-1})$	(1)/(2)	$ln(c_t)$	$ln(c_{t-1})$	(3)/(4)
$Cultivation_{t-1}$	0.1033	0.0656	1.575	0.1029	0.0652	1.578
	[0.0235]	[0.0203]		[0.0236]	[0.0204]	
$Cultivation_{t-2}$	0.0112	0.047		0.0135	0.0498	
	[0.0207]	[0.0164]		[0.0204]	[0.0166]	
$Cultivation_{t-3}$	-0.0283	-0.0295		-0.0376	-0.0396	
	[0.0318]	[0.0326]		[0.0325]	[0.0334]	
$Livestock_{t-1}$	0.0141	0.0223	0.632			
	[0.0147]	[0.0120]				
$Livestock_{t-2}$	0.0104	0.0085				
	[0.0057]	[0.0073]				
$Livestock_{t-3}$	0.0039	0.002				
	[0.0105]	[0.0092]				
$Fish_{t-1}$				0.0396	0.0516	0.767
				[0.0166]	[0.0142]	
$Fish_{t-2}$				0.0121	0.0077	
				[0.0083]	[0.0091]	
$Fish_{t-3}$				0.012	0.0129	
				[0.0094]	[0.0092]	
Rank in 1999	0.027	0.0273		0.0274	0.0278	
	[0.0027]	[0.0027]		[0.0027]	[0.0026]	
Constant	9.057	8.9959		9.0472	8.9854	
	[0.0500]	[0.0487]		[0.0496]	[0.0483]	
N	2124	2124		2124	2124	
Chi-sqared statistic (p-value) on ratios of $t-1$ coefficients equal	4.1286	(0.0422)		3.7292	(0.0535)	

Notes: Standard errors clustered at the household level in brackets. Coefficients and standard errors on income variables (in levels) are multiplied by 100,000. "Cultivation" is income from growing crops (rice, corn, orchard crops, etc.). "Livestock" is income from raising cows, pigs, ducks, etc. "Fish" is income from raising fish and shrimp. "Rank in 1999" is the household's rank in the 1999 distribution of per capita consumption.

Table 8: Testing the hidden income model, nonparametric $u()$

Panel A: LHS=Prediction residuals from a regression of $ln(c_t)$ on $f(c_{t-1})$ and a village-year effect.

	OLS	IV
	(1)	(2)
Constant (α)	-0.370	-0.141
	[0.0643]	[0.0668]
Lagged log income (β)	0.034	0.014
	[0.0059]	[0.0060]
Control for aggregate shock interactions?	Yes	Yes
Chi-square stat ($\alpha<0$, $\beta>0$)	33.86	7.30
p value	(0.000)	(0.026)
Observations	2781	2322

Panel B: LHS=$\ln(c_t)$		
	OLS	IV
LIMU ($f(c_{t-1})$)	0.906***	1.140***
	[0.0178]	[0.0286]
Lagged log income	0.0446***	0.0209**
	[0.0066]	[0.0079]
Village-year effect?	Yes	Yes
N	2781	2322

Notes: In Panel A, standard errors bootstrapped (50 replications) to account for the generated regressor. LHS variable is prediction residuals from OLS or IV regression of $ln(c_t)$ on $f(c_{t-1})$ and a village-year effect. Column (1) uses the nonparametric spline estimate of $f(c_{t-1})$ as an explanatory variable to form the predicted value of $ln(c_t)$; column (2) instruments this nonparametric estimate with its lag, $f(c_{t-2})$. Chi-square stat is the statistic for the test that the slope>0, intercept<0. p-values in parentheses.

Table 9a: Testing the hidden income model:

Split by predictive power of rainfall

LHS=Prediction residuals from a regression of $ln(c_t)$ on $ln(c_{t-1})$ and a village-year effect.

	High rainfall R^2	Low rainfall R^2
	(1)	(2)
Constant (α)	-0.421	-0.621
	[0.088]	[0.090]
Lagged log income (β)	0.047	0.056
	[0.008]	[0.008]
Control for aggregate shock interactions?	Yes	Yes
Chi-square stat (α<0, β>0)	28.581	54.156
p value	(0.000)	(0.000)
Observations	1173	1326

Notes: Bootstrapped standard errors in brackets. Chi-square stat is the statistic for the test that the slope>0, intercept<0. p-value in parentheses.

Table 9b: Testing the hidden income model:

Split by variance of income

LHS=Prediction residuals from a regression of $ln(c_t)$ on $ln(c_{t-1})$ and a village-year effect.

|	High variance	Low variance
	(1)	(2)
Constant (α)	-0.49	-0.406
	[0.087]	[0.089]
Lagged log income (β)	0.047	0.037
	[0.008]	[0.008]
Control for aggregate shock interactions?	Yes	Yes
Chi-square stat (α<0, β>0)	56.96	22.03
p value	(0.000)	(0.000)
Observations	1387	1394

Notes: Bootstrapped standard errors in brackets. Chi-square stat is the statistic for the test that the slope>0, intercept<0. p-value in parentheses.

Table 10: Predicting income with rainfall

| Occupation	R^2	N
Rice farmer	0.386	752
Construction	0.292	32
Orchard farmer	0.222	36
Shrimp/fish farmer	0.195	76
Agricultural wage labor	0.143	108
Livestock	0.142	188
Other crop farmer	0.120	92
Non-agricultural wage labor	0.116	252
Other	0.100	156
Corn farmer	0.088	208

Notes: R^2 is the R-squared of annual income on quarterly income deviations and squared deviations, plus province-fixed effects. N is the number of household-year observations.
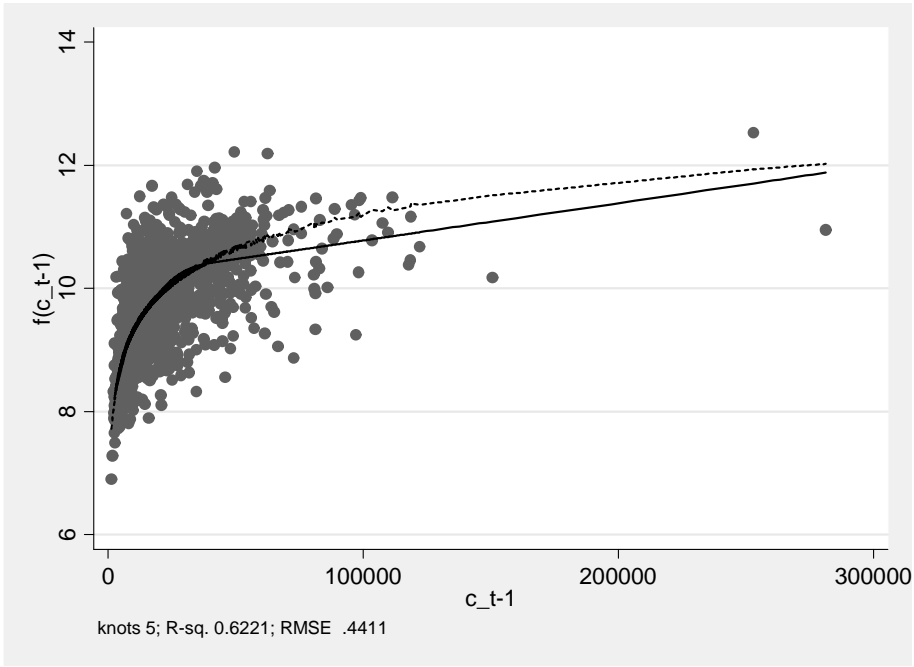
C   Appendix: Figures
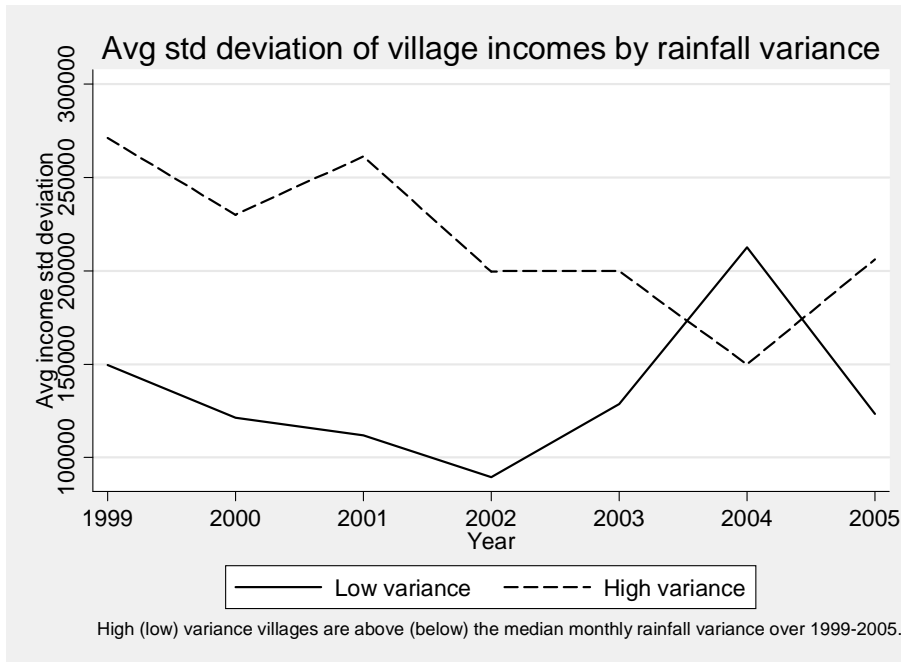
Standard deviation of incomes by rainfall variance
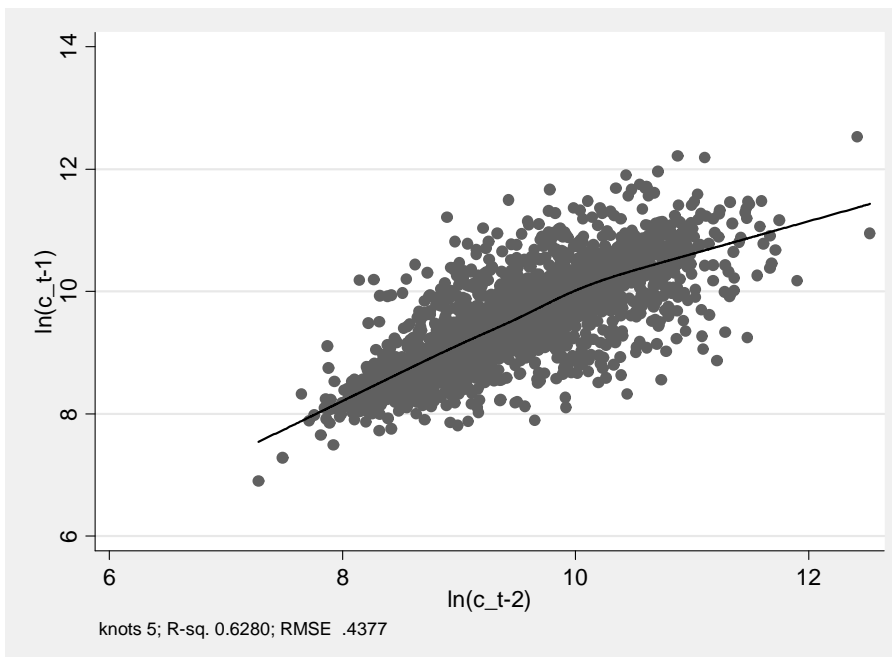
Spline regression of $\ln\left(c_{t-1}\right)$ on $\ln\left(c_{t-2}\right)$

knots 5; R-sq. 0.6221; RMSE .4411

Spline regression of c_t on $f\left(c_{t-1}\right)$