Temporary Migration and Endogenous Risk-Sharing in Village India

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Abstract

When people can self-insure via migration, they may have less need for informal risk-sharing. At the same time, informal insurance may reduce the need to migrate. To understand the joint determination of migration and risk-sharing I study a dynamic model of risk-sharing with limited commitment frictions and endogenous temporary migration. First, I characterize the model. I demonstrate theoretically how migration may decrease risk-sharing. I decompose the welfare effect of migration into changes in income and changes in the endogenous structure of insurance. I then show how risk-sharing alters the returns to migration. Second, I structurally estimate the model using the new (2001-2004) ICRISAT panel from rural India. The estimation yields: (1) improving access to risk-sharing reduces migration by 25 percentage points; (2) reducing the cost of migration reduces risk-sharing by 13 percentage points; (3) contrasting endogenous to exogenous risk-sharing, the consumption-equivalent gain from reducing migration costs is 32 percentage points lower for the former than for the latter. Third, I introduce a rural employment scheme. The policy reduces migration and decreases risk-sharing. The welfare gain of the policy is 50%-90% lower after household risk-sharing and migration responses are considered.

Keywords: Internal migration, risk-sharing, Limited Commitment, Dynamic Contracts, India, Urban, Rural

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1 Introduction

Rural households in developing countries face extremely high year-to-year volatility in income. Economists have long studied the complex systems of informal transfers that allow households to insulate themselves against income shocks in the absence of formal markets (Udry, 1994; Townsend, 1994). However, households can also migrate temporarily when hit by negative economic shocks. In rural India, 20% of households send at least one temporary migrant to the city, with migration income representing half of their total income. The migration option offers a form of self-insurance, and hence may fundamentally change the incentives for households to participate in informal risk-sharing. At the same time, informal risk-sharing provides insurance against income shocks, altering the returns to migrating. To properly understand the benefits of migration, and to consider policies that might help households address income risk, it is, therefore, important to consider the joint determination of risk-sharing and migration.

To analyze the interaction between risk-sharing and migration I study a dynamic model of risk-sharing that incorporates limited commitment frictions and endogenous temporary migration. Households take risk-sharing into account when deciding to migrate. Similarly, the option to migrate affects participation in informal risk-sharing. My model combines migration in response to income differentials (Sjaastad, 1962; Harris and Todaro, 1970), as well as risk-sharing with limited commitment frictions (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002). First, I demonstrate theoretically the channels through which migration may decrease risk-sharing, by changing the value of the outside option for households. I decompose the welfare effect of migration into changes in income and changes in the endogenous structure of the insurance market. I then show how risk-sharing alters the returns to migration and determines migration decisions. Second, I apply the model to the empirical setting of rural India. I structurally estimate the model using the second wave of the ICRISAT household panel dataset (2001-2004). The quantitative results are as follows: (1) introducing migration into the model reduces risk-sharing by 13 percentage points; (2) contrasting endogenous to exogenous risk-sharing, the consumption-equivalent gain in welfare from introducing migration is 32 percentage points lower for the former than the latter; and (3) improving access to risk-sharing reduces migration by 25 percentage points. Third, I show that the joint determination of risk-sharing and migration at the household level may have key policy implications. I simulate a rural employment scheme (similar to the Indian Government's Mahatma Gandhi National Rural Employment Guarantee Act) in the model. Households respond to the policy by adjusting both migration and risk-sharing: migration decreases and risk-sharing is reduced. I show that the welfare benefits of this policy are overstated if the joint responses to migration and risk-sharing are not taken into account. The welfare gain of the policy is 50%-90% lower after household risk-sharing and migration responses are considered.

This paper makes an important contribution by considering the joint determination of migration and risk-sharing. Empirical tests reject the benchmark of perfect insurance, but find evidence of substantial smoothing of income shocks (Mace, 1991; Altonji, Hayashi and Kotlikoff, 1992; Townsend, 1994; Udry, 1994). Models of limited commitment endogenously generate incomplete insurance because households can walk away from agreements (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002; Alvarez and Jermann, 2000).[1] Using the limited commitment framework, other studies have examined how risk-sharing responds to changes in households' outside options, including public insurance schemes (Attanasio and Rios-Rull, 2000; Albarran and Attanasio, 2003; Golosov and Tsyvinski, 2007; Abramitzky, 2008; Krueger and Perri, 2010), unemployment insurance (Thomas and Worrall, 2007), and options for saving (Ligon, Thomas and Worrall, 2000). However, these papers have not examined how migration decisions are jointly determined with risk-sharing decisions.

The paper also fits into a body of literature that examines the determinants and benefits of migration and remittances.[2] I add to this literature by showing that it is important

[1]See also the application of limited commitment in labor markets (Harris and Holmstrom, 1982; Thomas and Worrall, 1988) and insurance markets (Hendel and Lizzeri, 2003).

[2]For example, Rosenzweig and Stark (1989) show that in India marriage-migration can be an important income smoothing mechanism for households. Yang and Choi (2007) show that remittances from migrants respond to income shocks. In a series of papers examining rural-urban migration in China, Giles (2006, 2007); de Brauw and Giles (2014) show that migration reduces the riskiness of household income at the destination, reduces precautionary savings, and potentially shifts production into riskier activities. Bryan et al. (2014) document large returns to migration in a randomized controlled trial in Bangladesh. Other

to study how migration interacts with informal risk-sharing. In a standard migration model, households take into account income differentials between the village and city and migrate if the utility gain of doing so is positive (Lewis, 1954; Sjaastad, 1962; Harris and Todaro, 1970). In contrast, when households enter into risk-sharing agreements, the relevant comparison is post-transfer, rather than gross, income differentials. As a result, risk-sharing has two effects on migration. Households use migration as an ex-post income-smoothing mechanism, so households with members who migrate have experienced negative income shocks. These households would be net recipients of risk-sharing transfers in their villages. Risk-sharing reduces the income gain between the village and the city and reduces migration. On the other hand, migration is risky (Bryan, Chowdhury and Mobarak, 2014; Tunali, 2000). Risk-sharing can insure against risky migration outcomes, facilitating migration.

This paper focuses on temporary migration. Temporary migration is the relevant margin on which to focus in the case of rural India because permanent migration there is very low (Munshi and Rosenzweig, 2015; Topalova, 2010), but, as I document in this paper, short-term migration for approximately six months is widespread. I study the decision of a household to send at least one of its members to work in the city. On average, a migrant household includes 1.8 temporary migrants, with a migration duration of 192 days. A key difference between temporary and permanent migration is that in the latter case migrants are less likely to remain in risk-sharing networks (Banerjee and Newman, 1998; Munshi and Rosenzweig, 2015). Because temporary migrants remain members of their households and thus in risk-sharing networks, I study how the option to migrate temporarily changes the equilibrium risk-sharing, holding the network itself constant.

Before proceeding to the structural estimation, I first establish five empirical facts relating migration to risk-sharing. First, migration responds to exogenous income shocks. When monsoon rainfall is low, migration rates are higher. This matches the modeling assumption that migration decisions are made after income is realized. Second, households move in and out of migration status. Forty percent of households send a migrant to the

studies have investigated the role of learning in explaining observed migration behavior, particularly repeat migration (Pessino (1991); Kennan and Walker (2011)).

city at least once during the sample period. Yet, an individual who migrated in any one year migrates in the following year in less than half of the observations. This implies that households migrate in response to income shocks and that temporary migration is not a persistent strategy. Third, risk-sharing is imperfect and is worse in villages where temporary migration is more common. This is consistent with the occurrence of an interaction effect between informal risk-sharing and migration. Fourth, conditional on income, the past history of transfers negatively predicts current transfers. This is consistent with the limited commitment model (Foster and Rosenzweig, 2001). Fifth, although a household increases its income by 30% during the years in which it sends a migrant to the city, total expenditure (consumption and changes in asset positions) increases by only 85% of the increase in income. This last fact is consistent with migrants transferring remittances back to the network.

To quantify the effects of the joint determination of migration and risk-sharing I structurally estimate the model. Empirically, households are more likely to migrate if they have more males and if they have smaller landholdings. To match this heterogeneity in migration across households, I allow land holdings to affect village income, and I also allow households to face costs of migration that depend on their household composition (in particular, based on the number of males in the household).[3] Using the structural estimates, I then construct counterfactuals to simulate the effects on risk-sharing from reducing the costs of migration as well as the effects on migration of improving access to risk-sharing. I also illustrate how the joint determination of migration and risk-sharing has important implications for understanding the benefits of policies designed to address the income risk faced by poor rural households, using the example of the Indian Government's Mahatma Gandhi National Rural Employment Guarantee Act.

In the following section, I present the risk-sharing model with endogenous migration. Section 3 introduces the household panel used to estimate the model, and verifies that the modeling assumptions hold in these data. Section 4 discusses how to apply the model to

[3] In Section 3 I discuss an alternative hypothesis that males migrate more than females because they receive higher returns, rather than because they face lower costs. However, using labor market data, I find, if anything, evidence of higher returns to migration for females than males (although the number of female migrants is low).

the data, and Section 5 presents the structural estimation results and performs the policy experiments. Section 6 concludes with a discussion of the findings.

2 Joint model of migration and risk-sharing

Consider a two-household endowment economy. Both households have identical preferences.[4] In each period t the village experiences one of finitely many events s_t that follows a Markov process with transition probabilities $\pi^s(s_t|s_{t-1})$. The village event determines the endowment of each household in the village, $e^i(s_t)$. In each period t the city experiences one of finitely many events q_t that follows an i.i.d process with probabilities $\pi^q(q_t)$. The city event determines the migration income of each household in the village if they migrate, $m^i(q_t)$.[5] Income is perfectly observable.[6]

The timing in the model is as follows. Households observe their endowments in the village (state s) and decide whether to send a temporary migrant to the city. Let $\mathbb{I}^i$ be an indicator variable for whether household i migrates. Each household either sends or does not send a migrant, with the vector $\mathbb{I}(j) = \{\mathbb{I}^1(j), \mathbb{I}^2(j)\}$ denoting the migration decisions of the two households. If a household sends out a migrant it then realizes the migration income (state q) and pays a utility cost $d(z)$, which captures both the physical costs of migration (for example, transportation costs) as well as the psychic costs (for example, being away from friends and family) (Sjaastad, 1962).[7] For state of the world s_t, migration outcome q_t, and migration decision j_t, after-migration income for household i is given by

[4]For papers that analyze risk-sharing when preferences are heterogeneous, see Mazzocco and Saini (2012); Chiappori, Samphantharak, Schulhofer-Wohl and Townsend (2014) and Schulhofer-Wohl (2011).

[5]The model easily extends to allow a Markov process for city income, with the addition of one more state variable to keep track of the past state of the city. I find no evidence, however, of persistence in migration income and so model the city income as an i.i.d. process.

[6]It is reasonable to consider whether migration income is less easily observable than income earned in the village. I find no evidence that villages with larger shares of their migrants going to the same destination engage in risk-sharing differentially when compared with villages sending migrants to many destinations, assuming that in the first case, migration income is, on average, more easily observable. These results are presented in Appendix E.

[7]In the model, conditional on the income realization and the Pareto weight, migration is deterministic. An alternative way to model migration would be to model unobserved preference (or unobserved cost) shocks, as in Kennan and Walker (2011). This would make the migration rule probabilistic. An unobserved preference shock is observationally equivalent to an unobserved income shock and it is therefore not identifiable. I choose to assign everything on the income draw.

$\tilde{y}^i(s_t, q_t, j_t; z^i)$. This incorporates the case where the household may receive some income from the village and some income from the city.[8] Once all income is realized, households make or receive risk-sharing transfers, $\tau(s, q, j)$, and consumption occurs. Migration is temporary and all migrants who leave return home at the end of the period. This is a reasonable assumption in the case of rural India: as I discuss in Section 3, I find little evidence of permanent migration in the data, consistent with other work that has documented very low rates of permanent migration in India (Munshi and Rosenzweig, 2015; Topalova, 2010). The household then faces the same problem in the following period.

The timing of the model is based on two empirical facts, both of which are documented in Section 3. First, the average migration rate depends on the rainfall realization, consistent with households making migration decisions after observing the village level income. Second, 37% of migrants experience unemployment at the destination, consistent with the delay of migration income realization until after the migration decision occurs.[9]

In the model and the estimation, I make several simplifying assumptions, based on patterns in the data. In the data, a household that participates in migration sends on average 1.8 migrants and such a household earns 60% of its income from migration. I define a household as a "migrant household" if there is at least one member who works outside the village. One assumption is that I focus on the extensive decision to migrate rather than on which member, or how many members, to send.[10] I focus on the extensive margin of migration because the number of migrants does not appear to be a primary margin of adjustment. In the data 80% of all household migration events involve either one or two people migrating, and within any given household, those who migrate are highly correlated over time (77% of households have exactly the same members migrat-

[8]In the data, a household with a migrant earns 60% of total income from migration income. In the estimation I set after-migration income exogenously to $0.6m^i(q_t; z^i) + 0.4e^i(s_t; z^i)$ for a household who has a migrant. For a household without a migrant, after-migration income is given by $e^i(s_t; z^i)$.

[9]The magnitudes are the following. (i) A realization of rainfall one standard deviation about the mean reduces village level migration by 3.6 percentage points. (ii) 37% of migrants report some involuntary unemployment. Across all migrants the mean is 11 days out of an average trip length of 180 days; conditional on reporting some degree of unemployment, the mean is 31 days out of an average trip length of 192 days. See Section 3 for a full discussion.

[10]In the data, there does not appear to be a large role for comparative advantage in migration inside the household: Appendix Table 2 shows that observable characteristics such as education, age, and experience all correlate weakly with wages in the destination labor market, although it should be noted that these estimates are only correlations and not returns.

ing whenever any single member migrates, suggesting that households do not send more migrants in years in which the returns to migrating are higher). However, I do allow the overall household composition to potentially affect the migration decision at the household level: for example, households with more land may face higher opportunity costs of migrating, and households with more males may face differential access to migration opportunities. The characteristics of household i are indexed by a vector z^i. Another assumption is that I model the income that a household receives as a fixed combination of the village income realization and the migration income realization. This implies that the income composition of the household is independent of the number of migrants. Although this assumption is not strictly supported by the data (a 10% increase in the share of the household that migrates is associated with a 6.2% increase in the share of household income from migration), I make this assumption to match the focus on the extensive margin of migration given that the differences in the share of the household migrating do not appear to be driven by economically meaningful variation.

Households cannot borrow or save in autarky. Including savings would introduce an additional state variable into the maximization problem. In the data, I find that savings (including both financial and physical assets such as livestock) are small and, importantly, do not respond to migration. Therefore, I abstract from capital accumulation to highlight the main mechanism of interest, the interaction between migration and risk-sharing.[11] Finally, I assume that within-household risk-sharing is Pareto efficient.[12]

[11]For papers that extend limited commitment to include asset accumulation, see for example Ligon et al. (2000); Kehoe and Perri (2002); Krueger and Perri (2006); Abraham and Laczo (2016). In particular, Abraham and Laczo (2016) show that if there is a public savings technology, then under specific assumptions on the return to savings agents never have an incentive to use private savings. An alternative way to justify the assumption that agents cannot save is that there may indeed be constraints on saving in low-income countries. A growing body of work has documented that many people in poor countries lack access to formal financial products and that this constrains their ability to save, because informal modes of savings are costly: savings under the pillow are subject to theft, or to a form of "kin tax," or simply to self-control problems; savings in merry-go-rounds are subject to default; and livestock need not only to be fed, but can also fall prey to diseases. See, for example, Baland et al. (2011); Bauer et al. (2012); Dupas and Robinson (2013a,b); Jakiela and Ozier (2016).

[12]For studies examining migration with intra-household incentive constraints, see Chen (2006); Gemici (2011); Dustmann and Mestres (2010).

2.1 Model of endogenous migration and risk-sharing

First, I present the model of migration and risk-sharing under full commitment. Following the setup in Ligon et al. (2002), the social planner maximizes the utility of household 2, given a state-dependent level of promised utility, $U(s)$, for household 1.

The optimization problem is to choose migration, transfers, and continuation utility to maximize total utility:

$$V(U(s);z) = \max_j \sum_j \tilde{V}(U(s), j; z)$$

where $\tilde{V}(U(s), j; z)$ is the expected value if migration decision j is chosen:

$$\tilde{V}(U(s), j; z) = \max_{\tau(s,q,j), \{U'(q,j,r;z)\}_{r=1}^{R}} \mathrm{E}_q \left[u(\tilde{y}^2(s,q,j) + \tau(s,q,j)) - \mathbb{I}^2(j)d(z^2) + \beta \sum_{r'} \pi^s(r'|s) V(U(r',s,q,j;z);z) \right]$$

subject to a promise-keeping constraint that expected utility is equal to promised utility:

$$\mathrm{E}_q \left[u(\tilde{y}^1(s,q,j;z) - \tau(s,q,j)) - \mathbb{I}^1(j)d(z^1) + \beta \sum_{r'} \pi^s(r'|s) U(r',s,q,j;z) \right] = U(s;z) \;\; \forall j$$

Let λ be the multiplier on the promise-keeping constraint. The first order condition yields the familiar condition that the ratio of marginal utilities of consumption is equalized across all states of the world and migration states:[13]

$$\frac{u'(c^2(s,q,j;z))}{u'(c^1(s,q,j;z))} = \lambda \quad \forall s,q,j$$

[13]These first order conditions hold only for interior solutions, i.e., the migration states that occur with positive probability. When I estimate the model, I smooth the discrete objective function; doing so implies that there is an interior solution for all j.

2.2 Adding in limited commitment

I now introduce limited commitment constraints into the model. The key mechanism in the limited commitment model is the value of walking away and consuming the endowment stream (the "outside option") (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002).[14] In a world where agents can migrate, compared with a world where they cannot migrate, the opportunity to migrate weakly increases the outside option for households and will endogenously affect the amount of insurance that can be sustained.

I study the constrained-efficient equilibrium where migration and risk-sharing are jointly determined. That is, a social planner chooses both migration and risk-sharing transfers to maximize total utility, conditional on satisfying two incentive compatibility constraints. These two constraints correspond to the two potential times in which a household may wish to renege. The first, the "before-migration constraint," applies at the time that migration decisions are made: the expected value of following the social planner's migration rule (and continuing to participate in the risk-sharing network) needs to be at least as great as the expected value of making an independent migration decision and then being in autarky. This is a new constraint I introduce to capture the constrained-efficient migration decision. The second, the "after-migration constraint," applies after migration decisions have been made and all migration outcomes have been realized. At this stage, the final income has been realized and the value of following the social planner's risk-sharing transfer rule needs to be at least as great as the value of consuming this current income and then remaining in autarky. This constraint is similar to the standard limited commitment constraint (such as in Kocherlakota (1996); Ligon et al. (2002)) and implies that the incentive to remain in the network after income uncertainty has been resolved depends on the realization of that income.

To be precise, I define the outside option at the two points in time as follows. Before-migration autarky, Ω, is the value of deciding whether or not to migrate today when only the state of the world in the village (s) is known and the household has an expectation for the outcome if it migrates, and then facing the same choice in the future:

[14] See also Coate and Ravallion (1993); Kehoe and Levine (1993); Attanasio and Rios-Rull (2000); Dubois, Jullien and Magnac (2008).

$$\Omega^i(s;z^i) = \max\{u(y^i(s)); \mathrm{E}_q[u(\tilde{y}^i(s,q,j;z)) - d(z^i)]\} + \beta \sum_{r'} \pi^s(r'|s)\Omega^i(r';z^i)$$

After-migration autarky, $\tilde{\Omega}$, is the value of consuming period t income, conditional on the migration choice (j), the state in the village (s), and the state at the destination (q), and then facing the before-migration decision problem from period $t+1$.

$$\tilde{\Omega}^i(s,q,j;z^i) = u(\tilde{y}^i(s,q,j;z)) - \mathbb{I}^i(j)d(z^i) + \beta \sum_{r'} \pi^s(r'|s)\Omega^i(r';z^i)$$

2.2.1 Optimization problem

The optimization problem is to choose migration, transfers and continuation utility so as to maximize total utility:

$$V(U(s);z) = \max_j \sum_j \tilde{V}(U(s),j;z)$$

where $\tilde{V}(U(s),j;z)$ is the expected value if migration decision j is chosen:

$$\tilde{V}(U(s),j;z) = \max_{\tau(s,q,j),\{U(r',s,q,j;z)\}_{r=1}^R} \mathrm{E}_q\left[u(\tilde{y}^2(s,q,j) + \tau(s,q,j)) - \mathbb{I}^2(j)d(z^2) + \beta \sum_{r'} \pi^s(r'|s)V(U(r',s,q,j);z)\right]$$

subject to:

1. A promise-keeping constraint that states that expected utility is equal to promised utility:

$$(\lambda): \quad \mathrm{E}_q\left[u(\tilde{y}^1(s,q,j;z) - \tau(s,q,j)) - \mathbb{I}^1(j)d(z^1) + \beta \sum_{r'} \pi^s(r'|s)U(r',s,q,j;z)\right] = U(s;z) \ \forall j$$

2. Two after-migration constraints that state that that the utility of remaining in the

risk-sharing group is at least as great as the value of being in autarky:

$$(\pi^q(q)\alpha^1_{s,q,j}): \quad u(\tilde{y}^1(s,q,j) - \tau(s,q,j)) - \mathbb{I}^1(j)d(z^1) + \beta \sum_{r'} \pi^s(r'|s)U(r',s,q,j;z) \geq \tilde{\Omega}^1(s,q,j;z^1) \quad \forall s,q,j$$

$$(\pi^q(q)\alpha^2_{s,q,j}): \quad u(\tilde{y}^2(s,q,j) + \tau(s,q,j)) - \mathbb{I}^2(j)d(z^1) + \beta \sum_{r'} \pi^s(r'|s)V(U(r',s,q,j;z);z) \geq \tilde{\Omega}^2(s,q,j;z^2) \quad \forall s,q,j$$

3. Two before-migration constraints (for the following period) that state that the expected gain from participating in the risk-sharing migration will be at least as great as the expected value of being independent:

$$(\beta\pi^s(r'|s)\pi^q(q)\phi^1_{r',s,q,j}): \quad U(r',s,q,j;z) \geq \Omega^1(r';z^1) \quad \forall r',s,q,j$$

$$(\beta\pi^s(r'|s)\pi^q(q)\phi^2_{r',s,q,j}): \quad V(U(r',s,q,j;z);z) \geq \Omega^2(r';z^2) \quad \forall r',s,q,j$$

It is convenient to rescale the multipliers for person 1 by their initial weight, λ. Then, the first order conditions and the envelope condition can be written as:

$$\frac{u'(c^2(s,q,j;z))}{u'(c^1(s,q,j;z))} = \lambda \left(\frac{1+\alpha^1_{s,q,j}}{1+\alpha^2_{s,q,j}} \right) \quad \forall s,q,j \tag{1}$$

$$V'(U(r',s,q,j;z);z) = -\lambda \left(\frac{1+\alpha^1_{s,q,j}+\phi^1_{r',s,q,j}}{1+\alpha^2_{s,q,j}+\phi^2_{r',s,q,j}} \right) \quad \forall r',s,q,j \tag{2}$$

$$V'(U(s);z) = -\lambda \tag{3}$$

The slope of the value function is, therefore, equal to the slope of the value function in the previous period, updated for any binding before-migration and after-migration constraints:

$$V'(U(r',s,q,j;z);z) = V'(U(s);z) \left(\frac{1+\alpha^1_{s,q,j}+\phi^1_{r',s,q,j}}{1+\alpha^2+s,q,j+\phi^2_{r',s,q,j}} \right) \quad \forall r',s,q,j$$

To establish convexity of the ex-post constraint set, consider two alternative transfer schemes, $\tau(s,q,j)$ and $\hat{\tau}(s,q,j)$, that are each incentive compatible. Because the contemporaneous utility function, $u(\cdot)$ is concave, the average transfer $\alpha\tau(s,q,j) + (1-$

$\alpha)\hat{\tau}(s, q, j)$, for $\alpha \in [0, 1]$, must also satisfy the incentive compatibility constraints. Next consider the set of discounted ex-post utilities that correspond to each of the two alternative transfer schemes. Because the average transfer satisfies the incentive compatibility constraints, the average ex-post utilities also satisfy the incentive compatibility constraints. This implies that the ex-post utility for agent 1 is an interval that lies between $[\underline{\tilde{U}}_{sqj}, \overline{\tilde{U}}_{sqj}]$, and similarly, for household 2, an interval that lies between $[\underline{\tilde{V}}_{sqj}, \overline{\tilde{V}}_{sqj}]$. Because the migration decision is discrete, the ex-ante constraint set is not necessarily convex. If necessary, lotteries over migration can be introduced in order to convexify the set; such an approach is considered for the case of savings in Ligon et al. (2000).[15] The ex-ante value function for household 1 will be an interval that lies between $[\underline{U}_s, \overline{U}_s]$, and similarly, for household 2, an interval that lies between $[\underline{V}_s, \overline{V}_s]$.

2.2.2 Updating rule for the endogenous Pareto weight

There is a simple updating rule for the endogenous Pareto weight in this economy. Denote the history of village income, migration income, and migration events up to and including period t by $h^t = (\{s_0, q_0, j_0\}, ..., \{s_t, q_t, j_t\})$. Let $\lambda(s_t, h^{t-1})$ be the value of the Pareto weight at the start of date t if the history is h^{t-1} and the state of the world at time t is s_t. The consumption at time t, which occurs after migration decisions have been made and all migration income uncertainty has been resolved, is determined by the Pareto weight at the start of the period adjusted for the after-migration constraints, as given by Equation 1: $\tilde{\lambda}(s_t, q_t, j_t, h^{t-1}) = \lambda(s_t, h^{t-1}) \left(\frac{1+\alpha^1_{s_t,q_t,j_t}}{1+\alpha^2_{s_t,q_t,j_t}} \right)$. Equation 2 then determines if the Pareto weight is adjusted again before the start of the following period, depending on whether the before-migration constraints bind the following period, yielding of Pareto weight at the beginning of period $t+1$, $\lambda(s_{t+1}, s_t, q_t, j_t, h^{t-1})$, equal to $\lambda_t(s_t, h^{t-1}) \left(\frac{1+\alpha^1_{s_t,q_t,j_t}+\phi^1_{r_{t+1},s_t,q_t,j_t}}{1+\alpha^2_{s_t,q_t,j_t}+\phi^2_{r_{t+1},s_t,q_t,j_t}} \right)$.

The updating process for the endogenous Pareto weight is closely related to the updating rule for the endogenous Pareto weight in Ligon et al. (2002). In that paper, there was one set of incentive compatibility constraints and a one-step updating rule. Here, there are two sets of incentive compatibility constraints and a two-step updating rule.

[15] I smooth the migration rule in the estimation, removing any kinks in the value function, and so do not face this issue in practice.

Proposition 2.1 (Adapted from Ligon et al. (2002), Proposition 1)**.** *A constrained-efficient contract can be characterized as follows: There exist S state-dependent, before-migration intervals* $[\underline{\lambda}_s, \overline{\lambda}_s], s = 1, ..., S$ *and, for each migration decision j,* $S \times Q$ *after-migration intervals* $[\underline{\lambda}_{sqj}, \overline{\lambda}_{sqj}], s = 1, ...S; q = 1, ..., Q$ *such that the before-migration Pareto weight,* $\lambda(s_t, h^{t-1})$*, evolves according to the following rule. Let* h^{t-1} *be given and let s be the state in the village at time t, q be the state in the destination at time t, r′ be the state in the village at time t + 1; then for each migration decision j the after-migration Pareto weight,* $\tilde{\lambda}(s_t, q_t, j_t, h^{t-1}) = \tilde{\lambda}(h^t)$*, is determined by:*

$$\tilde{\lambda}(h^t) = \tilde{\lambda}(s_t, q_t, j_t, h^{t-1}) = \begin{cases} \tilde{\underline{\lambda}}_{sqj} & \text{if } \lambda(s_t, h^{t-1}) \leq \tilde{\underline{\lambda}}_{sqj} \\ \lambda(s_t, h^{t-1}) & \text{if } \lambda(s_t, h^{t-1}) \in [\tilde{\underline{\lambda}}_{sqj}, \tilde{\overline{\lambda}}_{sqj}] \\ \tilde{\overline{\lambda}}_{s,q,j} & \text{if } \lambda(s_t, h^{t-1}) \geq \tilde{\underline{\lambda}}_{sqj} \end{cases}$$

and the following period's before-migration weight $\lambda(r_{t+1}, s_t, q_t, j_t, h^{t-1}) = \lambda(r_{t+1}, h^t)$ *is determined by:*

$$\lambda(r_{t+1}, h^t) = \begin{cases} \underline{\lambda}_r & \text{if } \tilde{\lambda}(h^t) \leq \underline{\lambda}_r \\ \tilde{\lambda}(h^t) & \text{if } \tilde{\lambda}(h^t) \in [\underline{\lambda}_r, \overline{\lambda}_r] \\ \overline{\lambda}_r & \text{if } \tilde{\lambda}(h^t) \geq \overline{\lambda}_r \end{cases}$$

Proof: Define $\tilde{\underline{\lambda}}_{sqj} = -\tilde{V}(\underline{\tilde{U}}_{sqj})$ *and* $\overline{\lambda}_{sqj} = -\tilde{V}(\overline{\tilde{U}}_{sqj})$ *where* $\underline{\tilde{U}}_{sqj}$ *is the minimum after-migration utility that satisfies the after-migration incentive compatibility constraint for household 1 and* $\overline{\tilde{U}}_{sqj}$ *is the maximum utility for household 1 such that household 2's after-migration incentive compatibility constraint is satisfied. Consider a before-migration Pareto weight of* $\lambda(h^t)$ *and assume that* $\lambda(h^t) < \tilde{\underline{\lambda}}_{sqj}$*. Since* $\tilde{\lambda}(s_t, q_t, j_t, h^{t-1}) \in [\tilde{\underline{\lambda}}_{sqj}, \tilde{\overline{\lambda}}_{sqj}]$ *then* $\tilde{\lambda}(s_t, q_t, j_t, h^{t-1}) > \lambda(h^t)$*. By equation 1 it must be that* $\alpha^1_{s,q,j} > 0$ *and so it must be that* $U_{sqj} = \underline{U}_{sqj}$*. The reverse holds for the opposite case. For the before-migration case, define* $\underline{\lambda}_r = -V(\underline{U}_r)$ *and* $\overline{\lambda}_r = -V(\overline{U}_r)$ *where* $\underline{U}_r$ *is the minimum before-migration utility that satisfies the incentive compatibility constraint for household 1 and* $\overline{U}_r$ *is the maximum utility for household 1 such that household 2's before-migration incentive compatibility constraint is satisfied. Consider an after-migration Pareto weight* $\tilde{\lambda}(h^t)$ *and assume that* $\tilde{\lambda}(h^t) < \underline{\lambda}_{r'}$*. Since* $\lambda(r_{t+1}, h^t) \in [\underline{\lambda}_r, \overline{\lambda}_r]$ *it must be that*

$\lambda(r_{t+1}, h^t) > \tilde{\lambda}(h^t)$ and by equation 2 it must be that $\phi^1(r, s, q, j) > 0$. But then $U_r = \underline{U}_r$ and the condition holds. The reverse holds for the opposite case.

This simple updating rule yields a clear algorithm for solving the model. I compute the upper and lower bounds of the before-migration and after-migration intervals based on the relevant incentive compatibility constraints. I describe this algorithm in Section 4.1.

2.3 Comparative statics on migration, risk-sharing, and welfare

This section derives results pertaining to migration, risk-sharing, and welfare. The limited commitment model is complex and closed-form solutions for the key quantities do not exist except in specific cases. I discuss one such example in Appendix F.2.

2.3.1 Effect of improving access to risk-sharing on migration

How does introducing access to risk-sharing, when examined in comparison to a world in which risk-sharing is not possible, affect migration decisions?[16] Under autarky, households compare the rural-urban wage differential and migrate if the expected utility gain is positive. Under risk-sharing, households compare the post-transfer rural-urban income differentials instead of comparing the gross income differentials. Improving access to risk-sharing will have two offsetting effects on migration. Households that migrate have experienced negative income shocks. These households would be net recipients of risk-sharing transfers in the village. Facilitating risk-sharing reduces the income gain between the village and the city and reduces migration (the 'home' effect). On the other hand, migration is risky. Risk-sharing can insure the risky migration outcome, facilitating migration (the 'destination' effect). The net effect of improving access to risk-sharing on migration will depend on whether the destination effect is greater than the home effect.

[16] For example, assume that there is an exogenous per-unit cost, d_τ to transfer resources between households, such that \$1 sent from one household yields \$$(1 - d_\tau)$ for the recipient household. Introducing risk-sharing can be modeled as a reduction in this cost of transferring resources. In the extreme, when $d_\tau = 1$, households will never find it optimal to make risk-sharing transfers. When $d_\tau = 0$, risk-sharing transfers are costless.

2.3.2 The effect of reducing the cost of migration on risk-sharing

The decision to migrate depends on the cost of migrating, d. Reducing the costs of migration may affect both the distribution of consumption and the distribution of income across households in the village. Define risk-sharing, RS_t, as the ratio of the covariance between income and consumption, scaled by the variance of income, $RS_t = \frac{\sigma_{c,y}(F_E, F_M, d, d_\tau)}{\sigma_y^2(F_E, F_M, d, d_\tau)}$.[17] Perfect risk-sharing occurs when there is no covariance between income and consumption, i.e., $RS_t = 0$. Both income and consumption are endogenous and will depend on the distribution of earnings in the village, F_E, the distribution of earnings at the destination, F_M, the cost of migration, d, and the cost of transferring resources between households, d_τ. I decompose the change in risk-sharing resulting from an exogenous reduction in the cost of migrating, d, as:

$$\frac{\mathrm{d}RS_t}{\mathrm{d}d} = \underbrace{\frac{\partial RS_t}{\partial \sigma_{c,y}} \left(\frac{\partial \sigma_{c,y}(F_E, F_M, d, d_\tau)}{\partial d} \right)}_{\text{Effect on covariance of income and consumption}} + \underbrace{\frac{\partial RS_t}{\partial \sigma_y^2} \left(\frac{\partial \sigma_y^2(F_E, F_M, d, d_\tau)}{\partial d} \right)}_{\text{Effect on variance of income}}$$

The first term considers the effect of improving access to migration on the correlation between income and consumption. This could occur through several channels: households now face a weakly higher outside option, which may reduce the returns to participating in risk-sharing, increasing the covariance of income and consumption. On the other hand, if reducing the cost of migrating allowed households to migrate out in times of negative aggregate shocks, this could make it easier to make transfers between households and could reduce the covariance of income and consumption. The second term adjusts the risk-sharing measure for the underlying variance in income. A reduction in the costs of migration could decrease income variance, because migrant households are negatively selected on village income, or could increase income variance, if migration income is highly variable. The overall effect of providing access to migration on risk-sharing will depend on the effect of introducing migration on the covariance term, adjusted for the effect on the income variance term.

[17] This is the coefficient β in an OLS regression of c_{it} on y_{it}, which matches this measure to the Townsend (1994) tests of perfect risk-sharing.

2.3.3 Decomposition of the welfare effect of reducing the cost of migration

Total welfare depends on the distribution of consumption and total income. Total welfare is maximized if all households have an equal share of consumption, which implies that that the covariance between income and consumption, $\sigma_{c,y}$, is equal to zero. I approximate welfare for this economy as a function of the covariance of consumption and income and the mean level, μ_Y, of ex-post income.[18]

$$W = W(\sigma_{c,y}(F_E, F_M, d_\tau, d), \mu_Y(F_E, F_M, d_\tau, d))$$

Reducing migration costs will have two effects on welfare. First, it directly changes the total resources available to the network. If total resources increase (i.e., μ_Y increases), holding constant the covariance of income and consumption, then welfare increases. Second, it endogenously changes the distribution of consumption across network members. If the distribution of resources becomes more unequal (i.e., $\sigma_{c,y}$ increases), holding total resources constant, then welfare decreases. The net effect on welfare from reducing the costs of migration depends on the relative magnitude of the increase in income and any change in risk-sharing. A priori, the net welfare effect of migration can be either positive or negative.

Because the theoretical results are ambiguous, determining the net effect is an empirical question. I now introduce the empirical setting of rural India, where I will estimate the model and then numerically simulate the effects of changing the cost of migration on migration, risk-sharing, and welfare.

3 Panel of rural Indian households

This paper uses the new ICRISAT dataset (VLS2) collected between 2001-2004 from semi-arid India. The ICRISAT data represent the results of a highly detailed panel household

[18] I use a first-order approximation for the effect of the income distribution on welfare. Higher-order moments of the income distribution may also be important for welfare and could easily be incorporated into this formula.

survey, with modules covering consumption, income, assets, and migration.[19]

3.1 Descriptive migration statistics

The focus of this paper is temporary migration. Because of its short-term nature, temporary migration is often undercounted in standard household surveys. A key feature of the ICRISAT data is the presence of a specific module for temporary migration. Such a module was included because temporary migration is widespread: in the ICRISAT data, 20% of households participate in temporary migration each year. The prevalence of temporary migration varies by village and time. For example, migration is much higher in the two villages in the state of Andhra Pradesh due to their proximity to Hyderabad, a main migration destination. Figure 1 plots migration prevalence by village and year.

Summary statistics for the sample are reported in Table 1. On average, a migration trip lasts for 193 days (approximately six months) and 1.8 members of the household migrate. Forty percent of households send a migrant in at least one of the four years of the survey. Migrants are predominantly men (only 28% of temporary migrants are women) and when women migrate they are almost always accompanied by a male member of the household (in 94% of the cases if there is only one migrant from a household it is a male).

Households that migrate at all differ from households that never migrate. Migrating households are slightly larger and include more adult males (2.2 vs 1.7), but they own less land (4.5 vs 5.1 acres). A probability model for migrating is reported in Appendix Table 1. The number of males, controlling for household size, positively predicts migration. The interaction between males and land owned predicts migration negatively. This appears reasonable: households with more land presumably have higher incomes in the village, and thus face a larger opportunity cost of migrating; and households with more males may have surplus labor, and hence are better able to send someone to the city.

Temporary migration is the relevant margin on which to focus in the case of rural In-

[19] The VLS2 data can be merged onto the original first wave (VLS1) ICRISAT data, covering 1975-1984. To focus on the period where both migration and risk-sharing are present I use the 2001-2004 wave of data for the estimation. There are also two waves of the VLS2 data, covering the periods 2005-2008 and 2009-2014. It is very challenging to merge the three waves of the VLS2 data due to changes in the survey design and inconsistent household and individual IDs. I provide a full discussion of the consistency of migration patterns between the 2001-2004 waves and the later waves in Appendix B.

dia because permanent migration is very low there: using the nationally representative 2006 REDS data, Munshi and Rosenzweig (2015) show that the permanent migration rate for males aged 15-24 never increased to more than 5.4% over the 1961-2001 period. I verify the lack of permanent migration in the ICRISAT data. In Appendix B I show that between 1-4% of the individual observations are members living outside the village, and that there is also substantial churn in this measure, with 3%-20% transition probabilities of moving from living outside the village to being a non-migrant in the following year. I find no evidence that temporary migrants transition to permanent migration status and no evidence that households with temporary migrants experience larger changes in the household roster than households without temporary migrants. Additionally, I find no evidence that households with permanent migrants are differentially insured than households with no migrants. I also verify that the patterns are not an artifact of the length of the panel by using two later waves of the VLS2 data, covering the periods 2005-2008 and 2009-2014, and showing the stock of permanent migrants does not increase from the value in the 2001-2004 rounds.

It is reassuring to confirm that the migration behavior observed in the ICRISAT villages is consistent with what other studies report. Other researchers have found widespread temporary migration in India of up to 50% (Rogaly and Rafique, 2003; Banerjee and Duflo, 2007). Coffey et al. (2014) survey households in a high-migration area in North India and find that 82% of households had sent a migrant in the last year. The nationally representative National Sample Survey (NSS) asks about short-term migration, defining it as any trip lasting between 30 and 180 days. Imbert and Papp (2015b) use NSS data and find national short-term migration rates of 2.5%. However, there is evidence that the NSS may undercount shorter-term migration episodes: for the specific regions that overlap with the household survey in Coffey et al. (2014) the short-term migration rate in the NSS data is 16%, compared with 30% in the household survey. Taken together, these studies suggest that the migration rates observed in the ICRISAT data, approximately 20%, are consistent with other data from India and Bangladesh.[20]

[20]For the prevalence of temporary migration in other developing countries refer to de Brauw and Harigaya (2007) (Vietnam); Macours and Vakis (2010) (Nicaragua); Bryan, Chowdhury and Mobarak (2014) (Bangladesh).

3.2 Five facts linking migration and risk-sharing

I verify five facts in the data: (1) migration responds to exogenous income shocks; (2) households move in and out of migration status; (3) risk-sharing is imperfect, and is worse in villages where temporary migration is more common; (4) risk-sharing transfers depend negatively on the history of past transfers; and (5) the marginal propensity to consume from migration income is less than 1. For the rest of the analysis I scale all household variables to per adult equivalents to control for household composition. I define household composition based on the first year in the survey to control for endogenous changes due to migration.

1. *Migration responds to exogenous income shocks*

   The summer monsoon rain at the start of the cropping season is a strong predictor of crop income (Rosenzweig and Binswanger, 1993). I verify the results reported by Badiani and Safir (2009) and show, in Figure 2, that migration responds to aggregate rainfall. When the monsoon rainfall is low, migration rates are higher.[21] This matches the modeling assumption that migration decisions are made after income is realized.

2. *Households move in and out of migration status*

   Forty percent of households migrate at least once during the sample period. However, an individual who migrated in any one year migrates the following year in less than half of the observations.[22] This is consistent with households migrating when their returns are highest – for example, if they receive a low idiosyncratic shock – rather than with temporary migration becoming a persistent strategy.

3. *Risk-sharing is incomplete*

[21] Pooling across villages, the coefficient on the standardized June rainfall is -0.036 without village fixed effects, or -0.024 with village fixed effects; in both cases, the constant in the regression is 0.18. Migration caused by an ex-post response to rainfall variation explains 13%-19% of the cross-sectional variation in migration rates. In the model, the remaining variation in migration will be explained by the realization of idiosyncratic income shocks.

[22] At the individual level, the transition probability from temporary migration to non-migration is 40.2%. At the household level, this probability is 39.2%. See Appendix B for details.

Risk-sharing in the ICRISAT villages is incomplete and is worse in villages with higher temporary migration rates. To show this, I test for full risk-sharing. I estimate the following regression for household i in village v at time t:

$$\log c_{ivt} = \alpha \log y_{ivt} + \beta_i + \gamma_{vt} + \epsilon_{ivt},$$

where β_i is a household fixed effect, γ_{vt} is a village-year fixed effect that captures the total resources available to the village at time t, and c_{ivt} is per-capita consumption (excluding savings). The intuition for tests of full risk-sharing is that individual income should not predict consumption, conditional on total resources (Townsend, 1994).

Table 2 reports the results of the tests. Full risk-sharing is rejected. The estimated income elasticity is 0.07, a magnitude that is similar to other estimates of this parameter (Townsend, 1994). Column 2 interacts the mean level of migration in the village with income. The estimated coefficient is positive and statistically significant: a 10% increase in the mean level of migration in the village increases the elasticity of consumption with respect to income by 0.23. In other words, villages with higher rates of temporary migration exhibit lower rates of risk-sharing. While this does not indicate causality, it is consistent with the joint determination of risk-sharing and migration.[23]

4. *Transfers are insurance*

Next, I provide evidence that transfers provide insurance and depend on the history of shocks. Transfers are defined as the difference between income and consumption.[24] Limited commitment models predict that transfers will depend negatively on the history of transfers (see e.g. Foster and Rosenzweig (2001)). This holds in

[23]Results shown in Table 2 are robust over alternative definitions of household size: defining the number of household members as (adult-equivalent) baseline composition, adjusting for the number of migrants, and adjusting for the number of migrants and trip length. Refer to Appendix Table 20 for details.

[24]Results are robust to defining transfers as the difference between incomes and expenditures, accounting for any change in net asset position, and to robust to instrumenting income with rainfall. Refer to Appendix Tables 21 and 22.

the ICRISAT data. I run the following specification, regressing current transfers to the stock of received transfers and the income shock (see Foster and Rosenzweig (2001)):

$$\tau_{it} = \alpha_1 y_{it} + \alpha_2 \sum_{j=0}^{t-1} \tau_{ij} + \epsilon_{it}$$

The results, both in levels and in first differences (to control for household-specific predictors of transfers), are shown in Table 3. The coefficient on income is negative, indicating that the transfers provide insurance, and the coefficient on the stock of transfers is negative, indicating that current transfers depend on the history of shocks. These findings are consistent with predictions derived from the limited commitment model.

5. *Marginal propensity to consume from migration income is less than 1:*

   Table 4 decomposes the change in household expenditure for migrant households. Although a household increases its income by 30% in years in which it sends a migrant, total expenditures (consumption and changes in asset position) increase by only 60% as much. I do not directly observe transfer data in the dataset, but this shortfall between income and expenditure is consistent with an increase in transfers from households to the network.[25]

These empirical facts provide some evidence for a relationship between migration and risk-sharing. However, the primary feature of the model is the joint determination of risk-sharing and migration. To quantify this interaction, I now estimate the model structurally.

[25] Table 4 reports results in per capita terms using the baseline household composition. This may, however, understate the increase in consumption due to the absence of migrants from their households. I rerun an alternative version of this table where I include gross (instead of net) migration income and add migrant expenditures to the consumption term. Using this definition, household expenditures increase by only 42% of the increase in incomes. Results are shown in Appendix Table 23.

4 Structural estimation

This section describes the identification of the model and the estimation procedure. In the model both migration and risk-sharing are endogenous, and the equilibrium behavior is determined by the actions of all households in the village. Because of the strategic interactions between households it is substantially more complex to solve the model here than in the case of a single independent household deciding whether or not to migrate. As a result, I face an inherent tradeoff between the richness of the model and the computational burden entailed in estimating it. I have attempted to capture the main sources of variation in the data while retaining the ability to feasibly estimate the model. This section discusses the model solution and estimation algorithms. Full details on both algorithms are presented in Appendix G.

4.1 Solving the model

As described in Section 2.2.2 the limited commitment model is characterized by two sets of state-dependent intervals, "before-migration" and "after-migration," that give the lower and upper bounds for Pareto weights for each state of the world.

To compute the intervals I first need to specify the total resources available in the village. This requires specifying the total number of households in the village. The model presented in Section 2 was a two-household model. I extend that model to N agents in Appendix G. It is possible to estimate the model with N agents by including each agent's relative Pareto weight as an additional state variable. However, this strategy is computationally intensive. Instead, I follow Ligon, Thomas and Worrall (2002) and other empirical applications of the limited commitment model (Laczo, 2015), and construct an aggregated "average rest of the village" household. For each state of the world s I construct the average village member by assigning the income realization such that the sum of the incomes of household H and the rest of the village is equal to the average level of resources in the economy.[26] I show in Appendix G that this approximation method is very close to the

[26] This assumes that the rest of the village is, on average, sharing risk perfectly between one another. Assuming that the rest of the village shares risk perfectly may seem to be a contradiction. However, the assumption that the rest of the village is sharing risk perfectly is used only to generate the upper bound of

continuum solution for a simplified version of the limited commitment model.

The algorithm starts by guessing an initial migration rule. This migration rule is used to predict how many households migrate, and to then adjust the total resources available in the village by the expected migration outcomes. Next, I solve for the two intervals by discretizing the problem. The before-migration value function is solved on a grid, which is indexed by the state of the world in the village and the household's Pareto weight, (s, λ). The after-migration value function is solved on a grid indexing the state of the world in the village, the household's Pareto weight, the state of the world in the destination, and the migration decision, $(s, q, j, \tilde{\lambda})$. I locate the point for which the incentive compatibility constraints of either agent binds and then construct the two sets of intervals containing the lower and upper bounds of the endogenous Pareto weights.

Once the intervals have been computed, I calculate the transition rule for the Pareto weights such that the market-clearing condition (that total consumption across all households equals total income across all households) is satisfied for all states. To impose the budget constraint, I use a first order condition from the problem with N agents that states that the ratio of marginal utility growth across any two unconstrained agents is constant (see Appendix G for details). This implies that the Pareto weights for unconstrained agents for the current period are their previous Pareto weights multiplied by a common scaling factor. The algorithm solves for the values of the scaling factor (one for each aggregate state of the world) such that the invariant distribution of consumption over the after-migration state of the world $c(s, \tilde{\lambda}, q, j)$ is equal to the invariant distribution of income (accounting for the endogenous decision of which agents migrate). This procedure ensures that the aggregate resource constraint is satisfied across all households and all after-migration states.

The last step of the algorithm finds the fixed point over the migration decision for all households, taking into account the decisions of all other households. This step yields the equilibrium level of the total resources available for the network to share.

the interval. This upper bound is never actually used when computing simulated consumption: for each income realization an economy-wide budget constraint needs to hold, and so consumption by individuals who do not have a binding participation constraints will depend on their previous Pareto weights and the consumption of all other members such that the budget constraint is satisfied.

4.2 Estimating the model

I estimate the model using simulated method of moments (McFadden, 1989; Pakes and Pollard, 1989). I construct a vector of moments from the data, q_s, relating to migration, income, and risk-sharing. For a given value of the parameter vector, θ, the solution of the limited commitment model yields the migration rule, the updating rule for the Pareto weight, and the transfer rule, for each state of the world. The last step of the estimation is to simulate a wide cross-section and long time series of agents and compare simulated moments to real data moments. To do this, it is necessary to supply an initial Pareto weight. To minimize the effect of this initial weight, I construct a long time series and discard the initial periods. I then compute the simulated moments, $Q(\theta)$, from the simulated data and compare these moments with the same moments, q_s, computed from the household data. The criterion function is $(Q(\theta) - q_s)'W^{-1}(Q(\theta) - q_s)$, where W is a positive definite weighting matrix. I use a weighting matrix that is the inverse of the diagonal of the variance-covariance matrix of the data. This weighting matrix put more weight on matching the moments that have a smaller variance.[27] In the model, conditional on income and the value of the Pareto weight, the migration decision is deterministic, and so the objective function is non-differentiable. To avoid using non-differentiable algorithms to estimate the model I smooth the objective function using the approach presented in (Horowitz, 1992; Bruins et al., 2016).[28]

4.3 Identification of the model

The model is estimated by specifying a vector of moments in the data and then simulating the model to match the moments as closely as possible. There are four groups of model parameters to be estimated: (i) income distribution in the village; (ii) income distribution if migrating; (iii) utility cost of migrating; and (iv) parameters governing the utility func-

[27] Altonji and Segal (1996) discuss the potential biases arising from using the optimal weighting matrix. Because I do not use the optimal weighting matrix I cannot report formal over-identification tests for model fit. Instead, I discuss model fit on out-of-sample moments.

[28] I start by using a coarse smoothing parameter and a multi-start algorithm to find the approximate solution in the global parameter space. Once a candidate initial guess is found, I then solve the model by iterating on the smoothing parameter until the estimator converges on the same optimal parameter value.

tion (which I assume to be CRRA), in particular, the coefficient of relative risk aversion and the discount factor. This section discusses how the variation in the data identifies the model. In some cases, the link between a particular moment in the data and the resulting parameter is clear. In others, as highlighted in the simulation analysis at the end of this section, the equilibrium of the dynamic model is complex, and parameters jointly affect many moments in the data.

The primary source of exogenous variation identifying the model is the monsoon rainfall, which identifies the aggregate shock to the village income distribution. The monsoon rainfall predicts the share of households in the village who temporarily migrate in each period and therefore provides an instrument for determining whether people are observed in the city or in the village. I use the actual aggregate shock realization for the years 2001-2004 in the data and match this to the data when simulating the model.[29]

In the model, conditional on income and the endogenous Pareto weight, the decision to migrate is deterministic. Households who receive low income realizations in the village choose to send a migrant, who is then observed earning a wage in the city for that year. I assume that, conditional on migrating, the migrant receives income that is an *i.i.d.* draw from a log-normal income distribution. This assumption appears to be reasonable for this setting: I show in Appendix D that a joint skewness-kurtosis test for migration income, which tests the validity of the log-normal assumption, is rejected in only one of the five villages.

Because individuals who migrate are not observed in the village income distribution, I cannot directly estimate the income distribution from the observed data. I assume that the un-truncated income distribution in the village is log-normal and I construct a truncated village wage that is censored whenever an individual chooses, inside the model, to migrate. I then match this truncated distribution to that observed in the data for people who chose not to migrate. In Appendix D I overlay the distribution of village earnings

[29] I use a historical rainfall database covering the years 1900-2008 to compute the long-run rainfall distribution and estimate the magnitude of the aggregate shock. I estimate the effect of the rainfall shock on output using the earlier VLS1 data, and then take this income process as given for the estimation. Appendix Table 3 examines the effect of an aggregate shock on rainfall for the 1975-1984 ICRISAT data. I define the aggregate shock as a rainfall event falling below the twentieth percentile of the long-run rainfall distribution. A negative aggregate shock reduces income by 23% and occurs with a probability of 0.28.

with a log-normal distribution and show that the distributional assumption matches the observed data well.

The utility cost of migrating is a key parameter that determines the share of people migrating. Ceteris paribus, higher migration costs reduce migration rates, and so the average migration rate is informative about the average cost of migrating.

The coefficient of relative risk aversion and the discount factor both affect demand for risk-sharing as well as the decision to undertake risky migration. Ceteris paribus, agents who are more patient will value insurance more, and ceteris paribus, agents who are more risk-averse will also value insurance more. I match the correlation between income and consumption in the simulated data to the correlation between income and correlation in the household data. The coefficient of relative risk aversion also affects the decision to migrate, because migrating is itself risky, and so information about the average migration rate also influences the estimation of the coefficient of relative risk aversion.

Lastly, I want the model to replicate the observed heterogeneity in migration decisions across households. As I show in Appendix Table 1 the main determinants of migration at the household level are landholdings and the number of males. Households with more land, and households with more males, migrate more frequently (with the interaction between males and land statistically significant). I classify households as either above or below the median in landholdings and above or below the median in the number of males. This generates four "types" of households to track in the estimation process.[30]

This classification of households into types assumes that landholdings and household composition are exogenous to the household. These are admittedly strong assumptions to make. These assumptions would not be valid if, for example, households with high preferences for migrating chose to have more males living in the household; if temporary migrants eventually become permanent migrants, and so households who participate in migration eventually have fewer males in the household; or if households who liked to migrate chose to own less land. It is therefore important to verify whether these assump-

[30]The model is a model of village-level risk-sharing, where different types of households are interacting. To solve the model I need to construct the total level of resources in the whole village, which requires computing the fixed point of each individual's migration decision, taking into account the equilibrium responses of all other households. For this reason, I parsimoniously allow for four "types" of households to capture the relevant heterogeneity.

tions are valid for the empirical setting I study. For the first assumption, regarding the exogeneity of household composition, a body of research has documented very low rates of permanent migration in India (Topalova, 2010; Munshi and Rosenzweig, 2015). Consistent with these studies, I show in Appendix B that I find no evidence that migration behavior predicts eventual change in the composition of the household. Regarding the second assumption, that land holdings are exogenous, a large body of literature has documented frictions in land markets in India and has argued that landholdings are driven primarily by factors exogenous to the household such as deaths of household heads. For example, Foster and Rosenzweig (2011) find, using data from a nationally representative household panel in India, that only 3% of households bought or sold land between 1999 and 2008. In the ICRISAT data, landholdings remained constant for 57% of households between 1985 and 2001, with the bulk of the change that did occur due to family division.

I match the heterogeneity in migration behavior – that households with more land migrate less, and households with more males migrate more – by allowing (a) village income to be increasing with landholdings and (b) migration costs to be decreasing with the number of males. For (a), households with more land face higher opportunity costs of migrating and so choose to migrate less often. For (b), there are two possibilities. One hypothesis is that males have higher returns to migrating than females. Another explanation could be that there are differential costs to migrating, with women facing higher migration costs.[31] To attempt to separate out the two explanations, I look at individual wage data. In Appendix Table 2, I show that, while males do earn more than women in the migrant labor market, the relative gap in earnings is larger in the village labor market than in the migrant labor market. This suggests that, if anything, women have higher relative returns to migrating than men. Given this finding, I assume that the difference in migration rates is explained by the fact that migration is, on average, less costly for males than for females. While assuming that the cost of migration is driven only by the number of males in the household is likely an oversimplification, this categorization introduces

[31] For example, in a survey of temporary migrants Coffey et al. (2014) found that 85% of migrants had no formal shelter at the destination. It is easy to imagine that this environment could be less safe for women than for men. I see in the data that when there is only one migrant from a household, in 94% of the time, this migrant is male.

heterogeneity in a way that allows the model to generate different results for subgroups of households that are more or less directly affected by migration opportunities.

I then add several other parameters that help to provide additional information to help the simulated data match the real data as closely as possible. These parameters include the mean consumptions of migrants and non-migrants as well as the shares of migrants and non-migrants receiving transfers from the network. The full list of moments that are included in the estimation exercise is given in Table 5.

4.3.1 Simulation analysis

In the above section I discussed the relationship between moments in the data and specific parameters I estimate. Next, I simulate the dynamic model for a range of parameter values. I vary each parameter of interest and then plot the responses for eight of the matched moments as the parameter changes. For each plot, I normalize all moments to have the same relative magnitude for the baseline value of the parameter, so the plot can be interpreted as the relative effect on each moment. For each panel of the plot, I emphasize in bold type the moment that is most closely related to the parameter of interest. The results are plotted in Appendix Figure 1.

The figure shows that, while the general intuition holds, there are complex interactions between outcome variables in the dynamic model. For example, Panel A shows the effect of increasing the mean of the village income distribution. The main moment that captures this parameter is the mean income of non-migrants, which is bolded. However, as village income increases, there are endogenous responses, both from migration and risk-sharing. First, migration rates decrease, as the relative returns to migration drop. Both the mean migration rate and the mean migration rate for many-male households decreases (the two lines are overlaid after the initial point: overall migration and migration of many male households decrease at the same relative rate). Second, as village income increases households grow richer, which improves risk-sharing. The risk-sharing measure therefore decreases, indicating that consumption depends less on income.

Panel B shows the effect of changing the standard deviation of the income process. The primary moment that this parameter affects is the variance of non-migrant income.

Changing the variance of the income process, however, also changes risk-sharing. As the variance of income in the village increases insurance becomes more valuable, and risk-sharing endogenously improves, decreasing the risk-sharing coefficient (which measures the correlation between income and consumption). This is shown in the plot. The relationship between the discount factor and the risk-sharing coefficient is clear from Panel F. As the discount factor increases, the dominant effect is a reduction in the correlation between income and consumption, along with an endogenous reduction in migration as risk-sharing improves.

5 Structural Results

This section presents the structural estimation results and performs a counterfactual policy analysis. The structural results highlight why it is quantitatively important to consider migration and risk-sharing jointly.

Table 5 shows the fit of the model to the data for each village. The model criterion function is printed at the bottom of the table. Appendix Table 6 gives the point estimates. Migration yields a higher mean return than village income (the mean of the log-normal distribution is estimated to be 1.7 compared with 1.3) but is considerably riskier (with a standard deviation of 0.9 compared with 0.7). The estimated utility cost of migrating, 0.28, is substantial, equivalent to 23% of mean household consumption. For households with many males migration costs are 47% lower, equivalent to a cost of migration of 20% of mean consumption. The estimated discount factor is 0.75 and the estimated coefficient of relative risk aversion is 1.2.

Table 6 shows the effect of migration on income. Migration yields a positive return. The mean income of migrant households is 5800 rupees per equivalent adult (approximately 115 USD). Counterfactual income (the income the household would have had in the village) is close to half of actual income, at 3400 rupees (70 USD). This highlights the importance of accounting for the endogenous migration decision when estimating the returns to migration. Those who migrate temporarily are negatively selected on income, so a naive comparison of the income difference between migrants and non-migrants does not reflect the gains to migrating. The table also highlights the riskiness of migration in this empirical setting. Although I find that the average return to migrating is positive, I estimate that 30% of households would have received a higher income if they had stayed in the village. This number is slightly higher than the experimental findings in Bryan, Chowdhury and Mobarak (2014) who estimate a 10%-20% risk of "failure" from migration.

The estimated discount factor of 0.75 may appear to be low, especially compared with the results of studies conducted in developed countries, which estimate an annual discount factor closer to 0.9 (see, for example, Gourinchas and Parker (2002)).[32] Figure 3 plots estimated values of the discount factor for different values of the coefficient of relative risk aversion, indicating the model criterion at each point. There is a negative relationship between the estimated discount factor and the coefficient of relative risk aversion (for example, when the coefficient of relative risk aversion is 0.5 the discount factor is 0.88; when the coefficient of relative risk aversion is 2.5 the discount factor is 0.6). As the figure shows, the objective function is minimized when the coefficient of relative risk aversion is equal to 1.2 and the discount factor is equal to 0.75. The primary moment in the data that is driving the low estimated discount factor is the relatively high correlation between income and consumption. To match this moment the model generates agents who discount the future and therefore do not value the future gains to be realized by staying in the risk-sharing network.

To explore further the validity of the estimated coefficient of relative risk aversion (and associated discount factor), I examine the predicted time-series properties of consumption, and compare these to the time-series properties of actual consumption. I did not target any time-series properties during the estimation, so this exercise provides an out-of-sample test of the fit of the model. I show the results in Appendix Table 7. The table shows that the simulated data when the coefficient of relative risk aversion of 1.2

[32]It should be noted that is not a priori clear what the discount factor should be for low-income countries. The point estimate of 0.75 is larger than the range of 0.4-0.6 elicited experimentally from individuals in the ICRISAT villages (Pender, 1996). A discount factor of 0.75 would be equivalent to an interest rate of 33% in a perfect market economy, which is reasonable with respect to interest rates charged by microfinance organizations (for example, microfinance APRs are 100% in Mexico Angelucci et al. (2015), 60% in the Philippines Karlan and Zinman (2011), and 30% in India Banerjee et al. (2015)). The estimate is within the range of 0.7-0.95 estimated by Ligon et al. (2002) in their study of the same ICRISAT villages.

provides the closest match to the time series properties of consumption in the data.

While my preferred results are the estimates that minimize the model criterion, in what follows I present results over a range of the coefficient of relative risk aversion parameter to show the robustness of the results to alternative parameter values.

5.1 Theoretical comparative statics

I now quantify the three comparative statics linking migration, risk-sharing, and welfare.

5.1.1 Reducing the cost of migration reduces risk-sharing

Theoretically, the effect of reducing the cost of migration on risk-sharing is ambiguous. On the one hand, lower migration costs increase the outside option for households, decreasing risk-sharing. On the other hand, lower migration costs allow the network to smooth aggregate shocks, increasing risk-sharing. Table 7 shows the effect on risk-sharing of introducing migration into the model.[33] The correlation between income and consumption is 6.4% when there is no migration, and 19.8% when there is migration. Introducing migration into the model therefore reduces risk-sharing by 13.4 percentage points. Columns (3) and (4) make the same comparison with and without lower migration costs over the sample of agents who do not migrate. The households that do not migrate have the same income in both states of the world, so the only change that occurs is the change in the distribution of consumption for these households. The same pattern holds: the correlation between income and consumption is 5.9% when there is no possibility to migrate, and 19.5% when there is. The overall correlation masks a substantial degree of heterogeneity within each group. The group that experiences the largest change in risk-sharing comprises households that have many males and therefore can more easily migrate. For example, the correlation between income and consumption for landless households with many males, the group most likely to migrate, increases from 6.7% to 20.7% with lower migration costs.

[33] I consider the introducing migration into the model compared with the case in which migration was not possible. This is equivalent to reducing the exogenous cost of migrating from a very large number, such that no household ever migrates, to a finite cost such some households do migrate. I set the finite cost to the estimated level of migration costs.

Figure 4 plots the results from Columns (1) and (2) from the table for a range of values of the coefficient of relative risk aversion. The qualitative result – that risk-sharing is better when migration costs are prohibitively high – holds for all values of the coefficient of relative risk aversion larger than 1.

5.1.2 Decomposition of the welfare effect of reducing the cost of migration

Introducing migration to the model changes the resources available to the village as well as the endogenous level of risk-sharing. The net welfare effect of reducing migration costs can be decomposed into an income effect and a risk-sharing effect. To decompose the welfare effect, I contrast a model with endogenously incomplete markets to a model with exogenously incomplete markets. Specifically, I consider a model where households can borrow and save a risk-free asset (as in Deaton (1991); Aiyagari (1994); Huggett (1993)). The key difference between the two environments is that lower migration costs do not alter the structure of the insurance market if markets are exogenously incomplete as it does when markets are endogenously incomplete.[34] For ease of comparison, I also show the effect of migration under autarky, where households do not have access to any risk-smoothing technology.

The results for three regimes are shown in Table 8. The welfare benefits of reducing migration costs are greatest when households are in autarky and do not have access to any risk-smoothing technology. In this case, introducing migration is equivalent to a 22.0% increase in average consumption. The benefit is positive with borrowing and saving, but smaller: households could already mitigate income shocks, and hence, the additional mechanism of migration is less valuable. I estimate the consumption equivalent gain to be a 16.0% increase in average consumption. Finally, when markets are endogenously incomplete, the welfare benefit of reducing the cost of migration is smaller again because risk-sharing is crowded out. I estimate the benefit of reducing the cost of migration under limited commitment to be negative, equivalent to a 16.5% decrease in consumption.[35]

[34] I set the risk-free interest rate to 0.30 and apply an exogenous borrowing constraint of approximately 50% of average annual income.

[35] A large part of these welfare losses arise from the fact that households that migrate must pay a utility cost when they migrate. The utility cost is sunk at the time that the after-migration constraints are computed

Contrasting endogenous with exogenous risk-sharing, the consumption-equivalent gain from migration is 32.5 percentage points lower for the former than from the latter.

Figure 5 plots the effect on consumption from introducing migration into the model for a range of values of the coefficient of relative risk aversion. The same pattern holds for all values of γ: the largest returns to introducing migration occur under autarky, smaller returns occur under exogenously incomplete markets, and the smallest returns occur under endogenously incomplete markets. The welfare gain from introducing migration, when there is endogenously incomplete risk-sharing, is negative for all values of the coefficient of relative risk aversion greater than 0.5 (and slightly positive when the coefficient of relative risk aversion is equal to 0.5).

5.1.3 Increasing the ease of risk-sharing reduces migration

If households are able to make transfers to share risk, the migration decision no longer depends on the gross income differentials between the village and the city, but rather on the post-transfer income differential. I consider introducing risk-sharing into the model (modeled as a reduction in the tax on inter-household transfers from 100% to 0%). There are two potentially offsetting effects of reducing the costs of transfers on migration: a home effect, which reduces migration, and a destination effect, which increases migration. Migration rates under alternative risk-sharing regimes are presented in the first panel of Table 8. The migration rate is 42% under autarky, 26% under borrowing-saving, and 17% under endogenous risk-sharing. The net effect of introducing risk-sharing into the model is, therefore, to reduce migration by 25 percentage points.

Figure 6 shows migration rates under autarky, borrowing-savings, and endogenously incomplete markets for a range of values of the coefficient of relative risk aversion. The pattern than migration rates are highest under autarky, lower under borrowing-savings, and lowest under endogenous risk-sharing holds for all values of the coefficient of relative risk aversion greater than 0.5; at a value of 0.5 the migration rate under endogenously incomplete markets is slightly above the migration rate under borrowing-savings.

and so it is not insured by the network in the case of a low migration outcome. Setting the migration cost equal to zero, but keeping migration rates at the same level as estimated, yields a positive welfare gain of 37.6% under autarky; 16.0% under borrowing-savings; and -8.7% under endogenously incomplete markets.

5.2 Robustness

I run several robustness tests for the model, which are summarized in Appendix Table 6. The first robustness check is to investigate the low estimated discount factor by allowing the income process in the village to be autoregressive. Risk-sharing is determined by agents who experience high income shocks, and so persistent shocks increase the value of autarky for an agent that has a high income shock today, reducing risk-sharing. When I estimate the model with an autoregressive coefficient of 0.1, the discount factor increases slightly, from 75% to 77%. However, I find little evidence in the data that income is, in fact, autoregressive and the overall model fit worsens with autocorrelation in income.[36]

The second robustness exercise I undertake is to estimate the model while assuming a different number of households in the village. This affects how well-insured the average "rest of village" household is (averaging over more households reduces the idiosyncratic component of income), lowering risk-sharing. With this specification, I estimate a slightly lower discount factor, of 73%. This parameterization, however, does not fit the data as well (model criterion of 79.9 vs 72.5).

5.3 Policy implications

I now consider the policy implications of the joint determination of migration and risk-sharing by examining the Indian government's Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA), a large-scale public works program.

5.3.1 Effect of the MNREGA policy

The MNREGA, introduced in 2005, is the largest rural employment scheme in the world, providing 55 million households with employment during 2010-2011 (Government of India, 2011). The MNREGA guarantees 100 days of work to each rural household. I model the scheme as a form of insurance that provides a minimum income level in the village,

[36] I estimate a model of lagged income on household income using the VLS1 data, including household fixed effects and correcting for dynamic panel bias. The coefficient on lagged income is small (0.08) and is not statistically significant. Results are presented in Appendix Table 4.

and I simulate the effect of the program on migration, risk-sharing, and welfare.[37]

Other studies have documented how public transfers may crowd out informal risk-sharing, and hence, reduce the welfare gains of public transfer policies (Attanasio and Rios-Rull, 2000; Albarran and Attanasio, 2003; Golosov and Tsyvinski, 2007; Thomas and Worrall, 2007; Krueger and Perri, 2010). If households use migration as an insurance mechanism then public transfers may also crowd out migration, reducing the gains from such a program. I show that both effects are present.

Table 9 shows the effects of the MNREGA policy under alternative economic environments. I first consider the case in which there is no migration. The policy will have the largest effect if households are in autarky and do not have access to any income-smoothing technology. In this case, the MNREGA will act as a targeted income transfer. Column (1) shows that under autarky and no migration the welfare benefit of the MNREGA is equivalent to a 12.5% increase in average consumption. Column (2) recomputes the benefit if households have access to borrowing-saving (exogenously incomplete markets). The welfare benefit of the policy is still large and positive, but smaller in magnitude than under autarky: 4.4%. This is because households were already able to smooth some of the welfare fluctuations of the income shocks. Column (3) estimates the effect of the policy under limited commitment. This takes into account the endogenous reduction in informal insurance as a result of the MNREGA. The change in risk-sharing is shown in the second panel of the table. There is a large increase, of 220%, in the correlation between income and consumption with the program compared to without the program, representing a substantial decline in the level of informal risk-sharing. The predicted effect of the MNREGA policy under endogenously incomplete markets is that it will reduce consumption by 1.6%. This result implies that the gain in public insurance generated by MNREGA would not be enough to offset the reduction in informal insurance.

Columns (3) through (6) of the table consider the welfare effects of MNREGA with migration. The welfare effect of the MNREGA policy under autarky with migration is

[37] What follows can be interpreted as an ex-ante evaluation of the MNREGA policy. Ex-post, there were many difficulties and irregularities in implementing the MNREGA scheme. Additionally, Imbert and Papp (2015a) show that the MNREGA has general equilibrium effects on wages. I abstract from this effect in the analysis.

smaller, compared to the case of the policy under autarky without migration, with an estimated gain of 2.9% in consumption-equivalent terms compared with a predicted gain of 12.5%. This is because because migration is already an available mechanism that households use to smooth income shocks. The MNREGA causes households to substitute away from migrating – the third panel shows that migration rates fall by 10% – and toward the publicly provided insurance. The same logic applies for the borrowing-savings environment, Column (5) in the table. Because migration was already in use as an insurance mechanism, I estimate the policy leads to a consumption equivalent gain of 1.1%, compared with 4.4% without migration. When households have access to both informal risk-sharing and migration, Column (6) in the table, the effects of MNREGA are more complex. I estimate that MNREGA reduces slightly the level of risk-sharing in the case with migration (the correlation between income and consumption increases by 3.9%, compared with an increase of 220% for the case without migration). The equilibrium migration rate decreases by 25%, compared with a decrease of 10% under borrowing-saving (and a similar fall, of 10%, under autarky). The reduction in migration leads to gains in utility because of migrating is very costly for households. The predicted effect of the MNREGA scheme under endogenous risk sharing is a gain of 5.8% consumption-equivalent terms.

Figure 7 reports the results over the full range of the coefficient of relative risk aversion. Starting with the first panel, the gains for MNREGA under autarky, the gains are higher for the case without migration, compared with the gains for the case without migration, for values of the coefficient of relative risk aversion below two. The second panel shows the gains under borrowing-savings. The gains with migration are lower than the gains without migration across the full range of values of the coefficient of relative risk aversion. The third panel considers the effects of MNREGA under endogenously incomplete risk-sharing. I estimate negative gains of MNREGA in the environment without migration for values of the coefficient of relative risk aversion below 1.6, and positive gains of MNREGA for other values of the coefficient of relative risk aversion. I find positive gains for the environment with migration across the entire range. This heterogeneity in the effects highlights why it is important to account for the endogenous effects on both migration and risk-sharing to evaluate the welfare effects of policies designed to help households address income risk.

6 Conclusion

Economists have long studied the complex systems of informal insurance that households utilize in developing countries. Informal insurance is important because formal markets are generally absent from these environments, leaving households exposed to a high degree of income risk. However, studies of informal insurance have generally not considered that households have access to other risk-mitigating strategies. This paper studies temporary migration, a phenomenon that is both common (20% of rural Indian households have at least one migrant) and economically important (migration income is more than half of total household income for these households). Temporary migration provides a way for households to self-insure; hence, it may fundamentally change incentives to participate in informal insurance. At the same time, informal insurance changes the returns to migration. For this reason, this paper has argued that it is necessary to consider the household migration decision *jointly* with the decision to participate in informal risk-sharing networks.

The analysis proceeds in three steps. First, I characterize a model of endogenous limited commitment risk-sharing with endogenous temporary migration, in which risk-sharing and migration are jointly determined. In the limited commitment model, the key determinant of risk-sharing is the household's outside option. Migration changes the outside option, thereby changing the structure of endogenous risk-sharing. I demonstrate how the welfare effect of reducing the costs of migration can be decomposed into an income effect and a risk-sharing effect. I then show how improving access to risk-sharing alters the returns to migration, and determines the migration decision.

Second, I estimate the model structurally using the new wave of the ICRISAT panel dataset. I allow for heterogeneity in landholdings and household composition to match migration rates across groups. The quantitative results are: (1) reducing migration costs reduces risk-sharing by 13 percentage points; (2) contrasting endogenous to exogenous risk-sharing, the consumption-equivalent gain of reducing migration costs migration is

32 percentage points lower in the former than in the latter; and (3) improving access to risk-sharing reduces migration by 25 percentage points.

Third, that households make both risk-sharing and migration decisions jointly generates key implications for development policy. For example, policies that address income risk will have direct effects, but may also have indirect effects, such as crowding out informal risk-sharing. It is important to account for both the direct and indirect effects in welfare calculations. This point has been made for other contexts, such as public insurance in the PROGRESA program (Attanasio and Rios-Rull, 2000). I demonstrate that it is also important to consider how policy affects migration decisions. Using the example of the Indian Government's MNREGA policy, the largest-scale public works program in the world, I show the policy substitutes for informal insurance, reducing risk-sharing. In addition, the rural employment scheme increases income in the village, substituting for migration. I illustrate how the welfare benefits of this policy are overstated if the joint responses of migration and risk-sharing are not taken into account. The welfare gain of the policy is 50%-90% lower after household risk-sharing and migration responses are considered.

This paper has shown that it is both theoretically important and empirically relevant to consider the joint determination of migration and risk-sharing. While the current focus has been on migration, it is reasonable to think that many other decisions that households make may also be jointly determined with informal insurance. Additionally, an important open question concerns the determinants of the long-run changes observed between the first wave of the VLS in 1975 and the second wave in 2001: what caused the large increase in temporary migration over this time period and how did this increase in temporary migration affect the long-run development of India's village economies? Fruitful avenues for future research may including examining the implications of the joint determination of informal risk-sharing and investment or production decisions, as well as examining the determinants of the long-run changes observed in India's village economies.

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Figures and Tables

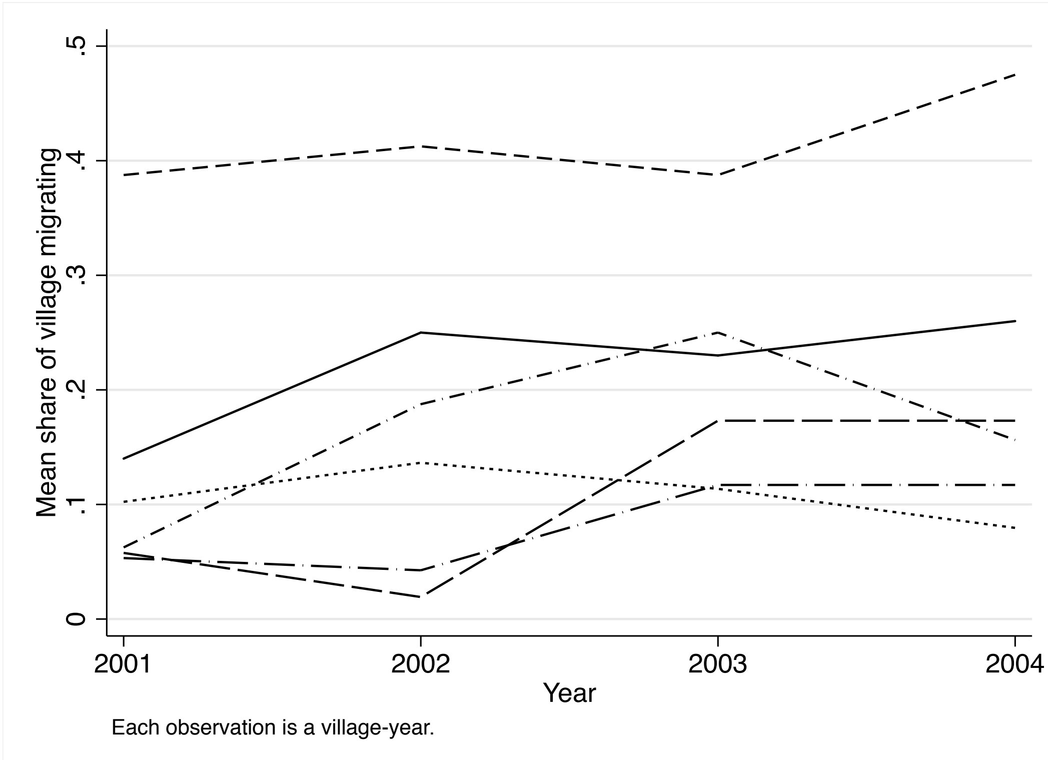


Figure 1: Migration varies over space and time: Temporary migration in the six ICRISAT villages over time.

Notes: The figure plots the share of households with a temporary migrant in each of the six ICRISAT villages by year.

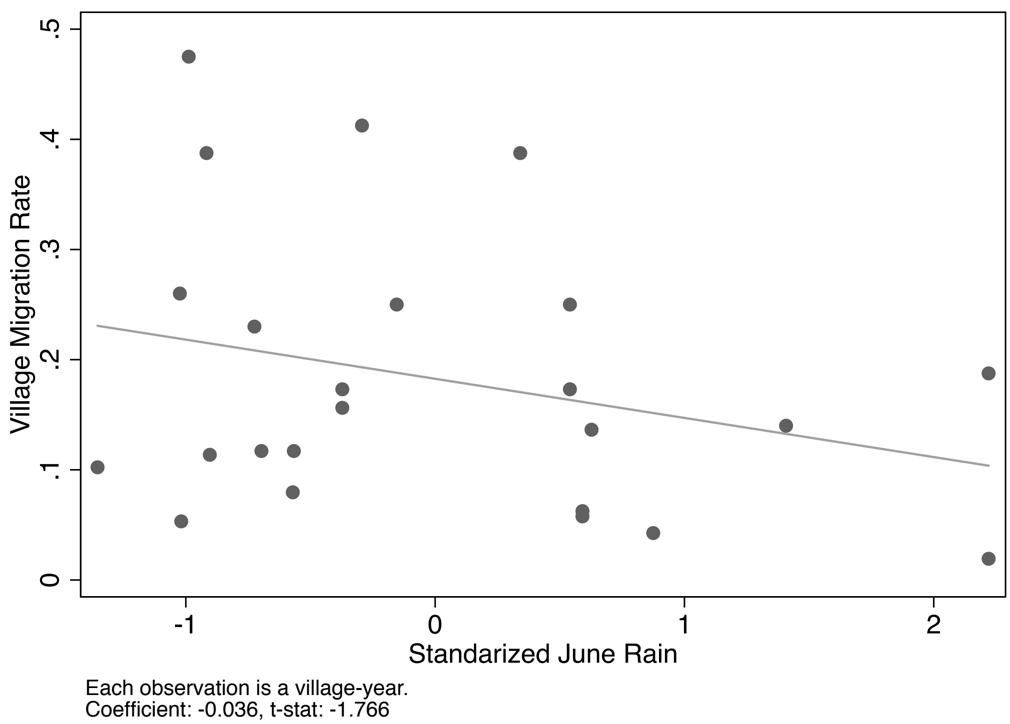


Figure 2: Verifying model assumptions: Temporary migration responds ex-post to income shocks.

Notes: The figure plots the relationship between the mean village migration rate and the standardized monsoon (June) rainfall in the six ICRISAT villages between 2001-2004. Monsoon rainfall is a strong predictor of crop income for the coming year. Migration decisions are made after the monsoon rainfall and respond to expected income shocks. The unit of observation is a village-year; there are 24 observations. A regression line is included in the figure.

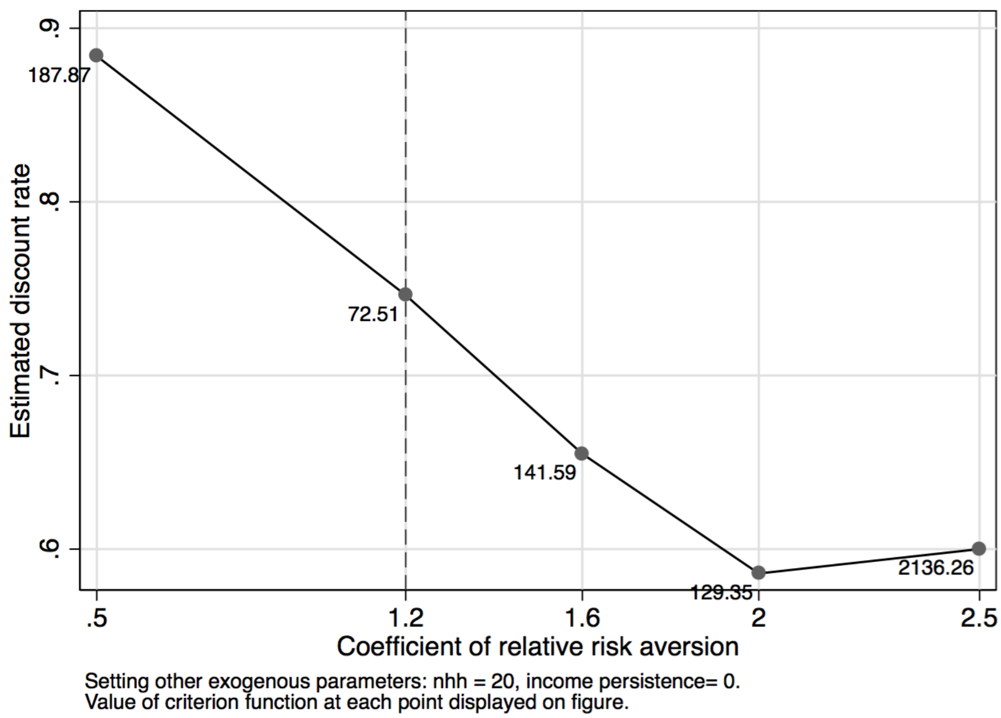


Figure 3: Estimation of the coefficient of relative risk aversion and discount factor

Notes: The figure plots the estimated discount factor for points along the grid of coefficient of relative risk aversion. The model criterion is displayed for each point in the figure.

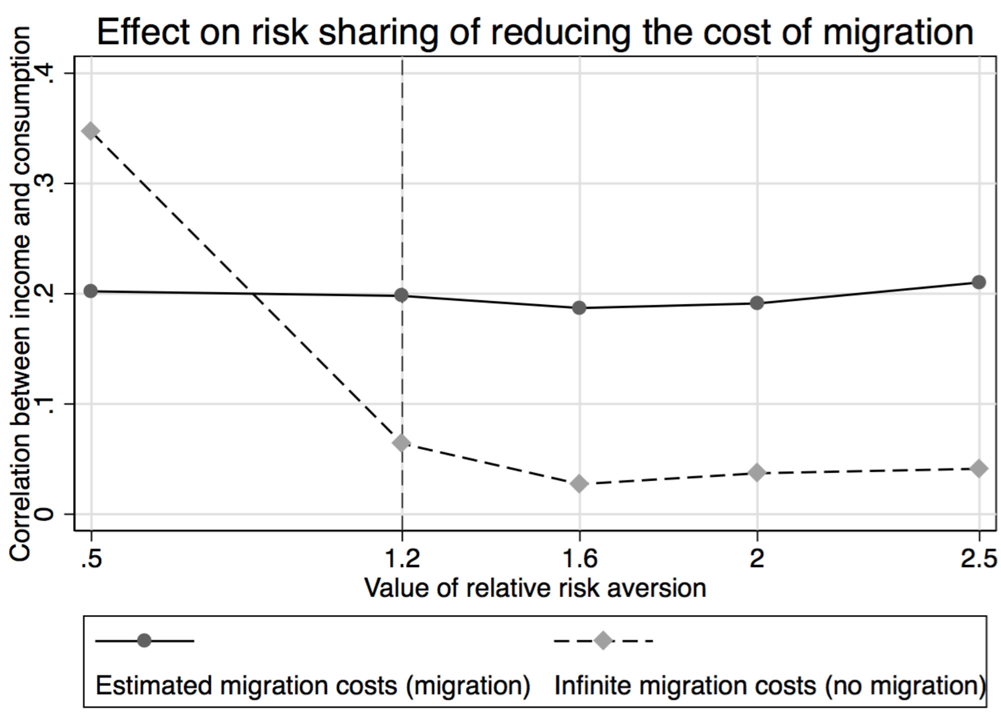


Figure 4: Robustness over γ: Effect on risk sharing of reducing the cost of migration

Notes: The figure plots the results from column (1) and column (2) of Table 7 for different values of the coefficient of relative risk aversion.

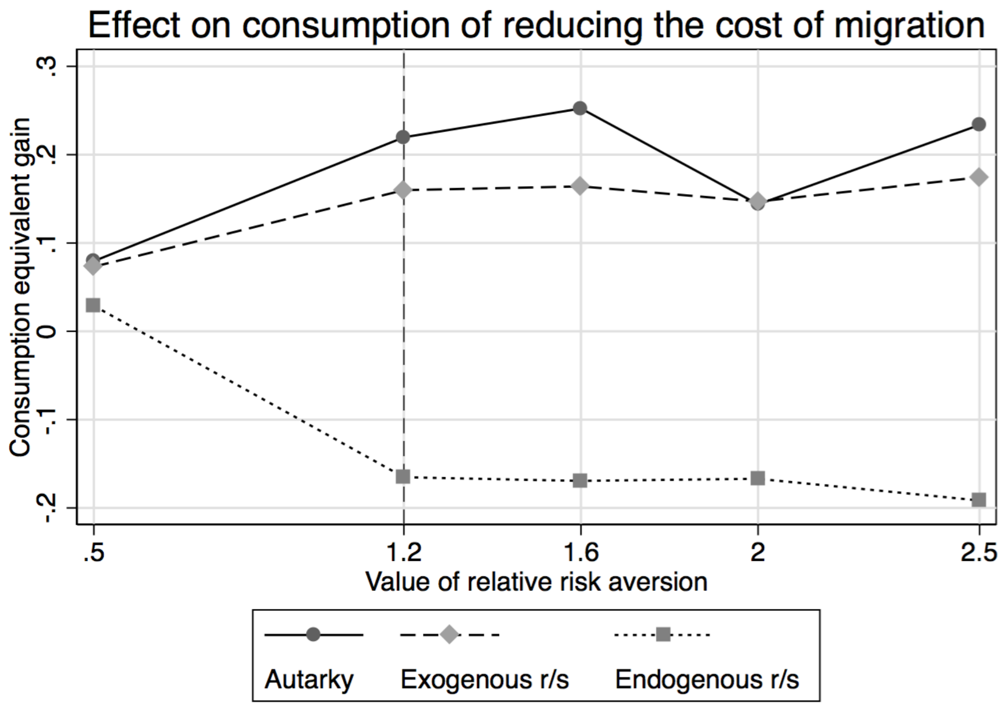


Figure 5: Robustness over γ: Effect of reducing the cost of migration under different risk sharing regimes

Notes: The figure plots the consumption results from column (1), (2) and (3) of Table 8 for different values of the coefficient of relative risk aversion.

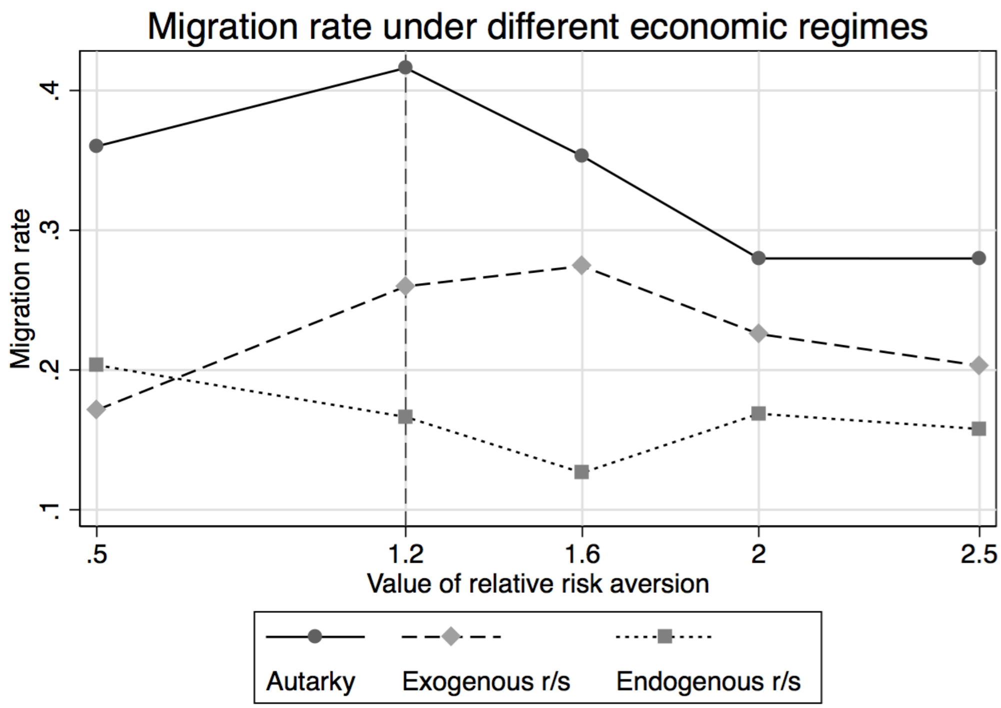


Figure 6: Robustness over γ: Effect of reducing the cost of migration under different risk sharing regimes

Notes: The figure plots the migration results from column (1), (2) and (3) of Table 8 for different values of the coefficient of relative risk aversion.

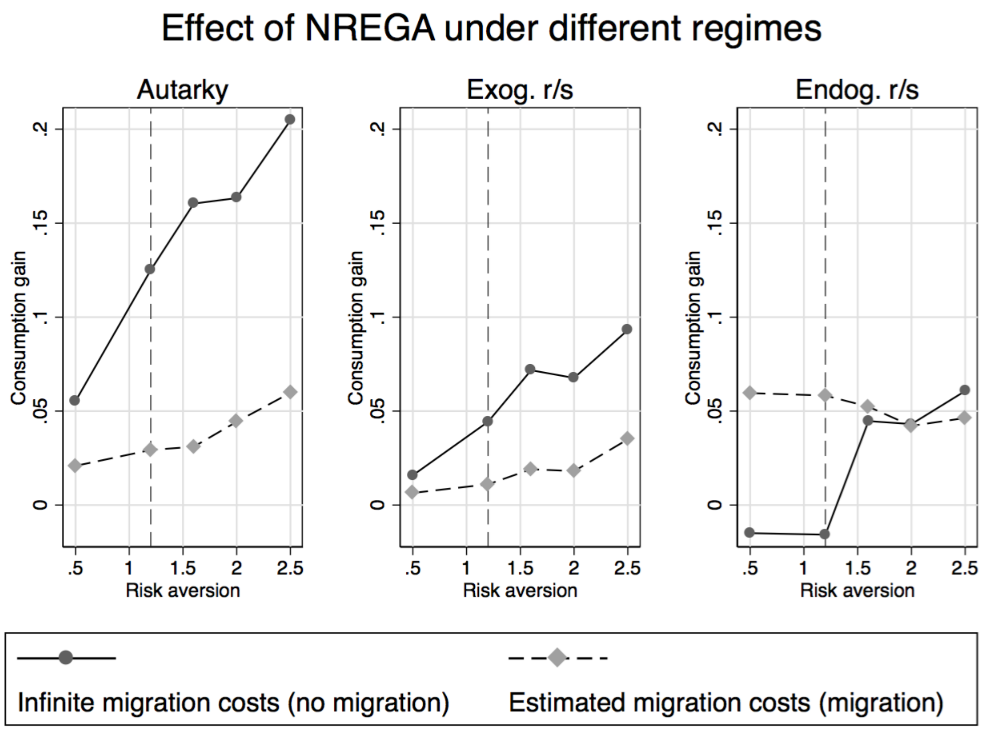


Figure 7: Robustness over γ: Effect of NREGA under different regimes

Notes: The first panel of the figure plots the results from column (1) and column (4) of Table 9. The second panel plots the results from column (2) and column (5) of Table 9. The third panel of the figure plots the results from column (3) and column (6) of Table 9.

Table 1: Summary statistics

Mean/sd	(1) All	(2) Ever Migrate	(3) Never Migrate
Total income	22.64	23.45	22.12
	(18.23)	(17.57)	(18.63)
Non-migration income	21.46	18.64	23.24
	(22.64)	(22.08)	(22.82)
Migration income	2.38	6.19	0.00
	(6.10)	(8.55)	(0.00)
Total consumption	26.73	26.71	26.74
	(16.22)	(15.56)	(16.63)
Per capita consumption	6.78	6.25	7.11
	(4.24)	(4.43)	(4.09)
Owned land	4.81	4.39	5.08
	(5.57)	(5.85)	(5.37)
Household size	5.08	5.82	4.61
	(2.44)	(2.57)	(2.23)
Number adults	3.72	4.23	3.40
	(1.64)	(1.65)	(1.56)
Number adult males	1.91	2.23	1.72
	(1.08)	(1.08)	(1.03)
Number migrants		1.77	
		(0.96)	
Share household migrating		0.33	
		(0.19)	
Migration length (days)		192.98	
		(102.67)	
Number households	439	171	268

Notes: Summary statistics calculated from VLS2. All financial variables in '000s of rupees. Per capita consumption computed in adult equivalent terms. Migration variables computed only for years in which the household migrates.

Table 2: Test for perfect risk sharing

Dep. variable: Consumption	(1) b/se	(2) b/se
Income	0.070***	0.029
	(0.016)	(0.022)
Mean village migration *X* Income		0.234*
		(0.122)
Village-Year FE	Yes	Yes
Household FE	Yes	Yes
R-squared	0.627	0.629
Number observations	1443	1443

Notes: OLS regressions of log income on log consumption. Standard errors clustered at village-year level for all columns. VLS2 is ICRISAT data 2001-2004. Mean village migration interacts the average village level of temporary migration with individual income.

Table 3: Transfers are insurance

	In levels		In first difference	
	(1)	(2)	(3)	(4)
Dep. variable: (Diff) Transfers	b/se	b/se	b/se	b/se
Total Income	-0.967***	-0.845***		
	(0.031)	(0.033)		
Stock of transfers		-0.261***		
		(0.024)		
D.Total Income			-0.971***	-0.736***
			(0.033)	(0.034)
D.Stock of transfers				-0.497***
				(0.033)
Village-Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	No	No
r2	0.729	0.753	0.534	0.650
N	1446	1236	919	824

Notes: Source: VLS2. Transfers are defined as the residal between income and consumption. Stock of transfers measures the combined value of transfers received, setting 2001 equal to zero.

Table 4: Change in household income and expenditure when migrate

Dep. variable:	(1) Income b/se	(2) Consumption b/se	(3) Δ Fin. Assets b/se	(4) Δ Phy. Assets b/se	(5) Expenditure b/se
Dummy if migrate	1451	602	404	339	1104
	(492)	(521)	(317)	(490)	(902)
Household FE	Yes	Yes	Yes	Yes	Yes
Mean dep. variable	5828	6856	-598	292	6247
R-squared	0.650	0.512	0.215	0.304	0.369
Number observations	1446	1449	1490	1490	1510
Number households	438	438	437	437	438

Notes: OLS regressions with standard errors clustered at village-year. Calculated from ICRISAT data 2001-2004. Change in financial assets is change in savings less change in debt. Change in physical assets is change in value of durables, farm equipment, and livestock. Change variables calculated 2002-2004. Expenditure is sum of columns 2-4, assigning predicted change in assets for year 2001. Mean dependent variable calculated over non-migrants.

Table 5: Goodness of fit of model to data, by village

	Overall		Village 1		Village 2		Village 3		Village 4		Village 5	
	(1) Data	(2) Model	(3) Data	(4) Model	(5) Data	(6) Model	(7) Data	(8) Model	(9) Data	(10) Model	(11) Data	(12) Model
Mean of non-migrant income	5.837	5.994	8.201	8.726	5.220	5.867	5.001	5.294	5.026	5.316	5.075	5.357
Std dev non-migrant income	4.261	4.161	4.672	4.902	3.225	3.145	4.130	4.121	3.937	3.964	3.680	3.454
Mean of non-migrant income: own land	6.525	6.222	8.959	8.751	5.281	5.963	5.401	5.493	5.843	5.737	6.076	5.686
Mean of migrant income	5.802	5.790	6.796	6.905	5.028	5.208	6.696	6.011	5.832	5.547	5.605	3.932
Std dev migrant income	3.736	3.519	3.897	3.846	3.195	3.036	4.462	3.859	3.770	3.662	5.290	2.177
Mean migration rate	0.197	0.173	0.238	0.282	0.454	0.390	0.078	0.074	0.074	0.075	0.078	0.046
Mean migration rate: male hh	0.306	0.265	0.553	0.477	0.536	0.558	0.105	0.105	0.109	0.093	0.125	0.093
Correlation of consumption and income	0.223	0.211	0.215	0.216	0.240	0.230	0.154	0.153	0.325	0.322	0.108	0.109
Mean non-migrant consumption	5.962	5.507	8.378	7.613	5.303	4.935	5.159	5.082	5.137	5.076	5.129	5.117
Mean migrant consumption	5.289	5.377	6.227	7.113	4.928	4.505	4.823	4.407	4.435	4.277	4.967	5.448
Percent nonmigrants receiving transfer	0.548	0.508	0.548	0.450	0.561	0.404	0.530	0.568	0.556	0.507	0.551	0.561
Percent migrants receiving transfer	0.496	0.499	0.500	0.498	0.500	0.496	0.426	0.478	0.458	0.457	0.441	0.466
Model criterion		72.519		28.734		25.941		6.820		2.770		8.255

Notes: Table reports how well the model matches the data by moment for each moment included in the estimation. All monetary values are 000's of rupees per adult equivalent in household. The model is estimated independently by village and so the overall model criterion (Column 2) is the sum of the model criterion for the five villages.

Table 6: Effect of migration on village income and income of migrants

	(1) Data	(2) Model
Income of Migrants		
Observed mean income	5.802	5.790
Mean income if stayed in village		3.356
Share of migrants with income gain		0.703
Village Income		
Observed mean income of non-migrants	5.837	5.994
Mean of untruncated village income distribution		5.536

Notes: Model column calculated using structural estimates. All monetary values are 000's of rupees per adult equivalent in household. Migration is endogenous: the agents with the lowest income realizations migrate. This causes the income distribution in the village to be left-truncated.

Table 7: Effect on risk sharing of reducing the cost of migration

	Whole sample		Only non-migrants	
	(1)	(2)	(3)	(4)
Risk sharing: corr(y, c)	No migration mean	With migration mean	No migration mean	With migration mean
Overall	0.064	0.198	0.059	0.195
Landless, few males	0.059	0.182	0.052	0.175
Landed, few males	0.066	0.194	0.061	0.190
Landless, many males	0.059	0.199	0.053	0.190
Landed, many males	0.066	0.207	0.064	0.205

Notes: Table compares risk sharing in an economy with the cost of migration very high so that noone migrates to the same economy with the cost of migration as estimated in the model. The risk sharing measure is the correlation between consumption and income. Columns 1 and 2 compute the statistic for the whole sample. Columns 3 and 4 compute the statistic only for households who don't migrate when they have the option: this keeps income constant. Risk sharing is crowded out by the increase in households' outside option with migration.

Table 8: Effect of reducing the cost of migration under different risk sharing regimes

	(1) Autarky	(2) Exogenous incomplete	(3) Endogenous incomplete
Migration rate			
Overall	0.416	0.260	0.166
Landless, few males	0.386	0.175	0.083
Landed, few males	0.333	0.139	0.068
Landless, many males	0.506	0.385	0.266
Landed, many males	0.440	0.341	0.248
Welfare gain relative to no migration			
Overall	1.126	1.080	0.923
Landless, few males	1.119	1.071	0.908
Landed, few males	1.090	1.053	0.913
Landless, many males	1.164	1.110	0.933
Landed, many males	1.129	1.086	0.937
Consumption equivalent gain relative to no migration			
Overall	0.220	0.160	-0.165
Landless, few males	0.195	0.133	-0.193
Landed, few males	0.160	0.106	-0.187
Landless, many males	0.284	0.218	-0.143
Landed, many males	0.239	0.182	-0.138

Notes: Table shows change in welfare with migration compared to no migration for whole sample and by subgroup. Endogenous incomplete markets is the limited commitment model. No risk sharing is autarky. Exogenous incomplete markets considers a Hugget (1993) economy where agents can buy and sell a risk-free asset.

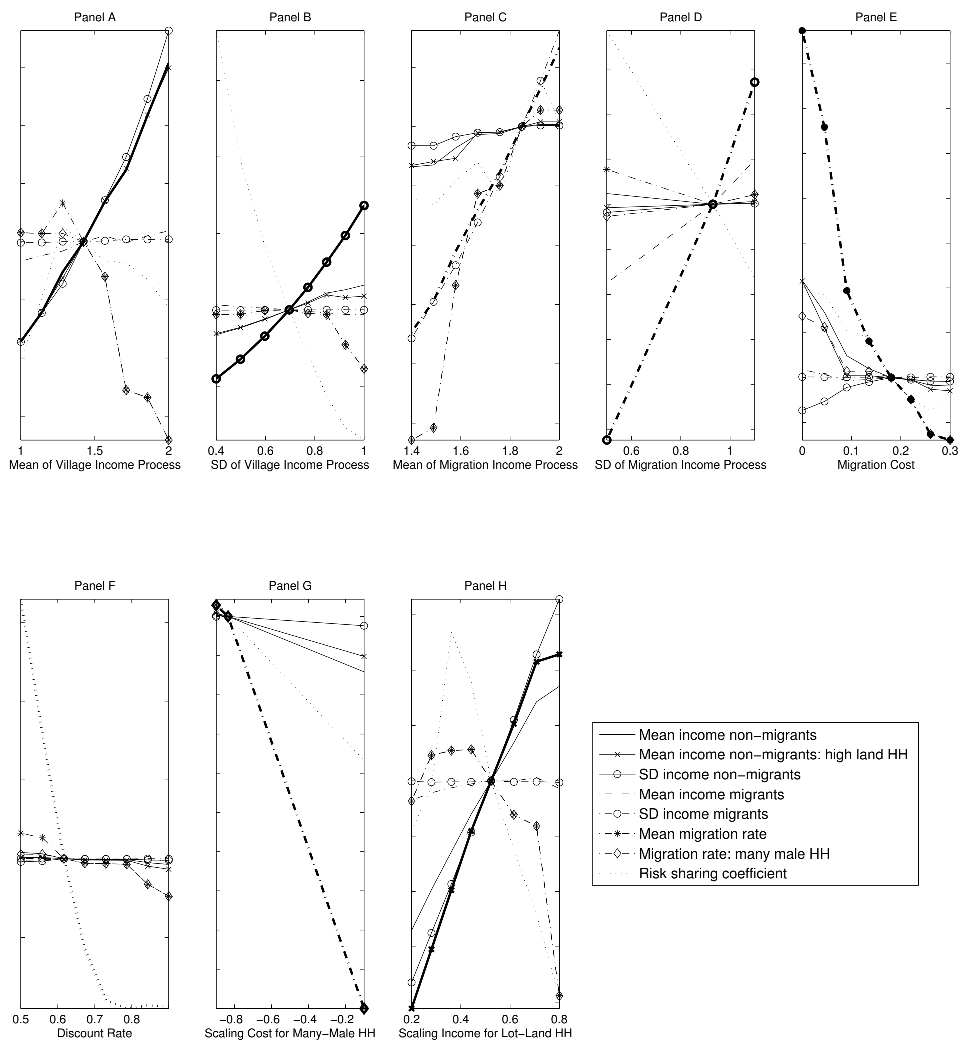
Table 9: Effect of NREGA under different regimes

	Without migration			With migration		
	(1)	(2)	(3)	(4)	(5)	(6)
	Autarky	Exog	Endog	Autarky	Exog	Endog
Consumption equivalent gain with NREGA						
Overall	0.125	0.044	-0.016	0.029	0.011	0.058
Landless, few males	0.137	0.051	-0.015	0.034	0.013	0.063
Landless, many males	0.113	0.038	-0.016	0.030	0.011	0.060
Landed, few males	0.137	0.051	-0.015	0.029	0.011	0.056
Landed, many males	0.113	0.038	-0.016	0.025	0.009	0.054
Correlation between income and consumption with NREGA relative to pre-NREGA						
Overall			3.189			1.039
Landless, few males			3.192			1.088
Landless, many males			3.187			1.069
Landed, few males			3.192			0.998
Landed, many males			3.187			1.001
Migration rate with NREGA relative to pre-NREGA						
Overall				0.900	0.901	0.748
Landless, few males				0.800	0.850	0.791
Landless, many males				0.800	0.867	0.783
Landed, few males				1.000	0.947	0.735
Landed, many males				1.000	0.939	0.684

Notes: NREGA policy enacts an income floor in the village. The policy is computed allowing for migration and not allowing for migration. Endog. is limited commitment. Exog. is exogenously incomplete markets. Autarky is no risk-sharing.

Appendices

A Appendix Tables and Figures



Appendix Figure 1: Model identification: effect of moments from changing parameters

Notes: This figure shows graphically how the moments in the model change as a function of the parameters. For each plot, I scale the moments so that they are equal for the initial parameter value. The x axis is the value of the parameter and the y axis yields the normalized value of the moment. For each plot, I scale the moments so that they are equal for the initial parameter value.

Appendix Table 1: Characteristics of migrant households

Dependent variable: Ever migrate	(1) b/se	(2) b/se
Number Males	0.197***	0.203***
	(0.036)	(0.034)
Land Owned	-0.004	0.002
	(0.006)	(0.006)
LandXMale	-0.010**	-0.011***
	(0.004)	(0.004)
HHsize	0.035***	0.038***
	(0.010)	(0.010)
Village FE	No	Yes
R-squared	0.110	0.213
Number observations	446	446

Notes: Dependent variable is a dummy for whether a household participates at least once in the temporary migrant labor market between 2001 and 2004.

Appendix Table 2: Correlations of attributes and wages in the village and migrant labor market

	Village Labor Market			Migrant Labor Market			Decision to Migrate		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Male	Female	Both	Male	Female	Both	Male	Female	Both
Dep. variable: Log Wage	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
Age	0.001*	-0.000	0.001**	0.004	-0.004	0.002	-0.005***	-0.003***	-0.004***
	0.001	0.000	0.000	0.004	0.007	0.003	0.001	0.001	0.001
Years of education	0.010***	0.003	0.007***	0.034**	0.108**	0.038***	0.021***	-0.000	0.019***
	0.003	0.004	0.002	0.015	0.049	0.013	0.004	0.005	0.003
Years of education missing	-0.007	0.016	0.003	0.151	0.242	0.141	0.114***	0.069**	0.122***
	0.028	0.020	0.017	0.145	0.232	0.119	0.032	0.029	0.022
Yrs experience in sector	0.038***	-0.005	0.015**	0.020	0.066	0.025			
	0.010	0.007	0.006	0.050	0.078	0.042			
Male			0.683***			0.214**			0.199***
			0.012			0.085			0.015
Vill-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1121	1172	2293	416	154	570	1448	1260	2708
r2	0.172	0.277	0.690	0.284	0.330	0.295	0.309	0.160	0.261

Notes: Sample is VLS2. Sectoral experience omitted in migration decision specification to avoid mechanical correlation and bad control problem.

Appendix Table 3: Effect of aggregate shocks on income

Dep. variable: Log Income	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Number days monsoon late	-0.009***			
	(0.001)			
Bottom 10% shock		-0.923***		
		(0.103)		
Bottom 20% shock			-0.231***	
			(0.064)	
Bottom 50% shock				-0.104**
				(0.050)
Household FE	Yes	No	No	No
Long run prob. shock		0.14	0.28	0.49
R-squared	0.606	0.625	0.591	0.586
Number observations	931	931	931	931

Notes: OLS regressions using VLS1 (1975-1984). Rainfall shocks computed using the distribution of rainfall 1900-2008 from the University of Delaware precipitation database, and these thresholds applied to the ICRISAT colllected rainfall for 1975-1984. Monsoon start date is computed as the first day with more than 20 mm of rain after June 1, following Rosenzweig and Binswanger (1993).

Appendix Table 4: No evidence of income persistence

Dep. variable: Log Income	(1) OLS b/se	(2) Arellano-Bond estimator b/se
Lagged income	-0.044	0.081
	(0.036)	(0.077)
Number observations	719	719

Notes: Regressions using VLS1 (1975-1984). Household fixed effects included in both specifications. Column (1) estimates the system by OLS. Column (2) estimates the system by Arellano-Bond system GMM to consistently estimate lagged effect in presence of fixed effect.

Appendix Table 5: Structural point estimates (by village)

	A	B	C	D	E	Average
	b/se	b/se	b/se	b/se	b/se	b/se
Village income						
Mean of village shock process	1.716	1.254	1.159	1.118	1.262	1.302
	(0.161)	(0.205)	(0.048)	(0.045)	(0.575)	(0.127)
Std. dev of village shock process	0.669	0.650	0.863	0.831	0.710	0.745
	(0.116)	(0.239)	(0.004)	(0.006)	(0.229)	(0.070)
Migration income						
Mean of migration income process	1.839	1.555	1.793	1.720	1.441	1.670
	(0.436)	(0.013)	(0.119)	(0.010)	(0.953)	(0.211)
Std. dev of migration income process	0.915	0.949	0.968	0.977	0.806	0.923
	(0.014)	(0.239)	(0.122)	(0.025)	(1.279)	(0.261)
Utility cost of migrating						
Utility cost of migrating	0.157	0.162	0.300	0.384	0.399	0.280
	(0.050)	(0.075)	(0.010)	(0.023)	(2.257)	(0.452)
Preference parameters						
Discount factor	0.771	0.784	0.741	0.658	0.777	0.746
	(0.062)	(0.015)	(0.044)	(0.015)	(0.037)	(0.017)
Coefficient of relative risk aversion	1.200	1.200	1.200	1.200	1.200	1.200
Heterogeneity parameters						
Scaling utility cost for male	-0.763	-0.693	-0.318	-0.164	-0.610	-0.509
	(1.826)	(0.482)	(0.131)	(0.003)	(2.401)	(0.611)
Scaling mean for land	0.006	0.056	0.089	0.211	0.125	0.097
	(0.201)	(0.081)	(0.060)	(0.038)	(0.588)	(0.126)
Scaling factor good aggregate shock	0.200	0.200	0.200	0.200	0.200	0.200
Share of income from migration	0.600	0.600	0.600	0.600	0.600	0.600

Notes: Table gives point estimates and standard errors from simulated method of moment estimation. Columns (1)-(5) yield village-specific estimates. Column (6) averages across villages (note: standard error for the average does not take into account covariance across village as this was not estimated). Two parameters are set exogenously: the share of household income from migration and the scaling effect of a good aggregate shock. The coefficient of relative risk aversion is estimated on a grid and so is common across all villages; I do not calculate standard errors for it in this table.

Appendix Table 6: Structural point estimates (by village)

	nhh = 4, $\rho = 0$					nhh = 20, $\rho = 0$					nhh = 4, $\rho = 0.1$					nhh = 20, $\rho = 0.1$				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	$\gamma = 0.5$	$\gamma = 1.2$	$\gamma = 1.6$	$\gamma = 2$	$\gamma = 2.5$	$\gamma = 0.5$	$\gamma = 1.2$	$\gamma = 1.6$	$\gamma = 2$	$\gamma = 2.5$	$\gamma = 0.5$	$\gamma = 1.2$	$\gamma = 1.6$	$\gamma = 2$	$\gamma = 2.5$	$\gamma = 0.5$	$\gamma = 1.2$	$\gamma = 1.6$	$\gamma = 2$	$\gamma = 2.5$
	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Village 1																				
Beta	0.877	0.768	0.900	0.603	0.529	0.891	0.771	0.674	0.611	0.557	0.863	0.754	0.688	0.550	0.545	0.900	0.797	0.695	0.606	0.657
Criterion	26.266	29.853	134.564	49.574	283.127	30.211	28.722	57.401	56.706	782.145	52.186	20.965	35.516	39.066	135.264	48.096	24.484	31.469	52.770	248.720
Village 2																				
Beta	0.874	0.755	0.669	0.558	0.420	0.857	0.784	0.721	0.590	0.543	0.866	0.734	0.610	0.582	0.474	0.894	0.803	0.740	0.622	0.530
Criterion	26.914	33.810	14.678	13.505	9.449	23.219	25.940	59.730	18.057	76.223	25.998	34.228	24.982	7.764	6.211	18.109	34.961	34.372	17.309	48.641
Village 3																				
Beta	0.890	0.748	0.651	0.489	0.552	0.898	0.741	0.644	0.597	0.646	0.900	0.771	0.584	0.470	0.549	0.896	0.760	0.637	0.604	0.633
Criterion	40.018	6.371	9.774	70.462	44.093	88.648	6.820	6.405	20.656	549.774	26.995	8.949	25.290	59.345	81.381	39.341	7.189	35.605	11.657	103.465
Village 4																				
Beta	0.823	0.603	0.582	0.431	0.525	0.876	0.658	0.593	0.513	0.505	0.855	0.634	0.552	0.525	0.503	0.857	0.693	0.597	0.481	0.500
Criterion	26.091	3.283	9.663	12.635	57.347	39.838	2.769	13.757	27.443	541.437	55.409	4.161	10.994	82.275	1279.907	41.062	6.707	34.750	22.335	90.508
Village 5																				
Beta	0.895	0.751	0.640	0.564	0.508	0.899	0.777	0.643	0.619	0.749	0.893	0.741	0.645	0.640	0.682	0.900	0.797	0.680	0.614	0.897
Criterion	10.487	6.531	9.448	19.151	46.464	5.954	8.255	4.298	6.490	186.684	8.450	13.275	13.438	108.465	92.557	9.069	15.178	20.270	5.048	158.752
Average Beta	0.872	0.725	0.688	0.529	0.507	0.884	0.746	0.655	0.586	0.600	0.875	0.727	0.616	0.553	0.551	0.889	0.770	0.670	0.585	0.644
Pooled model criterion	129.777	79.848	178.126	165.326	440.480	187.869	72.506	141.591	129.353	2136.263	169.037	81.578	110.220	296.915	1595.321	155.677	88.518	156.466	109.119	650.086

Notes: Table gives point estimates of beta and the critical value from simulated method of moment estimation. The model is estimated independently for each village so the model criterion for the pooled sample is given by the sum of the individual model criterions.

Appendix Table 7: Time series properties of consumption

	Real data	Simulated data (values of γ)				
		0.5	1.2	1.6	2	2.5
Dependent variable: Log consumption	b/se	b/se	b/se	b/se	b/se	b/se
Lagged log consumption	0.387***	0.552***	0.452***	0.526***	0.497***	0.751***
	(0.036)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Village-lotland-manymale FE	Yes	Yes	Yes	Yes	Yes	Yes
F stat		20.694	3.185	14.583	9.128	100.104

Notes: F stat is the F-test for whether the coefficient in Column (1) is equal to the coeffiicent in each of the other columns. The statistic is placed under the relevant simulated data column for ease of reading.

B Verifying migration patterns over the longer term

A concern is that the patterns of migration in the 2001-2004 data are not representative of migration patterns over a longer time period. To address these concerns I provide additional long-run facts on migration using ten additional years of the ICRISAT panel. This extended data series shows that the migration facts present in the four year panel are indeed representative of migration patterns over the longer time period.

In total, the ICRISAT VLS2 data has three waves of data: 2001-2004; 2005-2008, and 2009-2014. The data do not contain consistent individual IDs (or even consistent household IDs) across waves, and so it is unfortunately not possible to merge across waves. I answer each question for each wave and show the patterns are consistent across all 3 waves of the data.

Each wave covers a slightly different sample. The largest change is the 2009-2014 wave which was expanded to include 18 villages total, over the original 6 villages included in the first two waves. To construct the tables I used the restricted access datafiles to construct a panel of individuals within the household, matching across years within wave based on member names. I then coded each member in each year as either (i) a non-migrant: appears in the household roster and did not appear in the migration files, (ii) short-term migrant: appears in the household roster and in the migration files, or (iii) living outside the household: appears in the roster and coded as living outside the household, and does not appear in the migration or the village work files. I drop individuals who are coded as outside the household for non-employment (e.g. school). Living outside the household was only collected once, in 2001, for the 2001-2004 data. I construct this measure by using the status in 2001 and then I impose the 2001 status across the whole panel. This will likely overstate the persistence of living outside the household for the 2001-2004 wave.

This appendix considers five important issues. First, the level of permanent migration. Second, how many temporary migrants become permanent. Third, if the composition of the household is exogenous. Fourth, whether temporary migrants are perpetual migrants. Fifth, data on remittances by temporary and permanent migrants.

B.1 Level of permanent migration

Table 8 shows the household composition by household migration status. Between 1-4% of all observations, depending on wave, are household members who live outside the village.

Table 8 shows that between 5% of the members in a household with at least one temporary migrant are permanent migrants. The share of the household which are permanent migrants is 1% for the 2005-2008 and 2009-2014 waves. The share of permanent migrants in 2001-2004 is likely overstated because of data imputation issues as described above.

Appendix Table 8: Share of household members in each migration status

	2001-2004			2005-2008			2009	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All	≥ 1 temp. mig.	≥ 1 mem. outside	All	≥ 1 temp. mig.	≥ 1 mem. outside	All	≥ 1 temp. mi
Non migrants	0.91	0.65	0.67	0.94	0.61	0.61	0.94	0.70
Temporary migrants	0.05	0.30	0.08	0.06	0.38	0.09	0.05	0.29
Live outside household	0.04	0.05	0.25	0.01	0.01	0.29	0.01	0.01
HH size	5.51	6.58	6.33	4.64	5.38	5.41	5.13	5.36
No. of observations	1784	316	280	2447	359	68	5194	835
No. of households	446	163	97	701	183	60	913	320

Notes: Each observation is a household-year. The first column gives the statistics for all households. The second gives statistics for households with at least o
third gives statistics for households with at least one member living outside.

B.2 Temporary migrants who become permanent

Tables 9, 10 and 11 show the transition matrices for household migration status. There is substantial movement in and out of migration status. In 2001-2004 a household who has a temporary migrant in time t is observed to have no migrants in $t + 1$ 39% of the time; during 2005-2008 27% of the time, and during 2009-2014 29% of the time. A household who has a temporary migrant in time t is observed to have a member outside the household in $t + 1$ 8% of the time during 2001-2004; 21% of the time during 2005-2008, and 5% of the time during 2009-2014.

Tables 12, 13 and 14 show the transition matrices at the individual level. Again, there is substantial movement in and out of migration status. In 2001-2004 an individual who was a temporary migrant in time t does not migrate the following period 40% of the time; 33% of the time during 2005-2008 and 35% of the time during 2009-2014. The rates for living outside the household the year following temporary migration are 6% during 2001-2004; 15% during 2005-2008, and 3% during 2009-2014.

Putting these numbers together, a household who has a temporary migrant at least once has a member live outside for 19% of the time during 2001-2004. This number is 8% of the time for 2005-2008, and 7% for 2009-2014 (as stated earlier, the 2001-2004 likely overstates the persistence of members living outside). At the individual level, Table 16 shows that a temporary migrant spends 12% of the time living outside the village during 2001-2004, 5% during 2005-2008, and 5% during 2009-2014.

These findings are consistent with a body of literature that has documented particularly low rates of permanent migration by males in India (Topalova, 2010; Munshi and Rosenzweig, 2015).

Appendix Table 9: Transition matrix (hh): 2001-2004

t / t+1	Non-mig	Temp migrant	Living outside hh
Non-migrant	0.911	0.079	0.010
Temp migrant	0.392	0.525	0.082
Living outside household	0.036	0.187	0.778

Notes: Data from 2001-2004. Computed from 1338 hh-year observations. Sample drops one year because of lag.

Appendix Table 10: Transition matrix (hh): 2005-2008

t / t+1	Non-mig	Temp migrant	Living outside hh
Non-migrant	0.940	0.052	0.007
Temp migrant	0.266	0.522	0.213
Living outside household	0.042	0.792	0.167

Notes: Data from 2005-2008. Computed from 1745 hh-year observations. Sample drops one year because of lag.

Appendix Table 11: Transition matrix (hh): 2009-2014

t / t+1	Non-mig	Temp migrant	Living outside hh
Non-migrant	0.938	0.054	0.008
Temp migrant	0.289	0.665	0.046
Living outside household	0.183	0.183	0.635

Notes: Data from 2009-2014. Computed from 4280 hh-year observations. Sample drops one year because of lag.

Appendix Table 12: Transition matrix (indiv): 2001-2004

t / t+1	Non-mig	Temp migrant	Living outside hh
Non-migrant	0.973	0.026	0.002
Temp migrant	0.402	0.543	0.056
Living outside household	0.047	0.174	0.779

Notes: Data from 2001-2004. Computed from 7170 indiv-year observations. Sample drops one year because of lag.

Appendix Table 13: Transition matrix (indiv): 2005-2008

t / t+1	Non-mig	Temp migrant	Living outside hh
Non-migrant	0.978	0.019	0.002
Temp migrant	0.333	0.513	0.154
Living outside household	0.208	0.740	0.052

Notes: Data from 2005-2008. Computed from 7728 indiv-year observations. Sample drops one year because of lag.

Appendix Table 14: Transition matrix (indiv): 2009-2014

t / t+1	Non-mig	Temp migrant	Living outside hh
Non-migrant	0.982	0.016	0.002
Temp migrant	0.351	0.624	0.025
Living outside household	0.257	0.127	0.617

Notes: Data from 2009-2014. Computed from 21407 indiv-year observations. Sample drops one year because of lag.

Appendix Table 15: Share of years household spends in migration status

	2001-2004			2005-2008			2009-2014		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9
	All	Temp. mig.	Mem. outside	All	Temp. mig.	Mem. outside	All	Temp. mig.	Mem. o
No migrants	0.71	0.39	0.06	0.84	0.40	0.16	0.79	0.47	0.3
Temp migrants only	0.13	0.42	0.22	0.13	0.52	0.53	0.16	0.46	0.2
Member living outside household	0.16	0.19	0.72	0.03	0.08	0.30	0.05	0.07	0.4
No. of observations	446	141	97	701	182	60	913	314	10

Notes: Each observation is a household. The first column gives the statistics for all households. The second gives statistics for households with a temporary n
least one year in the survey. The third gives statistics for households with at least one member living outside at least one year in the survey.

Appendix Table 16: Share of years individuals spends in migration status

	2001-2004			2005-2008			2009-2014		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	Temp. mig.	Mem. outside	All	Temp. mig.	Mem. outside	All	Temp. mig.	Mem. outside
Non migrant	0.90	0.41	0.06	0.93	0.36	0.18	0.94	0.52	0.38
Temporary migrant	0.06	0.47	0.21	0.06	0.59	0.51	0.04	0.43	0.13
Living outside household	0.04	0.12	0.74	0.01	0.05	0.30	0.01	0.05	0.49
No. of observations	2654	327	152	3596	387	95	5233	525	151

Notes: Each observation is an individual. The first column gives the statistics for all individuals. The second gives statistics for individuals who migra
temporarily at least one year in the survey. The third gives statistics for individuals who live outside the household at least one year in the survey.

B.3 Is the composition of the household exogenous

This section considers whether the number of males in the household is truly exogenous, rather than some males breaking away from the household. In the estimation I assume that the number of males in the household in the first year of the data, 2001, is an instrument for the costs of migrating. If could be that the number of males in the household is itself a function of migration costs, perhaps because the households with low migration costs have already permanently lost members.

Table 17 shows the change in the number of males, females, and total household members across each wave. The measure is computed by looking at the change in household membership between the first and last years of each wave (the household composition in 2004 compared with 2001, 2008 compared with 2005, and 2014 compared with 2009). The table shows the raw change and then adjusts for household size because households with migrants are slightly larger.

The change in the number of males, divided by household size, is not statistically different by migration status across the 2001-2004 wave and the 2009-2014 wave. For the 2005-2008 wave, it is statistically significant although small in magnitude: migrant households had a decrease in males equivalent to 2% of the household's size, whereas non-migrant households had a decrease in males equivalent to 5% of the household's size. The relative difference between migrant and non-migrant households is the same in the other two waves, although is not statistically significant.

These data do not provide any evidence that the number of males in migrant households decreases more in migrant households than non-migrant households.

Appendix Table 17: Change in household demographics, by migration status

	2001-2004			2005-2008			20
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Non mig HH	Mig HH	t-stat	Non mig HH	Mig HH	t-stat	Non mig HH
	mean/sd	mean/sd	mean/sd	mean/sd	mean/sd	mean/sd	mean/sd
Change in the number of male	0.27	0.05	3.07	-0.31	-0.13	-2.68	-0.19
	(0.88)	(0.60)		(0.67)	(0.61)		(0.58)
Change male, dividing baseline hh size	0.08	0.05	0.93	-0.05	-0.02	-2.63	-0.03
	(0.22)	(0.35)		(0.11)	(0.13)		(0.17)
Change in the number of female	0.33	0.09	3.78	-0.19	-0.13	-0.81	-0.06
	(0.79)	(0.51)		(0.84)	(0.73)		(0.82)
Change female, dividing baseline hh size	0.09	0.05	1.60	-0.03	-0.01	-1.03	0.00
	(0.21)	(0.25)		(0.16)	(0.19)		(0.20)
Change in the number of total	0.60	0.14	3.70	-0.50	-0.26	-1.92	-0.26
	(1.56)	(1.01)		(1.31)	(1.15)		(1.17)
Change total, dividing baseline hh size	0.16	0.09	1.28	-0.08	-0.03	-2.02	-0.03
	(0.41)	(0.57)		(0.22)	(0.27)		(0.32)
No. households	260	632		252	984		576

Notes: Table shows the mean and standard deviation. Non-migrant HH defined as a household who never has a migrant or person living outside the househol of the round. Migrant household is a household that has either a migrant or person living outside the household in the first N-1 years of the round. Sample cons who are between 10-70 years old every year of each round. The third column tests gives the t-statistic for null hypothesis that the two groups have the same mea

B.4 Whether temporary migrants are perpetual temporary migrants

The concern is that temporary migration could itself be a permanent status if members engage in circular migration each year. I do not find evidence of this type of persistent temporary migration.

Tables 9, 10 and 11 show the transition matrices for household migration status. There is substantial movement in and out of migration status. In 2001-2004 a household who has a temporary migrant in time t is observed to have no migrants in $t+1$ 39% of the time; during 2005-2008 27% of the time, and during 2009-2014 29% of the time.

Tables 12, 13 and 14 show the transition matrices at the individual level. Again, there is substantial movement in and out of migration status. In 2001-2004 an individual who was a temporary migrant in time t does not migrate the following period 40% of the time; 33% of the time during 2005-2008 and 35% of the time during 2009-2014.

B.5 Data on remittances

This section discusses whether remittances are a form of insurance even for permanent migrants who leave but send transfers back. This is an important point. If a household has members outside the household they may be insured by remittances even if they do not appear to have a migrant in the data. I may, therefore, be understating the effect of migration on insurance.

Financial transaction data was not collected during the 2001-2004 wave, but it was collected during the 2005-2008 and 2009-2014 waves. Tables 19 and 18 summarize financial flows for households by migration status. The category of financial flows is transactions between "Friends/Relatives" that is in the "Gifts and remittances" category.[38]

The table shows that all types of households are equally likely to participate in gift/transaction flows, with 79% of non-migrant households, 82% of temporary migrant households, and 83% of households with an

[38] In the 2009-2014 there is specific ID associated with each transaction. However, the interpretation of this coding is not clear: for example, many remittances in the data are coded as "received" by a member of the household, and not as "sent" by the migrant. It is, therefore, difficult to separate out which of the flows are specifically sent by migrants to the household. Instead, I look at the aggregate of all flows received and sent. This has the advantage of also being consistent with the 2005-2008 data.

outside member reporting activity during 2009-2014 (and 90%, 95% and 97% reporting activity during 2005-2008). In 2009-2014 households with temporary migrants have twice as large gross flows as households with non-migrants or households with members outside the village, although this pattern is not present in 2005-2008. In terms of net flows, all three groups are statistically indistinguishable in both the 2005-2008 and 2009-2014 waves. In particular, households with members outside the village look very similar to households without migrants at all on all dimensions of financial activity.

Taken together, these data suggest that households with members outside the village look most similar to households without migration. There is no evidence that households with permanent migrants are receiving substantial insurance flows from their migrant members.

Appendix Table 18: Summary of transaction data, 2009-2014

	(1) Non migrant HH	(2) Temp migrant HH	(3) Member outside HH	(4) t-stat (1)=(2)	(5) t-stat (2)=(3)	(6) t-stat (1)=(3)
Send/receive a transfer	0.79	0.82	0.83	-1.93	-0.47	-1.64
	(0.0063)	(0.014)	(0.024)			
Amount given	7911.4	21333.3	9204.4	-3.01	0.72	-0.38
	(797.6)	(9353.1)	(3811.4)			
Amount received	9475.1	17272.8	10798.8	-2.30	1.09	-0.24
	(1338.8)	(3264.7)	(1947.9)			
Net amount received	1563.7	-4060.4	1594.4	1.02	-0.32	-0.0049
	(1506.4)	(9796.6)	(4226.0)			
Gross amount received	17386.6	38606.1	20003.2	-3.71	1.03	-0.39
	(1608.8)	(10015.3)	(4333.9)			
No. observations	4242	802	251			

Notes: An observation is a household-year. Table shows mean and semean. Computed from financial data, category= Gifts and Remittances. Column (4) tests between non-migrant and temporary migrant households. Column (5) tests between temporary and permanent migrant households. Column (6) tests between non-migrant and permanent migrant households.

Appendix Table 19: Summary of transaction data, 2005-2008

	(1) Non migrant HH	(2) Temp migrant HH	(3) Member outside HH	(4) t-stat (1)=(2)	(5) t-stat (2)=(3)	(6) t-stat (1)=(3)
Send/receive a transfer	0.90	0.95	0.97	-2.99	-0.80	-1.99
	(0.0062)	(0.012)	(0.021)			
Amount given	4145.1	3896.1	2875.7	0.15	0.35	0.20
	(719.8)	(745.6)	(771.2)			
Amount received	5259.6	3704.3	5675.7	1.02	-0.46	-0.073
	(633.2)	(1070.5)	(2756.3)			
Net amount received	1114.5	-191.8	2800.0	0.59	-0.75	-0.20
	(941.9)	(1004.3)	(2247.9)			
Gross amount received	9404.7	7600.4	8551.4	0.78	-0.15	0.098
	(975.0)	(1547.6)	(3366.1)			
No. observations	2392	344	68			

Notes: An observation is a household-year. Data is missing for 2007. Table shows mean and semean. Computed from financial data, category= Gifts and Remittances. Column (4) tests between non-migrant and temporary migrant households. Column (5) tests between temporary and permanent migrant households. Column (6) tests between non-migrant and permanent migrant households.

Appendix Table 20: Test for perfect risk sharing: adjust per cap

	Total		Per cap		Per cap, adjust mig		Per cap, adjust mig and trip length	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. variable: Consumption	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
Income	0.037**	-0.011	0.060***	0.015	0.097***	0.009	0.071***	0.006
	(0.017)	(0.024)	(0.016)	(0.022)	(0.022)	(0.021)	(0.018)	(0.021)
Mean village migration *X* Income		0.271*		0.258**		0.483***		0.360***
		(0.133)		(0.123)		(0.114)		(0.110)
Village-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.687	0.689	0.604	0.607	0.603	0.613	0.596	0.602
Number observations	1443	1443	1443	1443	1443	1443	1443	1443

Notes: OLS regressions of log income on log consumption. Standard errors clustered at village-year level for all columns. VLS2 is ICRISAT data 2001-2004. Mean village migration interacts the average village level of temporary migration with individual income.

C Robustness to the facts about migration and risk-sharing

This section undertakes several robustness tests of the analysis in Section 3.

C.1 Risk-sharing is incomplete

The baseline analysis in the paper takes household composition to be that of the baseline year (2001), and then constructs per capita adult equivalent consumption and income measures using this household composition. As a robustness check, I switch the denominator to account for those adults that are away from the household. The analysis from Table 2 is replicated below with 3 alternative definitions of household size in Appendix Table 20. The first column reports the specification in the paper, where the aggregate values for the household is used. Columns (3) and (4) use the number of equivalent adults in the household, defined in the first year of the survey. Columns (5) and (6) use the number of adult equivalents, subtracting off the number of adult equivalent migrants. Columns (7) and (8) make an adjustment for what share the migrants are away from the household. The results are robust across all household definitions.

C.2 Transfers are insurance

Appendix Table 22 replicates the analysis in Table 3 instrumenting income with rainfall shocks, and rainfall shocks interacted with the predictors of migration (males and land).

Appendix Table 21: Transfers are insurance: allow for expenditure

	Only consumption		All expenditure	
	(1)	(2)	(3)	(4)
Dep. variable: Transfers	b/se	b/se	b/se	b/se
Total Income	-0.967***	-0.845***		
	(0.031)	(0.033)		
Stock of transfers		-0.261***		-0.439***
		(0.024)		(0.029)
ln adult equiv - predetermined yr 1 level			-0.743***	-0.634***
			(0.044)	(0.041)
Village-Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
r2	0.729	0.753	0.565	0.643
N	1446	1236	1449	1241

Notes: Source: VLS2. Transfers are defined as the residal between income and consumption. Stock of transfers measures the combined value of transfers received, setting 2001 equal to zero.

The baseline definition I use for transfers is the difference between income and consumption. I rerun the test for perfect risk-sharing using the definition of total expenditure instead of consumption. The table is Appendix Table 21. The results still hold; the magnitude of the transfers to income is smaller, consistent with households being able to somewhat, but not perfectly, self-insure. This is also consistent with what is shown in the paper in Table 4, that the quantities of savings and other assets held by households are small.

C.3 Marginal propensity to consume from migration income is less than 1

A concern with Table 4 is that the results may understate the increase in consumption due to migrants being absent from the household. I rerun an alternative version of this table where I include gross (instead of net) migration income, and add migrant expenditure to the consumption term. Using this definition, household expenditure increases by only 42% of the increase in expenditure (compared to the increase of 60% in the initial table). The results are in Appendix Table 23.

As a second test, I compare the elasticity of household consumption to

Appendix Table 22: Transfers are insurance: IV results

	OLS		IV	
	(1)	(2)	(3)	(4)
Dep. variable: Transfers	b/se	b/se	b/se	b/se
Total Income	-0.967***	-0.845***	-1.334***	-0.988***
	(0.031)	(0.033)	(0.266)	(0.265)
Stock of transfers		-0.261***		-0.224***
		(0.024)		(0.068)
Village-Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
r2	0.729	0.753	0.702	0.753
N	1446	1236	1286	1105

Notes: Source: VLS2. Transfers are defined as the residal between income and consumption. Stock of transfers measures the combined value of transfers received, setting 2001 equal to zero.

net migration income to the elasticity of household consumption and migration expenses to gross migration income. The main definition of migration income used in the paper is income net of expenses occurred during the migration, so captures the net income returned to the household in the village. The results are in Appendix Table 24. For households with a current migrant, the elasticity of household consumption to net income is 0.14; the elasticity of household consumption to gross income is 0.106. The two coefficients are not statistically different (p-value: 0.385, shown in the table). This is consistent with the source of earnings not affecting the consumption expenditure, as would be the case if risk sharing is Pareto efficient within the household. which is reassuring.

Both exercises are reassuring that the changing household composition is not a key driver of the patterns observed in the data. However, it is worth being somewhat cautious about the interpretation because higher migration expenditure could for example represent higher transportation costs to get to a higher paying job, and not necessarily autonomous consumption.

Appendix Table 23: Change in household income and expenditure when migrate, accounting for migrant income and consumption

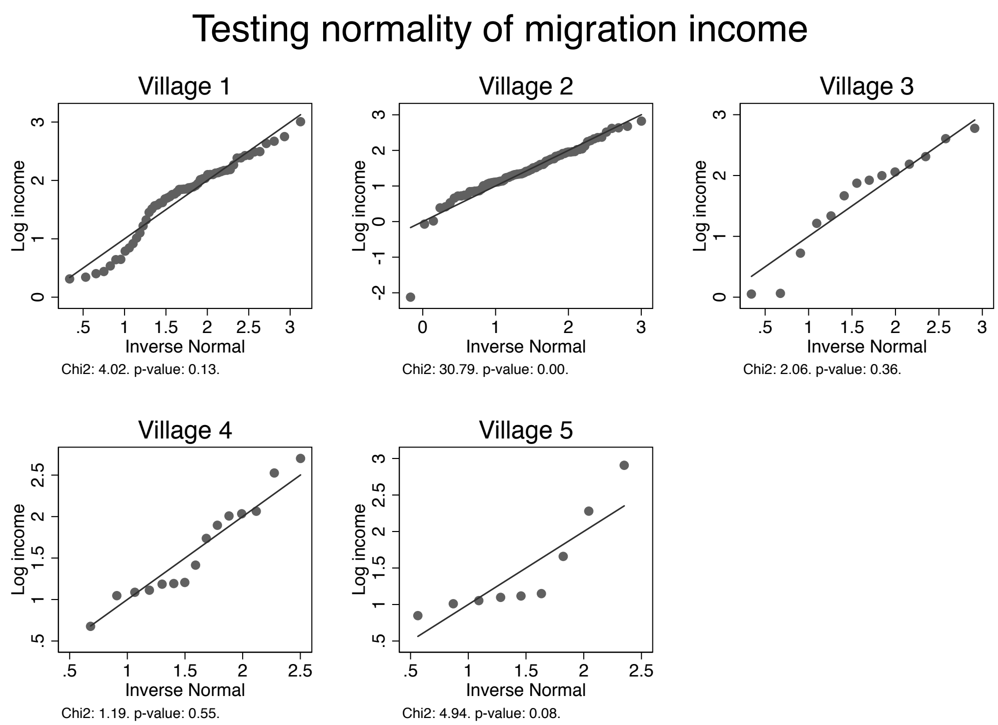
Dep. variable:	(1) Income b/se	(2) Consumption b/se	(3) Δ Fin. Assets b/se	(4) Δ Phy. Assets b/se	(5) Expenditure b/se
Dummy if migrate	3821	2125	-955	-313	1616
	(742)	(504)	(1356)	(1070)	(1504)
Household FE	Yes	Yes	Yes	Yes	Yes
Mean dep. variable	5860	6902	-598	292	6598
R-squared	0.754	0.643	0.648	0.734	0.662
Number observations	707	731	711	711	731
Number households	406	410	405	405	410

Notes: OLS regressions with standard errors clustered at village-year. Calculated from ICRISAT data 2001-2002. Change in financial assets is change in savings less change in debt. Change in physical assets is change in value of durables, farm equipment, and livestock. Expenditure is sum of columns 2-4, assigning predicted change in assets for year 2001. Mean dependent variable calculated over non-migrants.

Appendix Table 24: Elasticity of expenditure to different income sources

	Everyone		Only current migrants	
	(1) HH cons b/se	(2) HH +mig cons b/se	(3) HH cons b/se	(4) HH +mig con b/se
(Log) HH income + net migrant income	0.169***		0.139***	
	(0.011)		(0.033)	
(Log) HH income + gross migrant income		0.171***		0.106***
		(0.011)		(0.038)
Village-Year FE	Yes	Yes	Yes	Yes
R-squared	0.222	0.207	0.220	0.161
N households	1467	1467	311	306
p value consumption elasticity same		0.859		0.385

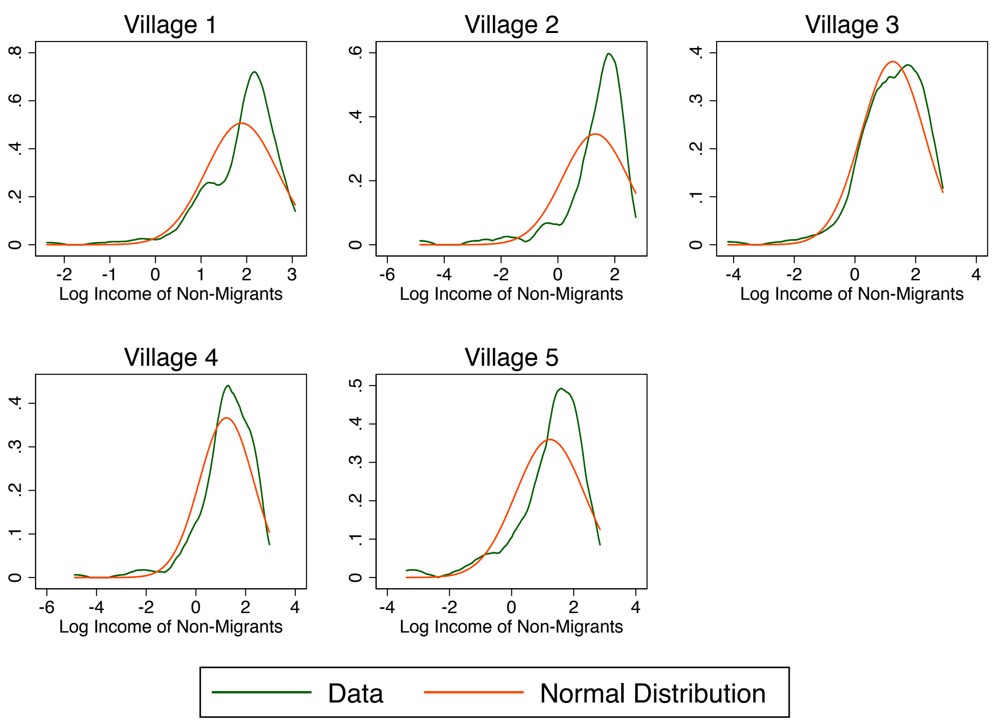
Notes: Net migration income is gross migration income less migration expenses.



Appendix Figure 2: Testing for normality of migration income

D Verifying identification assumptions in the data

This section verifies the two modeling assumptions made on the income distribution; namely that village income follows a (truncated) log-normal distribution, and migration income follows a log-normal distribution. Figure 2 shows a joint skewness-kurtosis test for migration income is only rejected in one of the five villages. Figure 3 overlays a normal distribution with the same mean and standard deviation on top of the observed village income distribution. In general, the distributions look reasonable, with the density of the data having less mass in the left tail than that of the normal distribution, consistent with truncation of the left tail.



Appendix Figure 3: Village income distribution overlaid with normal income distribution

E Is migration income observable?

The paper makes the assumption that the income that households receive is observable by other households, whether the household earns the income in the village or earns the income in the destination. The assumption that household income inside the village is observable is a standard assumption, usually justified by the fact that households can observe each other's plots and crops. However, it seems reasonable to ask whether, even if it the case the village income is perfectly observable, if migration income may be easier to conceal.

One hypothesis is that if migration income is unobserved to villagers, it may be still observed to co-migrants who are in the same destination. In which case, overall migration income for the village as a whole could be more observed if migrants tend to go to the same destination compared to the case where migrants go to several different destinations (of course, there could be other important reasons determining migration destination choice). To investigate further I use observed variation in which destinations migrants from a particular village go to examine correlations with risk sharing behavior. Appendix Table 25 shows there is meaningful variation in the concentration of migration destinations: for example, 87% of all migrants from Aurepalle travel to Hyderabad, while for Kanzara the most common destination, Pune, only has 30% of all trips. I then use this information to look for heterogenous effects on risk sharing by interacting the intensity measure (share of migrants going to the most common destination) with income. The results of this are in Appendix Table 26. Columns (3) and (4) adding in an interaction with the concentration of migration destination and income. The interaction has a small positive, but statistically insignificant, coefficient.

Another important difference between a limited commitment framework and a hidden income framework is which agents are constrained. Under limited commitment, agents with high income want to walk away from the risk sharing agreement, and so agents with high income shocks are those who are constrained. Under hidden income, the constraint that binds is when agents receive low income shocks. Agents need to be appropriately incentivized not to falsely report low income and receive transfers. Consequentially, in hidden income models, agents who report low incomes will optimally be assigned low consumption. If income is able to be observed in the village, but not in the destination, one implication that should hold in the data is that the same income realization is less insured for a migrant than for a non migrant. When I test for the responsive of transfers to income, allowing for an interaction effect of migration and income, I find in fact the opposite: migrants are more insured than non migrants, for the same income shock.

While the two exercises above do not rule out that income is unobservable (and, in reality, it does seem reasonable to think there could be several constraints that affect risk sharing other than limited commitment frictions) both suggest that some of the key correlations that one may expect if the observability of income was a key driver of risk sharing behavior are not present in this context.

Appendix Table 25: Top Migration Destinations, By Village

	(1) Share of trips b	(2) Distance from village b
Aurepalle_Hyderabad	0.87	70.37
Aurepalle_Tukkuguda	0.04	49.29
Aurepalle_Maheshwaram	0.02	50.00
Aurepalle_Rest	0.06	176.04
Dokur_Hyderabad	0.68	124.95
Dokur_Gujarat	0.14	1150.00
Dokur_Maharastra	0.04	538.46
Dokur_Rest	0.14	496.94
Kalman_Pune	0.30	260.77
Kalman_Mumbai	0.16	430.00
Kalman_Solapur	0.16	76.67
Kalman_Rest	0.37	157.89
Kanzara_Murtizapur	0.22	8.43
Kanzara_Akot	0.12	105.00
Kanzara_Amarawati	0.12	69.50
Kanzara_Rest	0.53	199.52
Kinkheda_Surat	0.45	590.14
Kinkheda_Murtizapur	0.13	12.75
Kinkheda_Kanzara	0.10	30.00
Kinkheda_Rest	0.32	290.00
Shirapur_Pune	0.23	210.91
Shirapur_Solapur	0.19	25.88
Shirapur_Mumbai	0.06	373.33
Shirapur_Rest	0.51	122.69

Notes: Top 3 destinations for each village shown, all other destinations are aggregated into category. Distance is distance in km from village.

Appendix Table 26: Test for effect of same migration destination on risk sharing

Dep. variable: Consumption	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Income	0.037**	-0.011	0.020	0.020
	(0.017)	(0.024)	(0.031)	(0.029)
Mean village migration *X* Income		0.271*		0.202
		(0.133)		(0.153)
Max share of migrants to same destination x Income			0.101	0.029
			(0.062)	(0.072)
Village-Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
R-squared	0.687	0.689	0.628	0.629
Number observations	1443	1443	1443	1443

Notes: OLS regressions of log income on log consumption. Standard errors clustered at village-year level for all columns. VLS2 is ICRISAT data 2001-2004. Mean village migration interacts the average village level of temporary migration with individual income.

F Theoretical appendix

F.1 Extending the model from 2 to N agents

The model presented in Section 2 was for two households. Here I show how to extend the model to N agents and then discuss the aggregation issues from solving a N agent games as if there were two households in the village.

F.1.1 Model with N agents

The model easily extends from 2 to N agents. Denote by H the numeraire household in the economy. We can write the model as:

$$V^H(U_s^1, ..., U_s^{H-1}; s) = \max_{\{c_{sjq}^i\}_{\forall i};\{U_{jqr}^i\}_{\forall i \neq H}} \sum_j \sum_q \pi_j \pi_q \left\{ u(c_{sjq}^H) - \mathbb{I}_j^H d + \beta \sum_r \pi_{sr} V^H(U_{qjr}^1, ..., U_{qjr}^{H-1}; r) \right\}$$

$$\text{PK: } \sum_{i \neq H} \lambda^i \left[\sum_j \sum_q \pi_j \pi_q \left(u(c_{sjq}^i) - \mathbb{I}_j^i d + \beta \sum_r \pi_{sr} U_{jqr}^i \right) - U_s^i \right]$$

$$\text{Ex ante IC: } \sum_{i \neq H} \sum_j \sum_q \sum_r \pi_j \pi_q \lambda_i \beta \pi_{sr} \phi_{jqr}^i \left[U_{jqr}^i - \Omega_r^i \right]$$

$$\text{Ex post IC: } \sum_{i \neq H} \sum_j \sum_q \pi_j \pi_q \lambda^i \alpha_{sjq}^i \left[u(c_{sjq}^i) - \mathbb{I}_j^i d + \beta \sum_r \pi_{sr} U_{jqr}^i - \hat{\Omega}_{sjr}^i \right]$$

$$\text{Ex ante IC (H) : } \sum_j \sum_q \sum_r \pi_j \pi_q \beta \pi_{sr} \phi_{jqr}^H \left[V(U_{jqr}^1, ..., U_{jqr}^{H-1}; r) - \Omega_r^H \right]$$

$$\text{Ex post IC (H): } \sum_j \sum_q \pi_j \pi_q \alpha_{sjq}^H \left[u(c_{sjq}^H) - \mathbb{I}_j^H d + \beta \sum_r \pi_{sr} V(U_{jqr}^1, ..., U_{jqr}^{H-1}; r) - \hat{\Omega}_{sjr}^H \right]$$

$$\text{Budget constraint: } \sum_j \sum_q \pi_j \pi_q \gamma_{jq} \left[\sum_i c_{sjq}^i - \sum_i e_{sjq}^i \right]$$

The first order conditions yield:

$$\frac{\partial}{\partial c^H_{sjq}} : \ \pi_j \pi_q u'(c^H_{sjq}) + \pi_j \pi_q \alpha^H_{sjq} u'(c^H_{sjq}) = -\pi_j \pi_q \gamma_{jq}$$

$$\frac{\partial}{\partial c^i_{sjq}} : \ \lambda^i \pi_j \pi_q u'(c^i_{sjq}) + \pi_j \pi_q \alpha^i_{sjq} u'(c^H_{sjq}) = -\pi_j \pi_q \gamma_{jq}$$

$$\frac{\partial}{\partial U^i_{jqr}} : \ \pi_j \pi_q \beta \pi_{sr} V^H_i(U^1_{jqr}, .., U^{H-1}_{jqr}; r) + \lambda^i \pi_j \pi_q \beta \pi_{sr} + \pi_j \pi_q \beta \pi_{sr} \phi^i_{jqr} + \pi_j \pi_q \lambda^i \alpha^i_{sjq} \beta \pi_s$$

$$\text{Envelope} : \ V^H_i(U^1_s, ..., U^{H-1}_s; s) = -\lambda_i$$

Rearranging the FOC yields:

$$\frac{u'(c^H_{sjq})}{u'(c^i_{sjq})} = \lambda^i \frac{1 + \alpha^i_{sjq}}{1 + \alpha^H_{sjq}} \tag{4}$$

$$V^H_i(U^1_{jqr}, .., U^{H-1}_{jqr}; r) = -\lambda^i \frac{(1 + \alpha^i_{sjq} + \phi^i_{jqr})}{(1 + \alpha^H_{sjq} + \phi^H_{jqr})} \tag{5}$$

$$V^H_i(U^1_s, ..., U^{H-1}_s; s) = -\lambda_i \tag{6}$$

F.1.2 Aggregating to a 'rest of village' household

It would be computationally difficult to keep track of N agents in the optimization procedure because it would be necessary to track each additional household's relative Pareto weight and income realization. Instead, I follow Ligon, Thomas and Worrall (2002) and most other empirical applications of the limited commitment model (Laczo (2015)) and construct an aggregated "rest of the village" household. To see this, consider the set of first order conditions that would result from a N person game, where the relative Pareto weight is with respect to household H

$$\frac{u'(c^H_{sjq})}{u'(c^i_{sjq})} = \lambda^i \frac{1 + \alpha^i_{sjq}}{1 + \alpha^H_{sjq}}, \quad \forall i \neq H$$

Then, by CRRA utility

$$\frac{c^i}{c^H} = \left(\lambda^i \frac{1 + \alpha^i_{sjq}}{1 + \alpha^H_{sjq}} \right)^{\frac{1}{\sigma}}$$

And, we can sum over all $i \neq H$

$$\frac{\sum_{i \neq H} c^i}{c^H} = \sum_{i \neq H} \left(\lambda^i \frac{1 + \alpha^i_{sjq}}{1 + \alpha^H_{sjq}} \right)^{\frac{1}{\sigma}}$$

Define the average member of the village, relative to agent H, as $c^{-H} = \frac{1}{N-1} \sum_{i \neq H} c^i$.

$$\frac{c^{-H}_{sjq}}{c^H_{sjq}} = \frac{1}{N-1} \sum_{i \neq H} \left(\lambda^i \frac{1 + \alpha^i_{sjq}}{1 + \alpha^H_{sjq}} \right)^{\frac{1}{\sigma}}$$

Then, let $\lambda^{-H} = \frac{1}{N-1} \sum_{i \neq H} \lambda^{-i}$, and $\alpha^{-H} = \frac{1}{N-1} \sum_{i \neq H} \alpha^{-i}$:

$$\left(\frac{c^{-H}_{sjq}}{c^H_{sjq}} \right)^{\sigma} = \lambda^{-H} \frac{1 + \alpha^{-H}_{sjq}}{1 + \alpha^H_{sjq}}$$

$$\frac{u'(c^H_{sjq})}{u'(c^{-H}_{sjq})} = \lambda^{-H} \frac{1 + \alpha^{-H}_{sjq}}{1 + \alpha^H_{sjq}}$$

That is, the ratio of marginal utilities of the average member of the village excluding household H and household H can be expressed in terms of the relative Pareto weight and the ex post constraints of the rest of the village.

Solving the model with the 2 household approximation assumes that the rest of the village is sharing risk perfectly with each other, and considers imperfect risk sharing between household i and the rest of the village. However, this assumption is not directly used when simulating the economy. Rather, I examine incentive constraints for each household one at a time, and then undertake an iterative process to ensure the economy-wide budget constraint is satisfied.

F.2 Simple model of risk-sharing under limited commitment

This section presents a simplified model of limited commitment risk sharing in order to derive some of the properties of risk-sharing. Consider an economy where the income process is deterministic and alternating. The agent who is currently rich has an income share α^Ω of total resources Y. The income stream for household A is:

$$e^i = \begin{cases} (1-\alpha^\Omega)Y & \text{if odd period} \\ \alpha^\Omega Y & \text{if even period} \end{cases}$$

and vice versa for agent B.

Assume that the two agents have identical initial Pareto weights. In this case, the two state economy will converge to an egodic set where consumption for the rich agent is given by $\alpha^c Y$, for some $\alpha^c \leq \alpha^\Omega$. If perfect risk sharing is not feasible the participation constraint for the agent with the high income realization will bind each period and equilibrium consumption is implicitly defined by the following equation:[39]

$$\sum_{j=0}^{\infty} \beta^j (u((\alpha^c)Y) + \beta u((1-\alpha^c)Y)) = \sum_{j=0}^{\infty} \beta^j (u((\alpha^\Omega)Y) + \beta u((1-\alpha^\Omega)Y))$$
$$u(\alpha^c Y) + \beta u((1-\alpha^c)Y) = u(\alpha^\Omega Y) + \beta u((1-\alpha^\Omega)Y)$$

Agents both discount the future, but also value smooth consumption across time. As a result, the net present value of consuming their income stream for the agent who has the good shock today is a concave function of the variability of income, α^Ω. Depending on the value of the discount factor and the coefficient of relative risk aversion, there will either be no risk sharing, incomplete risk sharing, or perfect risk sharing. This is summarized by the following proposition:

Proposition F.1. *For the two state deterministic economy, given a discount factor β and relative risk aversion γ, there exists a lower bound on the size of the income shock $\underline{\alpha}(\beta,\gamma)$ and an upper bound $\overline{\alpha}(\beta,\gamma)$such that consumption α^c is given by*

$$\alpha^c = \begin{cases} \alpha^\Omega & \textit{if } \alpha^\Omega < \underline{\alpha}(\beta,\gamma) \quad \textit{(Autarky)} \\ \alpha^c(\alpha^\Omega, \beta, \gamma) & \textit{if } \alpha^\Omega \in [\underline{\alpha}(\beta,\gamma), \overline{\alpha}(\beta,\gamma)] \quad \textit{(Imperfect risk sharing)} \\ 0.5 & \textit{if } \alpha^\Omega > \overline{\alpha}(\beta,\gamma) \quad \textit{(Perfect risk sharing)} \end{cases}$$

Further, the partial derivatives of α^c with respect to its arguments are signed as following:

[39] Perfect risk sharing is feasible if $(1+\beta)u(0.5Y) \geq u(\alpha^\Omega Y) + \beta u((1-\alpha^\Omega)Y$.

$\alpha^c_1(\alpha^\Omega, \beta, \gamma) < 0, \alpha^c_2(\alpha^\Omega, \beta, \gamma) < 0$, and $\alpha^c_3(\alpha^\Omega, \beta, \gamma) > 0$.
Proof: The participation constraint for the rich agent is given by:

$$u(\alpha^c Y) + \beta u((1 - \alpha^c)Y) = u(\alpha^\Omega Y) + \beta u((1 - \alpha^\Omega)Y)$$

Assuming CRRA utility, this simplifies to:

$$(\alpha^c)^{1-\sigma} + \beta(1 - \alpha^c)^{1-\sigma} = (\alpha^\Omega)^{1-\sigma} + \beta(1 - \alpha^\Omega)^{1-\sigma}$$

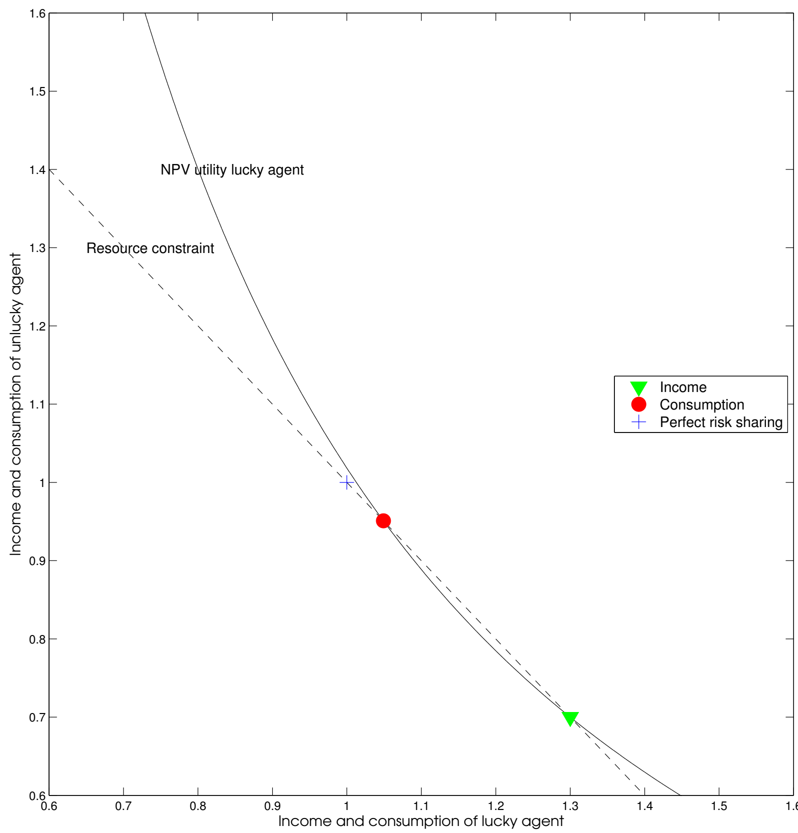
The RHS of the above expression is a concave function of α^Ω. Taking the derivative with respect to α^Ω and rearranging yields that $\underline{\alpha}(\beta, \gamma) = \frac{1}{1+\beta^{1/\gamma}}$. The upper bound where full risk sharing becomes optimal is defined as the $\overline{\alpha}(\beta, \gamma)$ that solves $(1 + \beta)0.5^{1-\gamma} = \overline{\alpha}^{1-\gamma} + \beta(1 - \overline{\alpha})^{1-\gamma}$. Then, by the implicit function theorem, if $\alpha^\Omega \in [\underline{\alpha}, \overline{\alpha}]$, $\alpha^c = f(\alpha^\Omega, \beta, \gamma)$ where $\frac{\partial \alpha^c}{\partial \alpha^\Omega} < 0$ (risk sharing is better, meaning that consumption is closer to 0.5, if income is riskier), $\frac{\partial \alpha^c}{\partial \beta} < 0$ (risk sharing is better if agents are more patient), and $\frac{\partial \alpha^c}{\partial \gamma} > 0$ (risk sharing is worse if agents are more risk averse).

This proposition says that whether perfect risk sharing, imperfect risk sharing, or no risk sharing is observed will depend on the discount rate, the coefficient of risk aversion, and the income process. If imperfect, then risk sharing improves (α^c gets decreases and so consumption becomes more equal across the two agents) if agents are more risk averse or income is riskier (and vice versa).

To give a simple numerical example, consider the case where agents have log utility, total resources in the economy are equal to 2, the discount factor is 0.7, the lucky agent receives 1.3 and the unlucky agent receives 0.7. Appendix Figure 4 shows the indifference condition for the lucky agent and the resulting risk-sharing equilibrium in the economy. The initial risk-sharing equilibrium is the bundle $\{1.05, 0.95\}$ (the lucky agent consumes 53% of total resources), compared with the autarkic bundle $\{1.3, 0.7\}$ (the lucky agent receives 65% of total income in the economy).

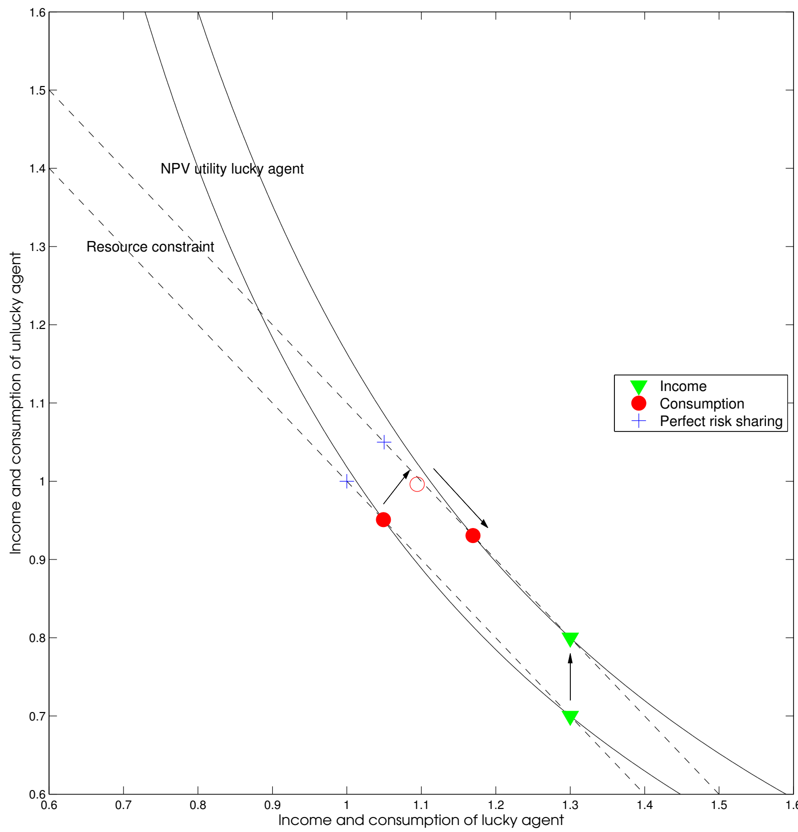
Now consider that there is a migration income opportunity that would pay 0.8. This changes the income process from the bundle $\{1.3, 0.7\}$ to the bundle $\{1.3, 0.8\}$. Appendix Figure 5 shows how this changes the incentive compatibility constraint of the lucky agent. Note that although the lucky agent doesn't migrate when lucky, the option to migrate still increases the value of autarky because it increases the autarkic value when unlucky. This is shown in the figure. The former division of resources is no longer incentive compatible: instead of consuming 52% of total resources, the new risk-sharing equilibrium is the bundle $\{1.2, 0.9\}$, with the lucky agent consuming 57% of total resources.

The overall effect on welfare is shown in Appendix 6. The figure shows the two offsetting effects on welfare from introducing migration. First, total resources increase, which increases welfare. Second, risk-sharing worsens, which decreases welfare. The net effect of migration in this case is positive overall.



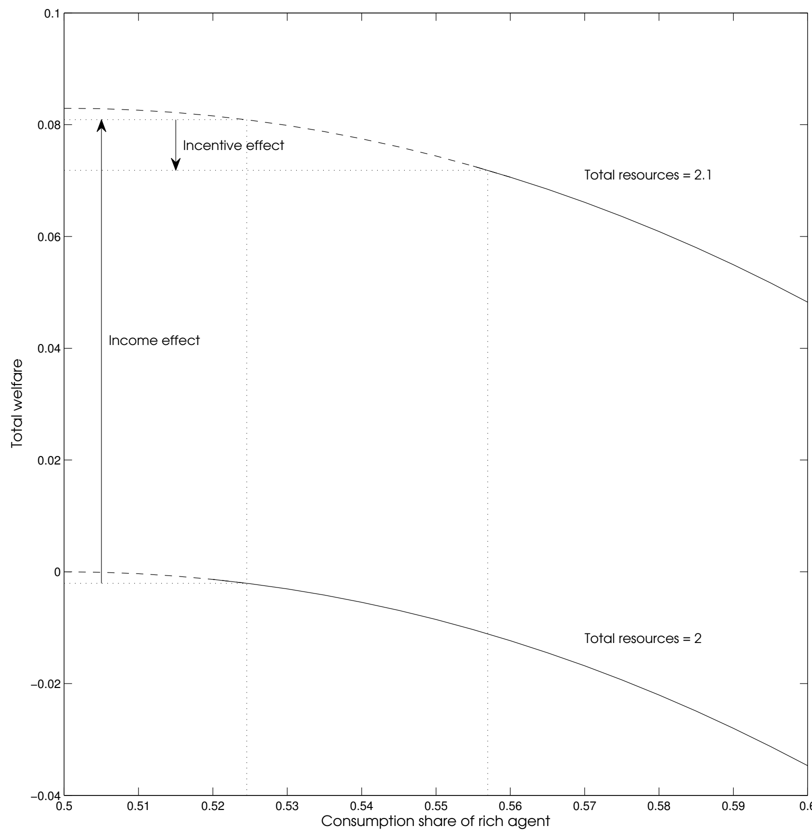
Appendix Figure 4: Incentive compatibility constraint of lucky agent

Notes: The dashed line shows the resource constraint (total resources are equal to 2, to be split between the lucky and unlucky agent). The solid line is the indifference curve over combinations of consumption for the lucky agent that give the same utility as autarky. The autarkic bundle, $\{1.3, 0.7\}$ is illustrated by the green income point. The lucky agent is indifferent between autarky and the bundle $\{1.05, 0.95\}$. This second bundle is the risk-sharing equilibrium, illustrated by the red consumption point.



Appendix Figure 5: Incentive compatibility constraint of lucky agent with migration

Notes: The dashed line shows change in the resource constraint (total resources are equal to 2.1, to be split between the lucky and unlucky agent). The solid line shows the change in the indifference curve over combinations of consumption for the lucky agent that give the same utility as autarky. The new autarkic bundle, $\{1.3, 0.8\}$ is illustrated by the green income point. The lucky agent is indifferent between autarky and the bundle $\{1.2, 0.9\}$. This second bundle is the risk-sharing equilibrium, illustrated by the red consumption point.



Appendix Figure 6: Effect on welfare of introducing migration

Notes: The figure shows the effect on total welfare from introducing migration. The first change, the income effect, shows the effect of increasing total resources from 2 to 2.1. The second change, the incentive effect, shows the result of the endogenous change in risk-sharing from a sharing rule of 52% of total resources for the lucky agent to a sharing rule of 57% of total resources for the lucky agent.

Appendix Table 27: Comparison of discrete approximation to continuum

	Continuum	Discrete			
	(1)	(2)	(3)	(4)	(5)
		4 HH	10 HH	30 HH	50 HH
Mean income	1.500	1.500	1.500	1.500	1.500
Mean consumption	1.500	1.500	1.500	1.500	1.500
Min consumption	1.073	1.099	1.099	1.099	1.099
Max consumption	1.765	1.807	1.790	1.694	1.631
Standard deviation consumption	0.160	0.315	0.301	0.222	0.163
Correlation income, consumption	0.808	0.976	0.964	0.876	0.806
Risk sharing beta	0.324	0.767	0.726	0.486	0.328

Notes: Table compares the limited commitment solution calculated two different methods.

G Computational appendix

This computational appendix discusses the accuracy of the discrete approximation and provides details on the algorithms used to solve the model.

G.1 Accuracy of the discrete approximation

It is possible to check the accuracy of the approximation method against an alternative method of assuming that there are a continuum of agents and solving the limited commitment model and comparing the simulated distributions of consumption. The following section does this. I do this for the case of the standard limited commitment model. It is necessary to shut down aggregate shocks to solve the continuum model because of the standard problem that the total resources will be an infinitely-dimensioned object. I use the algorithm for the continuum case outlined in Krueger and Perri (2010). Table 27 compares the two solution methods, solved for both the continuum and the discrete case. The number of households represents how many households are averaged to construct the "rest of the village" household. The correlation between the solution found in the continuum and discrete case is high.

G.2 Algorithm to solve the limited commitment problem

This section documents algorithm to find the state-specific before-migration intervals for the Pareto weight $[\underline{\lambda}_s, \overline{\lambda}_s] \forall s$, the after-migration intervals for the Pareto weights $[\underline{\hat{\lambda}}_{sqj}, \overline{\hat{\lambda}}_{sqj}], \forall s, \forall q, \forall j$ and the migration rule $\mathbb{I}(s, \lambda)$.

The algorithm is solved in two steps. The complete details follow this summary.

1. Solve the limited commitment algorithm for 2 households (household A and the "rest of the village" household) to find the before-migration intervals $[\underline{\lambda}_s, \overline{\lambda}_s] \forall s$, and the after-migration intervals $[\underline{\hat{\lambda}}_{sqj}, \overline{\hat{\lambda}}_{sqj}], \forall s, \forall q, \forall j$ and the migration rule $\mathbb{I}(s, \lambda)$. In this step, the fixed point of the migration decision (which determines the total resources available to the network) is found.
    (a) Guess an initial migration rule $\mathbb{I}_0(s, \lambda)$. Using this migration rule, construct the total resources available to the network.
    (b) Then, given these total resources, solve the after-migration allocation problem to find the constrained efficient level of transfers.
    (c) Then, solve the before-migration decision to find the optimal migration decision, $\mathbb{I}_1(s, \lambda)$ satisfying the before-migration participation constraint.
    (d) Complete Steps (a)-(c) until a fixed point of the migration decision is found.
2. Once the fixed point of the problem is found, use the lower bounds of the computed ex ante and after-migration intervals to compute a transition matrix between ex ante and ex post states and the invariant distribution over income and earnings. The Pareto weights of constrained agents are pinned down by the lower bound of the interval. The Pareto weights of unconstrained agents are updated to be the previous Pareto weight rescaled by state-specific factors β_s such that all agents have their participation constraint satisfied. In this step, the values of β_s such that market clearing occurs are found for each value of the state.

(a) Guess an initial rescaling factor for each state, β_s^0, $\forall s$.[40]

(b) For each grid point $(s, \hat{\lambda}, q, j)$ compute the after-migration Pareto weight for each possible ex post state of the world. This will be the lower bound of the interval if the participation constraint is binding. If the participation constraint is not binding this will be the current value of the Pareto weight, multiplied by an economy-wide scalar.

$$\hat{\lambda}_0(s, \lambda, q, j) = \max[\underline{\lambda}_{sqj}, \beta_s^0 \lambda]$$

(c) Now compute the before-migration Pareto weight for the following period. This will be the lower bound of the relevant interval if the participation constraint is binding. If the participation constraint is not binding this will be the current value of the after-migration Pareto weight.

$$\lambda_1(q, j, r) = \max[\underline{\lambda}_r, \hat{\lambda}_0(s, q, j)]$$

(d) Construct the transition matrices $Q_{\text{b-mig,a-mig}} : (s \times \lambda) \times (s \times \lambda \times q \times j) \to [0, 1]$ and $Q_{\text{a-mig,b-mig}} : (s \times \hat{\lambda} \times q \times j) \times (r \times \lambda') \to [0, 1]$. Using these transition matrices, find the invariant distribution of agents over the ex post states $\hat{\phi}(s, \hat{\lambda}, q, j)$.

(e) Compute aggregate net demand in the economy. Iterate on β_s until the budget constraint is satisfied for each state of the world.

The model presented in the text followed the notation of Ligon et al. (2002) and presented the problem in terms of a social planner's value function where the state variable was the expected utility for the household. When computing the model it is more straightforward to work directly with a value function for each agent; as Marcet and Marimon (2011) have shown the two formulations of the problem are equivalent.

G.2.1 Step 1: Find the Pareto intervals

Define the following, all computed recursively:

[40] Because a binding participation constraint in either the before-migration or after-migration problem resets the Pareto weight it is only necessary to search for one economy-wide scaling factor, not two separate factors.

- The before-migration participation constraint

$$\Omega^i_{\text{before-migration}}(s) = \max\{u(e^i(s)), \mathrm{E}u(m^i(q)) - d\} + \beta \mathrm{E}\Omega^i_{\text{before-migration}}(s')$$

- The after-migration participation constraint

$$\Omega^i_{\text{after-migration}}(s, q, \mathbb{I}^i) = \mathbb{I}^i u(m^i(q)) + (1 - \mathbb{I}^i)u(e^i(s)) + \beta \mathrm{E}\Omega^i_{\text{before-migration}}(s')$$

- First-best risk-sharing (no migration)

$$V^i_{\text{first-best}}(s) = u(\frac{e^A(s) + e^B(s)}{2}) + V^i_{\text{first-best}}(s)$$

1. Construct an before-migration grid over the state of the world and the Pareto weight (s, λ) and an after-migration grid over the village state of the world, the ex post Pareto weight, the migration state of the world, and the migration outcome $(s, \hat{\lambda}, q, j)$.

2. Construct an initial guess for the value of before-migration utility for agent A, $V^A_0(s, \lambda)$ and the utility of agent B, $V^B_0(s, \lambda)$. A good initial guess is to take the max of perfect risk sharing and autarky.

3. Guess an initial migration rule, $\mathbb{I}_0(s, \lambda)$.

4. Compute the total resources for the economy, taking into account the expected level of migration.

5. For each after-migration grid point (s_i, λ_j, q_k, j).

   (a) Construct the sub-value function if agent A does not migrate ($j = 0$):

   $$\hat{V}^A_0(s_i, \lambda_j, q_k, 0) = u(c^A(s_i, \lambda_j)) + \beta \sum_r \pi_{sr} V^A_0(r, \lambda_j)$$

   (b) Construct the sub-value function if agent A migrates ($j = 1$):

   $$\hat{V}^A_0(s_i, \lambda_j, q_k, 1) = u(c^A(s_i, \lambda_j, q_k)) - \mathbb{I}d + \beta \sum_r \pi_{sr} V^A_0(r, \lambda_j)$$

   (c) Construct the same values for agent B. Note we only consider the migration decision for agent A because B is the rest-of-village household; the average migration rate will be captured through the total resources available to the network.

$$\hat{V}_0^B(s_i, \lambda_j, q_k, 0) = u(c^B(s_i, \lambda_j)) + \beta \sum_r \pi_{sr} V_0^B(r, \lambda_j)$$
$$\hat{V}_0^B(s_i, \lambda_j, q_k, 1) = u(c^B(s_i, \lambda_j, q_k)) + \beta \sum_r \pi_{sr} V_0^B(r, \lambda_j)$$

(d) For each of the q migration outcomes find the intervals that satisfy both agents' after-migration participation constraints if A migrates:

$$\underline{\hat{\lambda}}_{s,q,1} := \hat{V}_0^A(\lambda^*, q, 1) = \hat{\Omega}^A(s, q, \mathbb{I})$$
$$\overline{\hat{\lambda}}_{s,q,1} := \hat{V}_0^B(\lambda^*, q, 1) = \hat{\Omega}^B(s, q)$$

(e) Find the intervals that satisfy both agents' after-migration participation constraints if A does not migrate):

$$\underline{\hat{\lambda}}_{s,q,0} := \hat{V}_0^A(\lambda^*, 0) = \hat{\Omega}^A(s)$$

$$\overline{\hat{\lambda}}_{s,q,0} := \hat{V}_0^B(\lambda^*, 0) = \hat{\Omega}^B(s)$$

(f) For values of $\hat{\lambda} \notin [\underline{\hat{\lambda}}_{sqj}, \overline{\hat{\lambda}}_{sqj}]$, $\forall s, \forall q, \forall j$ replace the value function with the value of after-migration autarky for *both* agent A and B.

6. For each before-migration grid point (s_i, λ_j).

(a) Construct the total expected utility of agent A and B if agent A migrates:

$$\hat{V}(s_i, \lambda_j, 1) = \sum_k \pi_{q_k}^m \hat{V}_0^A(s_i, \lambda_j, q_k, 1) + \sum_k \pi_{q_k}^m \hat{V}_0^B(s_i, \lambda_j, q_k, 1)$$

(b) Construct the total expected utility of agent A and B if agent A does not migrate:[41]

$$\hat{V}(s_i, \lambda_j, 0) = \sum_k \pi_{q_k}^m \hat{V}_0^A(s_i, \lambda_j, q_k, 0) + \sum_k \pi_{q_k}^m \hat{V}_0^B(s_i, \lambda_j, q_k, 0)$$

[41] The expectation does not depend on value of q, but it is defined over the same grid for completeness.

(c) Now construct the migration vector. We use a smoothed version of the discrete choice with smoothing parameter κ. As $\kappa \to 0$ this collapses to the discrete choice rule:

$$\mathbb{I}_1(s_i, \lambda_j) = \frac{\exp(\hat{V}(s_i, \lambda_j, 1)/\kappa)}{\exp(\hat{V}(s_i, \lambda_j, 0)/\kappa) + \exp(\hat{V}(s_i, \lambda_j, 1)/\kappa)}$$

(d) Update the before-migration value functions

$$V_1^A(s_i, \lambda_j) = \mathbb{I}(s_i, \lambda_j) \sum_k \pi_{q_k}^m \hat{V}_0^A(s_i, \lambda_j, q_k, 1) + (1 - \mathbb{I}(s_i, \lambda_j)) \sum_k \pi_{q_k}^m \hat{V}_0^A(s_i, \lambda_j, q_k, 0)$$
$$V_1^B(s_i, \lambda_j) = \mathbb{I}(s_i, \lambda_j) \sum_k \pi_{q_k}^m \hat{V}_0^B(s_i, \lambda_j, q_k, 1) + (1 - \mathbb{I}(s_i, \lambda_j)) \sum_k \pi_{q_k}^m \hat{V}_0^B(s_i, \lambda_j, q_k, 0)$$

(e) Find the before-migration interval $[\underline{\lambda}_s, \overline{\lambda}_s]$ that satisfy both agents' before-migration participation constraint:

$$\underline{\lambda}_s := V_1^A(\lambda^*; s) = \Omega^A(s)$$
$$\overline{\lambda}_s := V_1^B(\lambda^*; s) = \Omega^B(s)$$

(f) For values of $\lambda \notin [\underline{\lambda}_s, \overline{\lambda}_s]$, replace the exante-value function with the value of before-migration autarky for *both* agent A and B.

7. Compare $\{V_1^A(s, \lambda), V_1^B(s, \lambda)\}$ with $\{V_0^A(s, \lambda), V_0^B(s, \lambda)\}$. Repeat Steps 5 to 6 until convergence.

8. Compare $\mathbb{I}_1(s, \lambda)$ with $\mathbb{I}_0(s, \lambda)$. Repeat Steps 4 to 6 until convergence.

G.2.2 Step 2: Find the transition matrices

Once the ex ante intervals $[\underline{\lambda}_s, \overline{\lambda}_s] \forall s$, the after-migration intervals $[\underline{\hat{\lambda}}_{sqj}, \overline{\hat{\lambda}}_{sqj}]$, $\forall s, \forall q, \forall j$ and the migration rule $\mathbb{I}(s, \lambda)$ have been constructed, this step finds the transition matrices that are used to simulate the economy. Additionally we find state-dependent ex post scalars β_s to ensure that the economy-wide budget constraint (that total consumption is equal to total earnings, including earnings from migration) is satisfied for each point in time.

1. Start with a guess for each β_s e.g. $\beta_s = 1, \forall s$

2. For each grid point on the ex post grid (s_i, λ_j, q_k, j)

(a) Compute the updating rule for the Pareto weight. This will be the lower bound of the interval if the participation constraint is binding. If the participation constraint is not binding this will be the current value of the Pareto weight, multiplied by an economy-wide scalar.

$$\hat{\lambda}(s_i, \lambda_j, q_k, j) = \max[\underline{\lambda}_{sqj}, \beta_s \lambda_j]$$

(b) Find the two neighboring points λ_l, λ_h on the grid for λ such that $\hat{\lambda}(s_i, \lambda_j, q_k, j) = x\lambda_l + (1-x)\lambda_h$

(c) Define a transition matrix between before-migration and after-migration within the period

$$Q_{\text{b-mig,a-mig}} : (s \times \lambda) \times (s \times \lambda \times q \times j) \to [0,1]$$

as

$$Q_{\text{b-mig,a-mig}}((s_i, \lambda_j), (s_i, \lambda_j, q_k, j)) = \begin{cases} \pi^m(q_k)\pi^{\mathbb{I}}(j)x & \text{if } \hat{\lambda} = \lambda_l \\ \pi^m(q_k)\pi^{\mathbb{I}}(j)(1-x) & \text{if } \hat{\lambda} = \lambda_h \\ 0 & \text{otherwise} \end{cases}$$

$$\lambda_1(s_i, \lambda_j, q_k, j) = \max[\underline{\lambda}_{s_i}, \hat{\lambda}(s_i, \lambda_j, q_k, j)]$$

(d) Find the two neighboring points λ_l, λ_h on the grid for λ such that $\lambda_1(s_i, \lambda_j, q_k, j) = x\lambda_l + (1-x)\lambda_h$

(e) Define a transition matrix between the current after-migration and tomorrow's before-migration state:

$$Q_{\text{a-mig,b-mig}} : (s \times \hat{\lambda} \times q \times j) \times (s' \times \lambda') \to [0,1]$$

as

$$Q_{\text{a-mig,b-mig}}((s, \hat{\lambda}, q, j), (s', \lambda')) = \begin{cases} \pi^e(s_i)x & \text{if } \lambda' = \lambda_l \\ \pi^e(s_i)(1-x) & \text{if } \lambda' = \lambda_h \\ 0 & \text{otherwise} \end{cases}$$

3. Construct the full transition matrix Q. This matrix has dimension $(N_S, N_\lambda) \times (N_S, N_\lambda)$

$$Q : (s, \lambda) \times (r \times \lambda') \to [0,1] = Q_{\text{b-mig,a-mig}}((s, \lambda), (s, \hat{\lambda}, q, j)) \times Q_{\text{a-mig,b-mig}}((s, \hat{\lambda}, q, j), (r, \lambda'))$$

4. Then solve the matrix equation

$$\phi = Q^T \phi$$

where $\phi(s, \lambda)$ gives the steady state probability of being in state (s, λ).

5. Using $\phi(s, \lambda)$ compute the steady state ex post probability of being in state $\hat{\phi}(s, \hat{\lambda}, q, j) = Q^T_{\text{b-mig,a-mig}} \phi(s, \lambda)$

6. Compute the excess demand function

$$d(\beta_s) = \sum_{(s,\hat{\lambda},q,j) \in (N_S, N_\lambda, N_q, N_j)} \left(c(s, \hat{\lambda}, q, j) - e(s, \hat{\lambda}, q, j) - m(s, \hat{\lambda}, q, j) \right) \hat{\phi}(s, \hat{\lambda}, q, j)$$

7. Repeat Steps 2 to 6 and use a Newton procedure to find β_s such that $d(\beta_s) = 0$ so that market clearing is satisfied.