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 the change in income and the change 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) risk sharing reduces migration by 60%; (2) migration reduces risk sharing by 23%; (3) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain from migration is 7% lower. Third, I introduce a rural employment scheme. The policy reduces migration and decreases risk sharing. The welfare gain of the policy is 50-65% lower after household risk sharing and migration responses are considered.

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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, informal risk sharing is not the only option available to households who wish to smooth their income shocks. Households can also migrate temporarily. Temporary migration is both common and economically important. In rural India, 20% of households have at least one temporary migrant, with migration income representing 50% of total income for these households. The possibility of migration offers a form of self-insurance, hence may fundamentally change the incentives for households of participating in informal risk sharing. At the same time, informal risk sharing provides insurance against income shocks, altering the returns to migrating. In order to appropriately understand the benefits of migration, and to think about policies to 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 due to income differentials (Sjaastad, 1962; Harris and Todaro, 1970), and risk sharing with limited commitment frictions (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002). First, I characterize the model and develop comprehensive comparative statics with respect to migration, risk sharing and welfare. 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 the change in income and the change in the endogenous structure of the insurance market. I then show how risk sharing alters the returns to migration and determines the migration decision. 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). In order to match observed migration behavior, I allow for heterogeneity by landholdings and household composition. The quantitative results are as follows: (1) migration reduces risk sharing by 23%; (2) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain in welfare from migration is 7% lower; (3) risk sharing reduces migration by 60%. Third, I show that the joint determination of risk sharing and migration of the household may have key policy implications. I simulate a rural employment scheme (similar to the Indian Government's 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 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 50-65% lower after household risk sharing and migration responses are considered.

I derive three theoretical results linking migration, risk sharing and welfare. First, I show the channels through which migration may decrease 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 insurance is constrained by the fact that households can walk away from any agreement (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002; Alvarez and Jermann, 2000). The outside option (the value of consuming the autarkic income stream) is the key determinant of risk sharing. I show migration has two effects on risk sharing. On one hand, the ability to migrate increases the outside option of households and decreases risk sharing. On the other hand, migration allows the network to smooth the impact of aggregate shocks, increasing risk sharing. This result explores a similar channel to other studies examining how informal insurance adjusts to changes in households' outside option, including public insurance schemes (Attanasio and Rios-Rull, 2000; Albarran and Attanasio, 2002, 2003; Golosov and Tsyvinski, 2007; Krueger and Perri, 2010), unemployment insurance (Thomas and Worrall, 2007), and options to save (Thomas, Worrall and Ligon, 2000).

Second, I show that the welfare effect of migration can be decomposed into the change in income and the change in the endogenous structure of the insurance market. Welfare depends on total resources available to the network and the allocation of resources between members (intuitively, on the "size" and "slices" of the economic pie). To decompose the welfare effect I contrast a model with *endogenously* incomplete markets to a model with *exogenously* incomplete markets. When markets are exogenously incomplete, migration does not alter the structure of the insurance market. However, when markets are endogenously incomplete, migration directly alters the structure of insurance. Specifically, I consider a model where households can borrow and save a risk-free asset (Deaton (1991); Aiyagari (1994); Huggett (1993)). I use the comparison between endogenously and exogenously incomplete markets to decompose the net welfare effect of migration into an income and a risk sharing effect (similar to the exercise in Golosov and Tsyvinski (2007)).

Third, I show how risk sharing alters the returns to migration, and determines the migration decision. 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 are part of a risk sharing agreement, the relevant comparison is post-transfer, rather than gross, income differentials. As a result, risk sharing has two effects on migration. Households who migrate are the households who have bad income shocks. These households would be net recipients of risk sharing transfers in the village. Risk sharing reduces the income gain between the village and city and decreases migration. On the other hand, migration is risky (Harris and Todaro, 1970; Bryan, Chowdhury and Mobarak, 2013; Tunali, 2000). Risk sharing can insure the risky migration outcome, facilitating migration.

I apply the model to the empirical setting of rural India, where temporary migration is both common and economically important. I use the new wave of the ICRISAT household panel, covering the years 2001-2004. In these data, 20% of households have at least one temporary migrant, and for these households, migration income is half their total income.[1] I establish four empirical facts relating migration to risk sharing in these data.

[1]Other household surveys in India find widespread temporary migration of up to 50% (Rogaly and Rafique, 2003; Banerjee and Duflo, 2007). For a detailed case study of patterns of labor migration in India, see Breman (1996). For 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 (2013) (Bangladesh).

First, migration responds to exogenous income shocks. When the 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. 40% of households migrate at least once during the sample. However, on average, a migrant household only migrates half the time. This is consistent with households migrating in response to income shocks, rather than migration being a permanent strategy. Third, risk sharing is imperfect, and is worse in villages where temporary migration is more common. This is consistent with an interaction between informal risk sharing and migration. Fourth, although a household increases their income by 30% during the years they send a migrant, total expenditure (consumption and change in asset position) only increases by 85% of the increase in income. This last fact is consistent with the migrant making transfers back to the network.

The most important feature of the model is the joint determination of migration and risk sharing. To investigate this joint determination, I structurally estimate the model using simulated method of moments. I allow for heterogeneity by landholdings and household composition in the estimation. The quantitative results are as follows:

Effect of migration on risk sharing: Theoretically, I show that migration has offsetting effects on risk sharing. The option to migrate increases the outside option of households and decreases risk sharing. At the same time, migration allows the network to smooth aggregate shocks, increasing risk sharing. Within the structural model, I estimate the net effect of introducing migration to be a 23% reduction in risk sharing.

Decomposition of the welfare effect of migration: Welfare depends on the total resources available to the network and the distribution of resources between members. I estimate that the net welfare effect of migration is equivalent to an 19.5% increase in consumption. Households with low endowments (low landholdings) particularly benefit from migration due to the increase in total income in the village. To decompose the welfare effect into an income and a risk sharing component, I contrast endogenously incomplete markets to exogenously incomplete markets. The welfare gain from migration is 7% lower when markets are endogenously incomplete.

Effect of risk sharing on migration: When risk sharing is possible, the migration decision depends upon post-transfer income differentials between the village and city. Theoretically, I show that risk sharing can either increase or decrease migration. Within the structural model, I estimate the net effect of risk sharing is to reduce migration by 60%.

The joint determination of risk sharing and migration of the household has key implications for policy. To illustrate, I simulate the India Government's National Rural Employment Guarantee Act, the largest public works program in the world. This policy provides a guarantee of 100 days of employment to every rural household. I model the scheme as an income floor in the village. Households respond to the policy by adjusting both migration and risk sharing. First, income in the village increases, reducing migration. Second, the policy provides insurance against bad income shocks, reducing informal insurance. I show the welfare benefits of this policy are substantially overstated if the joint responses of migration and risk sharing are not taken into account. The welfare gain of the policy is 50-65% lower after household risk sharing and migration responses are considered.

An important piece of the analysis is the focus on temporary migration. Because migration is temporary, I assume households remain part of the risk sharing network if they migrate. This differs to the case of permanent migration, where households permanently leave the village and exit the risk sharing network if they migrate (Banerjee and Newman, 1998; Munshi and Rosenzweig, 2009). Temporary migration is an especially appropriate focus for the case of rural India, where permanent migration is very low (Munshi and Rosenzweig, 2009; Topalova, 2010), but temporary migration is widespread. Because migrants remain in the risk sharing network, a key contribution of this paper is to quantify how the risk sharing network adjusts to migration. As a result, the model predicts that migration will affect the entire network, not only those households who migrate.

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 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. I assume that all households have identical preferences, and households cannot borrow or save in autarky.[2] In each period t the village experiences one of finitely many events s_t. The village event determines the endowment of each household in the village, $e^i(s_t)$. Denote by $s^t = (s_0, ..., s_t)$ the history of events up to and including period t. The probability, as of period 0, of any particular history s^t is $\pi(s^t)$.

Temporary migration is the choice to migrate away from the village for one period. Temporary migration is modeled as a binary decision by the household. A household has several members, and in period t the household choses to either send no migrants, or to send at least one migrant.[3] In period t the migration destination experiences also one of finitely many events q_t. The destination event is only observed after the migration decision has been made, and determines the migration income for household i if they migrate, $m^i(q_t)$. Assume that the probability of migration event q_t is independent of the village event, and is independent across time, $\pi(q_t = q) = \pi(q), \forall t$.

The maximization problem is to choose migration and consumption. The timing in the model is as follows. Households observe their endowment in the village (state s), and decide whether to send a temporary migrant to the city. If a household sends out a migrant, they then realize their migration income (state q), and pay a utility cost d, which captures both the physical costs (for example, costs of transportation) and the psychic costs (for example, being away from friends and family) of migration (Sjaastad, 1962).[4]

[2]Including savings would introduce an additional state variable into the maximization problem. In the data, I find that savings are small (on average, financial assets are negative, and equal to 9% of annual consumption). Looking within a household, I do not see any significant response of savings to migration. I therefore abstract from capital accumulation to highlight the main mechanism of interest, the interaction between migration and risk sharing. I assume that households have identical preferences. For papers that analyze risk sharing when preferences are heterogeneous, see Mazzocco and Saini (2007); Chiappori, Samphantharak, Schulhofer-Wohl and Townsend (2011) and Schulhofer-Wohl (2011).

[3]The unit of analysis is the household. Each household has several members. If the household chooses to migrate, then at least one household member leaves the village temporarily. I assume that within the household risk sharing is Pareto efficient. For studies examining migration with intra-household incentive constraints, see Chen (2006); Gemici (2011); Chen and Hassan (2012).

[4]Assuming a utility cost from migrating is common in the literature. Such utility cost can easily explain why American Samoans, legal residents of the United States, choose to live in America Samoa where per capita income is \$8,000, instead of legally migrating to Hawa'ii where per capita income is \$21,000.

Once all income is realized, households make or receive risk sharing transfers, and consumption occurs. At the end of the period the migrant returns back to the village. The same problem is faced the following period.

2.1 Migration and risk sharing under perfect risk sharing

We first present the optimization problem under perfect risk sharing. The date-zero problem can be written as choosing consumption c_t^i and migration $\mathbb{I}_t^i \in \{0,1\}$ for each household $i = A, B$ to maximize total utility:

$$\max_{(c_t^i, \mathbb{I}_t^i)_{i=1,2}} \sum_{t=0}^{\infty} \sum_{s^t} \sum_{q} \beta^t \pi(s^t)\pi(q) \Big\{ \lambda_A [u(c_t^A(s^t, q_t, \mathbb{I}_t)) - \mathbb{I}_t^A(s^t)d] + \lambda_B [u(c_t^B(s^t, q_t, \mathbb{I}_t) - \mathbb{I}_t^B(s^t)d] \Big\} \tag{1}$$

where $\mathbb{I}_t = \{\mathbb{I}_t^A, \mathbb{I}_t^B\}$. Let $m^i(q_t)$ denote i's migration income if they migrate and the outcome is q_t, and $e^i(s^t)$ denote i's endowment income in the village. Total resources in the economy, $Y(s^t, q_t, \mathbb{I}_t)$, depend on the state of the world in the village, the migration decision, and the state of the world in the migration destination:

$$Y(s^t, q_t, \mathbb{I}_t) = \mathbb{I}_t^A m^A(q_t) + (1 - \mathbb{I}_t^A)e^A(s^t) + \mathbb{I}_t^B m^B(q_t) + (1 - \mathbb{I}_t^A)e^B(s^t) \tag{2}$$

The first order conditions for consumption yield the familiar result that the ratio of marginal utilities between the two households are constant:

$$\frac{u'(c_t^A(s^t, q_t, \mathbb{I}_t))}{u'(c_t^B(s^t, q^t, \mathbb{I}^t))} = \frac{\lambda^B}{\lambda^A}, \forall s^t, q_t, \mathbb{I}_t \tag{3}$$

2.2 Migration and risk sharing under limited commitment constraints

We now introduce limited commitment constraints to the above model. The key mechanism in the limited commitment model is the value of walking away and consuming the endowment stream (termed the "outside option") (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002).[5] The opportunity to migrate means households can choose to migrate

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

after observing their village income. Migration therefore weakly increases the outside option of households, and will endogenously affect insurance.

The timing in the model is as above. Households migrate after observing the income in the village, but before realizing the income in the city. Transfers are made once migration decisions and migration income are realized. If a household migrates, they remain part of the risk-sharing network. However, because migration affects the outside option of households, the amount of insurance endogenously responds to the option to migrate. I solve for the migration and transfer decisions that maximize total utility of all households in the village, subject to a set of incentive compatibility constraints.[6]

There are two incentive compatibility constraints that need to be satisfied, which match the two points in time when households may want to walk away from any risk sharing agreement. The first constraint is at the time migration decisions are made. Migration decisions are made ex ante of the realization of the migration state, so it must be the case that in expectation the utility from staying in the risk sharing network is at least as high as the expected value of autarky. The second constraint is at the time transfer decisions are made. Transfer decisions are made ex post of the realization of the migration state, so are a function of the migration state in addition to the state of the world in the village. It must be the case that once all income is revealed this period, utility from staying in the risk sharing network is at least as high as the utility from autarky. Conditional upon receiving at least the same utility as its outside option at both points in time, neither household has an incentive to deviate either by changing the amount it transfers, or from the prescribed migration decision.

To be precise, define the outside option at both points in time as follows (for ease of exposition, ex post variables will be denoted with a "˜" superscript). Ex-ante autarky is the value of deciding whether or not to migrate today, only knowing the state of the

[6] I solve for the constrained efficient allocation. Alvarez and Jermann (2000) show how to decentralize the limited commitment problem with endogenous solvency constraints; Abraham and Carceles-Poveda (2006) extend this result to the case of limited commitment with capital accumulation. I leave the decentralization of the model of limited commitment with migration to further research.

world in the village (s), and then facing the same choice in the future:

$$\Omega^i(s^t) = \sum_{r=t}^{\infty} \sum_{s^r} \beta^{r-t} \pi(s^r|s^t) \max \left\{ u(e^i(s^r)), \sum_q \pi(q) u(m^i(q_r)) - d \right\}$$

Ex-post autarky is the value of consuming period t income, conditional on the migration choice ($\mathbb{I}$), the state in the village (s) and the state in the destination (q), and then facing the ex-ante decision problem from period $t+1$.

$$\tilde{\Omega}^i(s^t, q_t, \mathbb{I}_t) = u(\underbrace{\mathbb{I}_t^i m^i(q_t) + (1 - \mathbb{I}_t^i) e^i(s^t)}_{\text{Income for household } i \text{ in period } t}) - \mathbb{I}_t^i d + \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \Omega(s^{t+1})$$

We now define the continuation utility of remaining part of the risk sharing network. The ex-post continuation value is given by the utility of consumption today and the future expected value of consumption:

$$\tilde{U}(s^t, q_t, \mathbb{I}_t) = u(c_t^i(s^t, q_t, \mathbb{I}_t)) - \mathbb{I}_t^i d + \sum_{r=t+1}^{\infty} \sum_{s^r} \sum_q \beta^{r-t} \pi(s^r|s^t) \pi(q) [u(c_r^i(s^r, q_r, \mathbb{I}_r)) - \mathbb{I}_r^i(s^r) d]$$

The ex-ante continuation value is the expectation over the migration outcome this period, and the future expected value of consumption :

$$U(s^t, \mathbb{I}_t) = \sum_{r=t}^{\infty} \sum_{s^r} \sum_q \beta^{r-t} \pi(s^r|s^t) \pi(q) [u(c_r^i(s^r, q_r, \mathbb{I}_r)) - \mathbb{I}_r^i d$$

$$U(s^t, \mathbb{I}_t) = \sum_q \pi(q) \tilde{U}^i(s^t, q_t, \mathbb{I}_t)$$

The constraints set the continuation value at least as high as the value of autarky at each of the two time points. The ex-post constraint is that the value of staying in the risk sharing network, once migration decisions and migration outcomes have been realized, is at least as high as the value of consuming the current income and being in autarky thereafter. This constraint will determine the constrained efficient transfer rule. The ex ante constraint is that, in expectation, the value of being in the risk sharing network is at least as high as walking away once the village income shock is realized. This constraint will determine the constrained efficient migration choice.

$$\text{Ex-post constraint:} \quad \tilde{U}(s^t, q_t, \mathbb{I}_t) \geq \tilde{\Omega}^i(s^t, q_t, \mathbb{I}_t) \quad \forall i = A, B \tag{4}$$

$$\text{Ex-ante constraint:} \quad \sum_q \pi(q)\tilde{U}(s^t, q_t, \mathbb{I}_t) \geq \Omega^i(s^t) \quad \forall i = A, B \tag{5}$$

The Lagrangian is constructed by adding these constraints to the date-zero maximization problem. Let the multipliers on the ex-post constraints, conditional on $\{s^t, q_t, \mathbb{I}_t\}$ to be given by $\beta^t \pi(s^t)\pi(q)\tilde{\mu}^i(s^t, q_t, \mathbb{I}_t)$, and the multipliers on the ex-ante constraints to be given by $\beta^t \pi(s^t)\mu^i(s^t, \mathbb{I}_t)$. The Lagrangian is formed by maximizing Equation 1, subject to the budget constraint (Equation 2), the ex ante incentive compatibity constraint (Equation 5) and the ex post incentive compatibity constraint (Equation 4).

The first order condition for the ratio of marginal utilities between the two households is given by:

$$\frac{u'(c_t^A(s^t, q_t, \mathbb{I}_t))}{u'(c_t^B(s^t, q_t, \mathbb{I}_t))} = \frac{\lambda_B + \mu^B(s^0, \mathbb{I}_0) + \tilde{\mu}^B(s^0, q_0, \mathbb{I}_0) + ... + \mu^B(s^t, \mathbb{I}_t) + \tilde{\mu}^B(s^t, q_t, \mathbb{I}_t)}{\lambda_A + \mu^A(s^0, \mathbb{I}_0) + \tilde{\mu}^A(s^0, q_0, \mathbb{I}_0) + ... + \mu^A(s^t, \mathbb{I}_t) + \tilde{\mu}^A(s^t, q_t, \mathbb{I}_t)} \quad \forall s^t, q_t, \mathbb{I}_t \tag{6}$$

The ratio of marginal utilities now depends on the entire history of binding participation constraints. Agents who have a binding incentive constraint have their weight in the social planner's problem increased, and this affects ever future period. This is in contrast to the case with perfect risk sharing, where the ratio of marginal utilities is always constant.[7]

It will be helpful to be able to write this problem recursively. I follow the notation from Kehoe and Perri (2002), based on Marcet and Marimon (1998, 2011). Define the history of

[7] The first order conditions for the limited commitment problem with endogenous migration also differ from the first order conditions in the limited commitment problem without migration. Without migration, the only incentive compatibility constraint is the ex-post constraint that determines constrained efficient transfers. The first order condition would be:

$$\frac{u'(c_t^A(s^t))}{u'(c_t^B(s^t))} = \frac{\lambda_B + \tilde{\mu}^B(s^0) + \tilde{\mu}^B(s^1) + ... + \tilde{\mu}^B(s^t)}{\lambda_A + \tilde{\mu}^A(s^0) + \tilde{\mu}^A(s^1) + ... + \tilde{\mu}^A(s^t)}$$

The difference from the limited commitment problem without migration is the additional constraint arising from migration decisions being taken before the outcome is realized: in addition to the ex-post constraints ($\tilde{\mu}$), the ratio of consumption also depends on the constraint on ex-ante utility (μ).

participation constraints up to an including time t constraints recursively as:

$$M_t^i(s^t, q_t, \mathbb{I}_t) = M_{t-1}^i(s^{t-1}, q_{t-1}, \mathbb{I}_{t-1}) + \mu^i(s^t, \mathbb{I}_t) + \tilde{\mu}^i(s^t, q_t, \mathbb{I}_t)$$

where $M_{-1}^i = \lambda_i$. Rearrange the maximization problem, Equation 1, to be expressed as follows:

$$\begin{aligned}\max_{(c_t^i, \mathbb{I}_t^i)_{i=A,B}} \sum_{t=0}^{\infty} \sum_{s^t} \sum_i \beta^t \pi(s^t) \Big\{ \sum_q \pi(q) \{ M_{t-1}^i(s^{t-1}, q_{t-1}, \mathbb{I}_{t-1})[u(c_t^i(s^t, q_t, \mathbb{I}_t)) - \mathbb{I}_t^i d] \ldots \\ + \tilde{\mu}_t^i(s^t, q_t, \mathbb{I}_t))[u(c_t^i(s^t, q_t, \mathbb{I}_t)) - \mathbb{I}_t^i d - \tilde{\Omega}(s^t, q_t, \mathbb{I}_t)] \} \ldots \\ + \mu_t^i(s^t, \mathbb{I}_t))[\pi(q) u(c_t^i(s^t, q_t, \mathbb{I}_t)) - \mathbb{I}_t^i d - \Omega(s^t)] \Big\}\end{aligned}$$

The first order condition for the ratio of marginal utilities is given by the following, which is equivalent to the previous first order condition (Equation 6):

$$\frac{u'(c_t^A(s^t, q_t, \mathbb{I}_t))}{u'(c_t^B(s^t, q_t, \mathbb{I}_t))} = \frac{M_{t-1}^B + \mu_t^B(s^t, \mathbb{I}_t) + \tilde{\mu}_t^B(s^t, q_t, \mathbb{I}_t)}{M_{t-1}^A + \mu_t^A(s^t, \mathbb{I}_t) + \tilde{\mu}_t^A(s^t, q_t, \mathbb{I}^t)} \tag{7}$$

Normalizing the ex-post and ex-ante multipliers by the start of period weight of household A, $\nu_t^i = \frac{\gamma_t^i}{M_{t-1}^A}$, and $\tilde{\nu}_t^i = \frac{\tilde{\gamma}_t^i}{M_{t-1}^A}$, write:

$$\frac{u'(c_t^A(s^t, q_t, \mathbb{I}_t))}{u'(c_t^B(s^t, q_t, \mathbb{I}_t))} = \frac{\frac{M_{t-1}^B}{M_{t-1}^A} + \nu_t^A(s^t, \mathbb{I}_t) + \tilde{\nu}_t^A(s^t, q_t, \mathbb{I}_t)}{1 + \nu_t^B(s^t, \mathbb{I}_t) + \tilde{\nu}_t^B(s^t, q_t, \mathbb{I}_t)} \tag{8}$$

Then, defining the ratio of marginal utilities by x_t, there is an updating rule for the endogenous pareto weight in terms of period t multipliers:

$$x_t(s^t, q_t, \mathbb{I}_t) = \frac{x_{t-1}(s^{t-1}, m_{t-1}, \mathbb{I}_{t-1}) + \nu_t^A(s^t, \mathbb{I}_t) + \tilde{\nu}_t^A(s^t, q_t, \mathbb{I}_t)}{1 + \nu_t^B(s^t, \mathbb{I}_t) + \tilde{\nu}_t^B(s^t, q_t, \mathbb{I}_t)}) \tag{9}$$

We focus on the case where the underlying shocks are markov, so $\pi(s^t|s^{t-1}) = \pi(s_t|s_{t-1})$. The solution to the programming problem can be recursively characterized by a set of policy functions for migration $\mathbb{I}_t^i(x_{t-1}, s_t)$, consumption, $c_t^i(x_{t-1}, s_t, q_t)$, the ex-ante multipliers $\nu_t^i(x_{t-1}, s_t, q_t)$, the ex-post multipliers $\tilde{\nu}_t^i(x_{t-1}, s_t, q_t)$ and the updating rule for the relative pareto weight $x_t(x_{t-1}, s_t, q_t,)$, such that Equation 1 is maximized subject to the incentive constraints (Equation 5 and Equation 4) and the budget constraint (Equation 2).

2.3 Comparative statics on migration, risk sharing, and welfare

This section derives comparative statics on migration, risk sharing and welfare.

2.3.1 Effect of risk sharing on migration

Risk sharing affects the decision to migrate. Under autarky, households compare the rural-urban wage differential, and migrate if expected utility gain is positive. With risk sharing, instead of comparing the gross income differentials, households compare the post-transfer income differentials. Risk sharing will affect migration in two ways. Households who migrate are the households who have bad income shocks. These households would be net recipients of risk sharing transfers in the village. Risk sharing reduces the income gain between the village and city and decreases 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 risk sharing on migration will depend on whether the destination effect is larger than the home effect.

To see this, it is clearest to compare the case of migration under autarky and migration under perfect risk sharing.[8] First, I show that agents with the lowest income realizations are those who migrate, and then I show how the destination and home effects affect migration.

Proposition 2.1. *Under autarky, migration is perfectly negatively selected on income realization in the village. Under perfect risk sharing, migration is perfectly negatively selected on income realization in the village, conditional on the time invariant pareto weights.*

Proof: see Appendix B.1

[8] It is very difficult to work with closed form solutions of the limited commitment model except under extensive assumptions on the income process. The amount of insurance provided under limited commitment risk sharing equilibrium will be within the range of autarky to perfect risk sharing, and so I show results for these two values.

Consider an agent who is indifferent between migrating and staying under autarky:

$$E_q u(m^i(q)) - d = u(e^i(s))$$

Now consider the migration decision when the agent is part of a risk sharing arrangement. Assume $e^i(s)$ is such that the agent will receive a positive transfer if they stay in the village, $\tau(e^i(s)) > 0$. If the agent migrates and receives a good migration outcome they make a transfer back to the village. If the agent migrates and does not receive a good migration outcome, they receive a transfer from the village. The migration transfer is therefore $\tau(m^i(q), s)$ where $\frac{\partial \tau(m^i(q),s)}{\partial m^i(q)} < 0$. The agent will now migrate if:

$$\underbrace{E_q u(m^i(q) + \tau(m^i(q), s))}_{\text{Destination effect}} - d > \underbrace{u(e^i(s) + \tau(e^i(s)))}_{\text{Home effect}}$$

The first component, the destination effect, measures the difference in expected destination consumption between perfect risk sharing and autarky. Migration is risky. An agent may travel to the city and be unable to find work. Migrants who have a bad outcome receive transfers from the network, and migrants who are lucky make transfers back to the network. The risk-sharing network therefore insures the migration outcome. If $\mathrm{E}_q u(m^i(q) + \tau(q, s)) \geq E_q u(m(i(q))$, this insurance increases the utility of migrating, increasing migration. The second component, the home effect, measures the difference in consumption in the village between perfect risk sharing and autarky. Migrant households are those with the lowest income realizations in the village. With risk sharing, these agents receive a net transfer from the network if they stay in the village. This reduces the rural-urban income gap, reducing migration. The overall effect risk sharing on migration depends on the relative magnitude of the destination and home effects.

2.3.2 The effect of migration on risk sharing

Now consider the effect of migration on risk sharing. Households in period t, conditional on an aggregate shock z, receive an income draw in the village from the distribution $F_{y_v|z}(\mu_v(z), \sigma_v(z))$. If households migrate, they receive a draw from the migration income distribution, $F_{y_m}(\mu_m, \sigma_m)$. Let $F_{y|z}$ be the realized income distribution across all the households in the village after migration decisions are taken and migration income realized. Endogenous migration will affect both the income and the variance of income: $F_{y|z} = F_{y_v|z}(\mu_v(z) + \Delta\mu(z), \sigma_v(z) + \Delta\sigma(z))$, for some $\Delta\sigma(z)$ and some $\Delta\mu(z)$. We derive results for risk sharing and migration as a function of the ex-post change in mean income $\Delta\mu(z)$ and the ex post change in the standard deviation of income $\Delta\sigma(z)$.

Define risk-sharing, following Krueger and Perri (2010), as the ratio of the variance of consumption to the variance of income.

Definition 1. *Risk sharing* is defined as $RS_t = 1 - \frac{\sigma(c_t)}{\sigma(e_t)}$ where $\sigma(c_t)$ is the standard deviation of consumption and $\sigma(e_t)$ is the standard deviation of income.

This measure of risk sharing is bounded between 0 and 1, taking the value 1 if resources are perfectly shared between households ($\sigma(c_t) = 0$) and the value 0 if there is no transfer of resources ($\sigma(c_t) = \sigma(e_t)$). Risk sharing decreases when the ratio between consumption and income increases. That is, risk sharing decreases if rich agents transfer relatively fewer resources to poor agents after a change to the income distribution.

Migration will have two offsetting effects on risk sharing. The first is an incentive effect. This is the endogenous change in consumption arising from the changes in the outside option. The second is a self-insurance effect, reflecting the direct change in income as a result of migration. Consider the effect of migration on risk sharing, captured by a change in the ex-post mean μ and standard deviation σ of the income distribution. Migration will change both the income of households, and the distribution of consumption across households. There are two effects on risk sharing (omitting the dependence on z for clarity):

$$\Delta RS_t = \underbrace{\frac{\partial RS_t}{\partial \sigma(c_t)} \left(\frac{\partial \sigma(c_t)}{\partial \sigma} \Delta\sigma + \frac{\partial \sigma(c_t)}{\partial \mu} \Delta\mu \right)}_{\text{Incentive effect}} + \underbrace{\frac{\partial RS_t}{\partial \sigma(e_t)} \left(\frac{\partial \sigma(e_t)}{\partial \sigma} \Delta\sigma + \frac{\partial \sigma(e_t)}{\partial \mu} \Delta\mu \right)}_{\text{Self-insurance effect}}$$

The incentive effect represents the change in the distribution of consumption, as a result of the change in transfers. The self-insurance effect represents the change in the distribution of income. The net effect on risk sharing depends on the relative strength of the incentive effect and the self-insurance effect. Both the incentive and the self-insurance effect will depend on the aggregate shock. In particular, migration allows the network a mechanism to smooth aggregate shocks.

2.3.3 Decomposition of the welfare effect 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 (if $\sigma(c_t) = 0$). We can express the welfare for this economy as a function of the distribution of consumption (σ) and mean income (μ): $W = W(\sigma(c_t), \mu)$.

Migration will have two effects on welfare. First, it directly changes the total resources available to the network. Second, it endogenously changes the distribution of consumption among network members. Decompose the change in welfare into the change in risk sharing (summarized by $\sigma(c_t)$) and the change in income (summarized by mean income, μ):

$$\Delta W = \underbrace{\frac{\partial W}{\partial \sigma(c_t)} \left(\frac{\partial \sigma(c_t)}{\partial \sigma} \Delta\sigma + \frac{\partial \sigma(c_t)}{\partial \mu} \Delta\mu \right)}_{\text{Risk sharing effect}} + \underbrace{\frac{\partial W}{\partial \mu} \Delta\mu}_{\text{Income effect}}$$

The risk sharing effect captures how the distribution of consumption changes. Total welfare is maximized when the cross-sectional distribution of consumption is zero, and welfare is lower when risk sharing is reduced. As a result, $\frac{\partial W}{\partial \sigma(c_t)}$ is negative. The sign of the first term will therefore depend on the effect of migration on risk sharing (the sign of the term in brackets). The income effect captures the change in mean resources as a result of migration. It is positive: a higher income increases welfare. The net effect on welfare from migration depends on the relative magnitude of the income and risk-sharing effects. A priori, the net welfare effect of migration can be either positive or negative.

2.4 Summary of theoretical predictions

This section presents a model of limited commitment with endogenous temporary migration where migration and risk sharing were jointly determined. I derive three comparative statics:

1. *Effect of migration on risk sharing:* Migration will change both the allocation of income (the self insurance effect) and the endogenous allocation of consumption (the incentive effect). If the variance of consumption decreases relative to the variance of income, then risk sharing increases. Theoretically, the effect of migration on risk sharing is ambiguous. On one hand, the option to migrate increases the outside option of households, decreasing risk sharing. On the other hand, migration allows the network to act to smooth aggregate shocks, increasing risk sharing.

2. *Decomposition of the welfare effect of migration:* Welfare depends on total resources available to the network and the allocation of these resources between members (the "size" and "slices" of the economic pie). The effect of migration on welfare can be decomposed into an income effect and a risk sharing effect. In the first case, changing the income distribution while holding the allocation constant has a positive effect on welfare. At the same time, migration affects the outside option of households, which may make it more difficult to satisfy incentive compatibility constraints and reduce the amount of risk sharing, in turn reducing welfare.

3. *Effect of risk sharing on migration:* With risk sharing, the migration decision depends on post-transfer income differentials between the village and city. There is a destination effect and a home effect. Households who migrate are the households who have bad income shocks. These households would be net recipients of risk sharing transfers in the village. Risk sharing reduces the income gain between the village and city and decreases migration. On the other hand, migration is risky. Risk sharing can insure the risky migration outcome, facilitating migration.

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.

3 Panel of rural Indian households

I use the ICRISAT Village Level Studies (VLS) data from semi-arid India. The ICRISAT data are a very detailed panel household survey, with modules covering consumption, income, assets, and migration. This paper uses both the original data (VLS1), collected over 1975-1984, and the *new* ICRISAT data (VLS2), collected from the same villages starting in 2001.[9] Pooling the two waves yields a 30-year panel on rural households. However, temporary migration is very scarce in VLS1 – fewer than 1% of households report having a temporary migrant – so the migration analysis is performed using the VLS2 data only[10]. This section introduces the data and verifies that the model assumptions hold in this empirical context.

3.1 Descriptive statistics of migration

Temporary migration is common in rural India today. On average, 20% of households participate in temporary migration each year. This prevalence varies over location, 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 its prevalence by village and year, using the VLS2 data.

Summary statistics for the sample are reported in Table 1. On average, a migration trip lasts for 191 days (approximately six months), and 1.7 members of the household migrate. 40% of households have a migrant at least one of the four years of the survey. Households who ever migrate have a slightly larger household, more adult males compared with households who never migrate (2.2 vs 1.7), and less land (4.5 vs 5.1 acres).[11] Intuitively, this makes sense: households with more land have higher income in the village and so lower returns to migrating, and households with more males may have surplus labor and hence more likely to migrate.[12] To match these differences in propensity to migrate across

[9]For more information about the initial ICRISAT panel, refer to Walker and Ryan (1990)).

[10]The majority of migration in VLS1 is due to marriage, with the woman migrating to her husband's home (Rosenzweig and Stark, 1989).

[11]A probability model for ever migrating is reported in Appendix Table 1. The number of males in the household is a significant predictor of migration, controlling for household size.

[12]Overall, 28% of temporary migrants are women. However, these women are almost always accompa-

households, I allow for heterogeneity by landholdings and household composition when estimating the model.

Table 2 provides evidence that transfers provide insurance, and depend on the history of shocks. Transfers are defined as the difference between income and consumption. I run the specification in Foster and Rosenzweig (2001) that links contemporaneous transfers, τ_{it} to the current income shock and the history of past transfers:

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

The coefficient on income is negative, indicating the transfers provide insurance, and the coefficient on the stock of transfers, α_2 is negative, indicating that current transfers depend on the history of shocks, as implied by limited commitment models.

3.2 Four key facts linking migration and risk sharing

I verify four key 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; and (4) marginal propensity to consume from migration income is less than 1. Throughout 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 result of 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. This matches the modeling assumption that migration decisions are made after income is realized.

nied by a male member of the household. If there is only one migrant from a household, 94% of the time this is a male migrant. This gender difference could reflect cultural norms about women traveling alone, or reflect differential returns from migration by gender.

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

   40% of households migrate at least once during the sample period. However, on average, a migrant household only migrates half the time. This is consistent with households migrating when their returns are highest – for example, if they receive a low idiosyncratic shock – rather than migration being a permanent strategy.

3. *Risk sharing is incomplete*

   Risk sharing in the ICRISAT villages is incomplete, and worse in villages with higher temporary migration. To show this, I estimate a 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 and γ_{vt} is a village-year fixed effect that captures the total resources available to the village at time t. The intuition of tests of full risk sharing is that individual income should not predict consumption, conditional on total resources (Townsend, 1994).

   Table 4 reports the results of the tests. The first 3 columns of the table report the results using the complete 30 year panel. I repeat the analysis using only the new VLS2 data in the last 3 columns. Results are consistent: full risk sharing is rejected. The estimated income elasticity is 0.20 using the full sample, or 0.08 using the new VLS2 sample.

   Columns 2 and 4 interact 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 0.025. In other words, villages with higher rates of temporary migration have lower rates of risk sharing. While this does not indicate causality, it is again consistent with the joint determination of risk sharing and migration.

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

Table 3 decomposes the change in household expenditure for migrant households. Although a household increases their income by 30% during the years they send a migrant, total expenditure (consumption and change in asset position) only increases by 85% 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 the household to the network.

These four empirical facts provide some reduced form evidence for a relationship between migration and risk sharing. However, the key feature of the model is the joint determination of risk sharing and migration. In order to quantify this interaction, I now estimate the model structurally.

4 Structural estimation

This section describes the structural estimation procedure. There are five groups of model parameters to be estimated:

1. *Income distribution in village:* The income distribution in the village determines the income of households if they do not migrate. I allow for idiosyncratic income shocks and a common village-level aggregate shock.

2. *Income distribution if migrating:* The income distribution at the destination determines the income of households if they migrate.

3. *Utility cost of migrating:* The utility cost is a key determinant of migration.

4. *Preference parameters:* The coefficient of relative risk aversion will determine migration. Both the coefficient of relative risk aversion and the discount factor will determine risk sharing.

5. *Heterogeneity parameters:* I allow for two sources of heterogeneity. First, idiosyncratic income to depend on landholdings. Second, migration cost to depend on the number of males in the household.

Section 4.1 discusses the simulated method of moments estimator; Section 4.2 identification in a simplified version of the model; Section 4.3 identification in the full dynamic model and Section 4.4 additional computational issues.

4.1 Simulated method of moments estimator

I estimate the model using simulated method of moments (McFadden, 1989).[13] The aim of the structural estimation is to generate a series of simulated data which matches the observed data as closely as possible. I construct a vector of moments from the data, q_s, relating to migration, income, and risk sharing. I then solve the model for a specific value θ of the underlying parameters, generate a simulated dataset, and construct the same moments from the simulated data. This yields a vector of simulated moments $Q(\theta)$. The simulated method of moments estimator $\hat{\theta}_{SMM}$ is given by:

$$\hat{\theta}_{SMM} = \underset{\theta}{\text{argmin}} (Q(\theta) - q_s)' W^{-1} (Q(\theta) - q_s)$$

where W is a positive definite weighting matrix.[14] Standard errors are calculated by first approximating the discrete migration choice with a continuous formula, following Keane and Smith (2004), and then utilizing numerical gradient methods to compute the covariance matrix.

I construct the simulated data by solving the model and applying the policy rules to a sequence of income shocks. For a given value of the parameter vector, θ, the solution of the limited commitment model yields the migration rule, updating rule for the Pareto weight, and transfer rule, for each state of the world. I use an algorithm, shown below, to generate the data. 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.

The algorithm is as follows:

[13] An alternative estimation procedure would be to construct a pseudo-likelihood using indirect inference methods (see, for example, Guvenen and Smith (2010)). I choose method of simulated moments as my model produces moments which map directly to the data.

[14] I use a weighting matrix where the diagonal elements are bootstrapped sample variances of the sample moments, thereby putting more weight on matching sample moments with lower variance. Results are robust to using an identity matrix where the moments are in levels, and an identity matrix where the moments have been converted into percentage changes.

1. Construct the vector of data moments q_s.
2. For the given θ solve the model and find the migration rule, Pareto intervals, and transfer rule.
3. Construct a history of $T-4$ aggregate shocks for each village. Use the actual realization of the aggregate shocks in the data for the last 4 years of the series.
4. Draw a history of T idiosyncratic shocks for N individuals in each village
5. Together, the idiosyncratic shock and aggregate shock determine the state of the world s for each T
6. Set the initial ($t = 0$) Pareto weight to a random number $x \in [0, 1]$ for each household
7. Use the migration rule, Pareto intervals, and transfer functions to simulate the N agents over T years.
8. Discard the first $T-4$ years of data. Compute the simulated moments $Q(\theta)$ using N individuals over 4 years where the aggregate shocks in the simulated data match the aggregate shocks in the data.
9. Compute the criterion function $(Q(\theta) - q_s)'W^{-1}(Q(\theta) - q_s)$

The specific algorithm I use to solve the limited commitment model in Step 2 is contained in Appendix C.

4.2 Identification

This section details the identification of each group of parameters. I start by discussing identification in a simplified model of migration, and a simplified model of risk sharing. The logic from this simplified models informs the identification discussion of the joint model of migration with endogenous risk sharing. I aim to match the basic heterogeneity in the data, that households who have more males or less land are more likely to migrate. To match this, I assume that income will depend on landholdings, and that the migration cost will depend on the number of males in the household.

4.2.1 Migration under autarky

This section presents a model of migration without risk sharing. Without risk sharing, the migration problem is a standard selection model.[15] Assume household i has land holdings x and number of males in the household z. I assume that income in the village depends on land holdings, $y_v \sim F_{Y_V|X}$. Income in the destination is not a function of landholdings, $y_m \sim F_{Y_M}$. The utility cost of migrating is a function of the number of males in the household, $d = d(z)$. Households have contemporaneous CRRA utility function $u(c)$.

Household i migrates if:

$$\text{Migrate} = \mathbb{I}\{E_{Y_M} u(y_m) - d(z) \geq u(y_v)\}$$

Letting $h(x) = u^{-1}(x)$ denote the inverse of the utility function, this can be written as:

$$\text{Migrate} = \mathbb{I}\{h(F_{Y_M}, z) \geq y_v\}$$

By assumption, the returns to migration are not a function of household characteristics. Therefore, F_{Y_M} is identified as it is directly observed. We then need to identify the utility function and the cost of migrating. From the selection equation above, the number of males in a household acts an instrument for migration and allows us to identify $h(F_{Y_M}, z)$. The identifying assumption is that the number of males in the household does not affect income (either in the village or in the city) directly.[16] Variation in the number of males shifts the returns to migration, which in combination with the observed migration income, F_{Y_M} identify the function h.

However, the h function contains both the contemporaneous utility function and the cost of migrating. Therefore, it does not separately identify the contemporaneous util-

[15] Park (2012) discusses how to non parametrically identify the extended Roy model. If there was no uncertainty about the migration outcome, then the identification results of his paper would go through and all parameters of interest can be non parametrically identified. However, in my model, agents make a migration decision based on the ex-ante expected utility of migrating. As a result, the identification results in Park (2012) paper cannot be directly applied to this model.

[16] I convert all income and consumption variable into per adult male equivalent values, using equivalence scales that weight male and females differently, removing any level effects of household composition.

ity function from the cost of migrating. The intuition is clear. Assume that the utility function is CRRA, so we would want to identify the coefficient of relative risk aversion. Households who are on average more risk averse will migrate less. But, households who face a higher migration cost will also migrate less. Although there is variation in the total effect from the observed migration behavior of households with more males, this does not separate the coefficient of relative risk aversion from the cost of migrating.

One possible way to proceed would be to assume that the cost of migrating is a function of two instruments: $d = d(z_1, z_2)$. For example, z_1 could be the number of males in the household and z_2 could be the distance to the nearest large city. If we estimated the model across villages we could use the variation in the distance to the nearest large city (under the assumption that this does not affect either the income distribution in the village nor the income distribution in the city) as a second instrument for migration. This would then let us separately identify the utility function and the cost of migrating. An alternative approach would be to estimate the model within the village, fix one of the coefficient of relative risk aversion or the mean migration cost, and estimate the other from the data.

The last distribution of interest is the income distribution in the village, $F_{Y_V|X}$. Here there is a classic selection problem: only the income for households who don't migrate is observed. From the theoretical framework, migration will be negatively selected on income. As a result, we will only observe the upper tail of the income distribution in the data. The instrument for migration also helps with identification of the home income distribution. A household with very few males will face a high cost of migration, $d(z)$, and so will need to have a lower income at home to migrate. This generates variation in the threshold for the income distribution and therefore variation in the observed income distribution in the village. With large enough support for z, it would be possible to trace out the income distribution in the village to identify $F_{Y_V|X}$. However, this again introduces a tradeoff between increased heterogeneity and increased computational burden. The other alternative is to assume a known distribution for $F_{Y_V|X}$. Assuming a parametric form for the income distribution is a strong assumption. However, it allows the underlying parameters of the distribution to be identified from the observed truncated income distribution.

4.2.2 Limited commitment risk sharing without migration

Now consider a simplified model of limited commitment, without endogenous migration. I show how the risk sharing moments can identify either the discount factor or the coefficient of relative risk aversion, but not both parameters.

For tractability, 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 for the agent with the binding participation constraint will bind each period, and equilibrium consumption is implicitly defined by the following equation:[17]

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

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:

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

Proposition 4.1. *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*

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

Further, the partial derivatives of α^c with respect to its arguments are signed as following:
$\alpha^c_1(\alpha^\Omega, \beta, \gamma) < 0, \alpha^c_2(\alpha^\Omega, \beta, \gamma) < 0,$ *and* $\alpha^c_3(\alpha^\Omega, \beta, \gamma) > 0.$
Proof: See Appendix B.2

This proposition says that whether we observe perfect risk sharing, imperfect risk sharing, or no risk sharing will depend on the discount rate, the coefficient of risk aversion, and the income process. If we observe imperfect risk sharing, then risk sharing gets better (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 risk sharing gets worse (α^c increases so consumption is more unequal) if agents are more risk averse.

We would like to identify the discount factor and the coefficient of relative risk aversion. It is only possible to identify either parameter if incomplete risk sharing is observed. However, even if incomplete risk sharing is observed, we can only identify *one* of the discount factor β or the coefficient of relative risk aversion γ. The intuition is clear. If agents are more risk averse, they value insurance more. If agents care more about the future, they also value insurance more. A higher coefficient of relative risk aversion is therefore equivalent to a lower discount factor. If perfect risk sharing or no risk sharing is observed, then we cannot identify either parameter. If we observe either perfect risk sharing or no risk sharing then we do not have any information about β or γ. Perfect risk sharing could occur because either the agents have a very high discount factor, or they are very risk averse. Autarky could occur because either agents have a low discount factor or because they are not risk averse.

For the more general dynamic limited commitment model, it may be possible to separately identify the time discount factor and the coefficient of relative risk aversion using additional intertemporal moments. However, in general, it is a very challenging problem to separately identify these two parameters (see, for example, the extensive discussion in Guvenen and Smith (2010)).

4.2.3 Summary of identification in the simplified model

The identification arguments made above for the simplified model where migration and risk sharing are separate processes is summarized by the following:

- Discount factor: can be identified from risk sharing data if the coefficient of relative risk aversion is fixed
- Coefficient of relative risk aversion: can be identified from a) within-village migration data if the mean migration cost is fixed; b) across-village migration data without fixing the migration cost; or c) risk sharing data if the discount factor is fixed.
- Migration cost: can be identified from a) within-village migration data if the coefficient of relative risk aversion is fixed; or b) across-village migration data without fixing the coefficient of relative risk aversion.
- Village income distribution: can be non parametrically identified if there is large enough support on the migration instrument. Can be parametrically identified from the observed selected sample.
- Migration income distribution: can be non parametrically identified.

This summary suggests that all parameters of interest could be identified if the model was estimated pooling across villages. However, there are a few practical constraints. To estimate the model I need to estimate the dynamic game between all households (or, more exactly, all types of household, indexed by permanent heterogeneity, current income shock and endogenous pareto weight), taking into account how one household affects the total income and consumption of every other household in the village. This differs from how you would be able to estimate a dynamic model where agents made choices that did not explicitly depend on other agents' choices. This hinders the ability to include rich heterogeneity in the model, because every additional degree of heterogeneity needs to be treated as another group of agents.

The first decision is whether to estimate the model village-by-village or across village. A key advantage of estimating the model for each village is the estimation procedure can be parallelized at the village level. This reduces the problem from dimension 40 to dimension 8 (8 parameters estimated each village, for 5 villages)[18] This does come at a cost. Without employing cross-village variation it is necessary to fix the coefficient of relative risk aversion exogenously in order to identify the migration cost. However, it is possible to do this and do undertake extensive robustness of the value of the coefficient of relative risk aversion. This is how I proceed.[19]

The second key decision is whether to estimate the income distributions non parametrically. With large enough support for the migration instrument (the number of men in the household), it would be possible to trace out the income distribution in the village. However, this again introduces a tradeoff between increased heterogeneity and increased computational burden. The model needs to be estimated separately for each type of agent. As a result, when I come to estimate the model I characterize households in a discrete way. Specifically, I will define each household as either a "low male" or a "high male" household. This does not generate enough variation in the instrument to trace out a full income distribution. To proceed, I assume a known income distribution, and identify the parameters from the selected sample of non migrants I observe in the data.

[18] I estimate the model on the Yale High Performance Computing Cluster using Matlab. To estimate the model for a single village takes approximately 24 hours running parallel Matlab on 8 cores on a single node (the maximum feasible under the standard license), and all five villages can be run concurrently on separate nodes. The Yale HPC cluster has one license to use the Matlab Distributed Computing Engine which allows the program to run over multiple nodes, with a maximum of 32 labs. When I estimate the model pooling the villages using the Matlab Distributed Computing Engine the model estimation takes approximately 7 days.

[19] It would also be possible to set the discount factor exogenously and then estimate the coefficient of relative risk aversion from the risk sharing data. However, runs of the model under a standard assumption of $\beta = 0.9$ could not get the risk sharing moments to match. I therefore proceeded by setting the coefficient of risk aversion to a constant and running robustness checks for this value. This is discussed more in the estimation section.

4.3 Identification of the dynamic model

The simplified models discussed above are helpful for thinking through the variation in the data. However, the full model of temporary migration with endogenous risk sharing is substantially more complex. In general, structural dynamic models are not non parametrically identified (Rust, 1994). To proceed, I make four parametric assumptions:

1. Village income follows a known distribution function $F^*_{Y_V|X}$.
2. Destination income follows a known distribution function $F^*_{Y_M}$
3. Utility is CRRA, $u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$
4. The coefficient of relative risk aversion is known $\gamma = \gamma^*$

It is not possible to prove identification analytically in the dynamic model. I proceed by using the simple models discussed above, where identification is clear, to motivate how to match the dynamic model to the data. I then show by simulating the model that the model moments are moving as predicted.

Table A summarizes how I match each parameter to the data. I estimate the model for each village separately. For each village, I estimate 8 parameters, and set 3 parameters exogenously. Because I allow for heterogeneity in land holdings and household composition when estimating the model, it is necessary to have a large enough sample size within each village. For this reason, I drop village 6 because its sample size is only 32 households. The final structural estimation sample is 5 villages. In total, I estimate 8 parameters for each village, yielding a total of 40 parameters to be estimated, and set 3 exogenously. The parameter vector $\theta = \{\theta_{\text{estimated}}, \theta_{\text{exogenous}}\}$ is a vector of 43 parameters which fully characterizes the risk sharing and migration model.

Table A: Parameter vector for structural model

Type of parameter	*Symbol*	*Main source of variation in data*
Income distribution in village	μ_v	Mean income of non migrants
	σ_v	Standard deviation of income for non-migrants
Income distribution if migrating	$\mu_{\text{mig},v}$	Mean income of migrants
	$\sigma_{\text{mig},v}$	Standard deviation of income for migrants
Utility cost of migrating	d_v	Mean households migrating
Discount factor	β_v	Correlation between income and consumption Mean consumption of migrants Mean consumption of non migrants Share of migrants receiving a transfer Share of non migrants receiving a transfer
Heterogeneity parameters	$\alpha^{\mu}_{\text{land},v}$	Mean income of non-migrant land owners
	$\alpha^{d}_{\text{male},v}$	Mean male households migrating
Parameters set exogenously		
Scaling parameter good agg shock	μ	1.2
Coefficient of relative risk aversion	γ	1.6
Income share from migration		0.6

Notes: Table summarizes how the parameters match to data moments. Parameters with a v subscript are estimated at the village level.

4.3.1 Specific moments matched

This section discusses how the model parameters map to the moments in the data.

Village income distribution: Household income depends on the aggregate income shock, idiosyncratic income shock, migration decision and migration income. Exogenous variation in income comes from monsoon rainfall, which determines the aggregate state of the world in the village. I make parametric assumptions for the income distribution faced by the households in the village and in the city.

Total household income depends on the migration decision. If the household does not migrate, their income comes only from their village income draw, y_{ivt}. If the household migrates, the migrant receives migration income draw, m_{ivt}, and total household income is a combination of income earned by the migrant and by the non-migrants.

Each household i in village v receives an income at time t that has an idiosyncratic (ϵ) and aggregate (ν) component:

$$y_{ivt} = \nu_{vt}\epsilon_{ivt}.$$

The idiosyncratic shock is an iid draw from a village-specific log-normal distribution with mean μ and variance $\sigma^2_{\text{idio,v}}$:

$$\log(\epsilon) \sim \mathcal{N}(\mu_v, \sigma^2_{\text{idio},v}).$$

I allow the village income distribution to be a function of land holdings. I scale the mean of the income distribution by $\alpha^{\mu}_{\text{land}}$, estimated structurally, if the household is in the top half of the land holding distribution within the village.

Village aggregate shock: The source of the aggregate shock for the villages is the exogenous realization of rainfall. I use a historical rainfall database covering the years 1900-2008 to compute the long run rainfall distribution and to 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.[20] Appendix Table 2 examines the effect of an aggregate shock on rainfall for the 1975-1984 ICRISAT data. I compute 4 different shock measures: the arrival of the monsoon (measured as the first day after June 1 with more than 20 mm of rain, following Rosenzweig and Binswanger (1993)), a rainfall shock that falls in the 10% percentile of the long run rainfall distribution, a rainfall shock in the 20% percentile and a shock in the 50% percentile. The monsoon start date is a strong predictor of rainfall. However, to calculate the monsoon start date it is necessary to have data on daily rainfall, and this was unfortunately not collected over 2001-2004 for the ICRISAT villages. Instead, I define the aggregate shock as a rainfall event falling below the 20% percentile of the long run rainfall distribution. This reduces output by 23%, and occurs with probability 0.28. I set the scaling parameter

[20] It is potentially feasible to estimate the aggregate shock process within the estimation procedure. However, as I only observe 4 realizations of the aggregate shock for each village, any such estimation would be very noisy. As a result, I take this income process as given.

to 0.2 and the probability of the shock to 0.3 for the structural estimation.[21] I then use the actual rainfall realization over the years 2001-2004 to characterize the realized aggregate state in the model.

Migration income distribution: If agent i migrates from village v they receive an income draw m from a log-normal distribution with mean $\mu_{\text{mig,v}}$ and variance $\sigma^2_{\text{mig,v}}$. I assume that all agents face the same ex-ante income distribution if they migrate:[22]

$$\log(m) \sim \mathcal{N}(\mu_{\text{mig,v}}, \sigma^2_{\text{mig,v}}).$$

To implement the estimation I discretize both income processes. To do this, I follow Kennan (2006), and choose points of support in the distribution such that there is equal probability placed on each support point. There is a trade-off between number of points of support and computational time of the algorithm. I allow 5 points of support for the idiosyncratic income process and 3 points of support for the migration income process.

Utility parameters: I assume CRRA preferences. The discount factor β and the coefficient of relative risk aversion γ both affect risk sharing: households who are more patient can share idiosyncratic risk more easily, and agents who are more risk averse also prefer to share risk. Risk aversion also affects migration, as agents who are more risk averse prefer certainty over uncertainty and require larger expected gains in order to migrate. As per the discussion above, it is very difficult to separately identify the discount factor for the coefficient of relative risk aversion.

I proceed by setting the coefficient of relative risk aversion and then estimating the discount factor to match the risk sharing moment. The baseline estimates set the coefficient of relative risk aversion equal to 1.6 to match the estimate in Ligon et al. (2002), and robustness over this value is performed. To capture risk sharing, I use the correlation between income and consumption as the summary risk sharing moment. I also include the

[21] As a robustness test I also define an aggregate shock as below-median rainfall. This occurs with $\pi = 0.49$, and reduces income by 10.4%.

[22] With richer data, it would be possible to incorporate additional dimensions of heterogeneity, such as education and learning from past migration outcomes. In the data I find no relationship between education and selection into temporary migration, but I do find a small and marginally significant difference in the wage rate if agents migrate. I also abstract from any learning about migration. For papers that consider learning and migration see Pessino (1991) and Bryan, Chowdhury and Mobarak (2013).

mean of consumption (for both migrants and non migrants) and the share of households receiving a positive transfer (again, for both migrants and non migrants).

Cost of migrating: The direct utility cost, d, is unobservable to the econometrician but is key to the household's decision to migrate. d is identified by matching mean migration rates. Intuitively, if the direct utility cost were zero there would be a threshold income level in the village below which agents would migrate. Increasing d increases this threshold and increases the share of the village who have income below this threshold.

In the data, the number of males in the household is a strong prediction of migration. To match this fact, I allow for heterogeneity in the migration cost by the number of males in the household. I assign a dummy indicator $\mathbb{I}_{\text{male}}$ if the household has more males than the median for all households, and estimate a scaling parameter α_{male} corresponding to the utility cost for these households. The specific moments I match in the data are the mean migration rate overall and the mean migration rate of many-male households.

4.3.2 Simulation analysis

As a check on how well the identification arguments for the simple model apply to the dynamic model I simulate the dynamic model for a range of parameter values. I vary each parameter of interest and then plot the responses of each of the 8 main 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 bold the moment that is most closely related to the parameter of interest. The results are plotted in Appendix Figure 1.

The figure shows that the intuition from the simple model holds for the dynamic case. It also highlights the 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 from risk sharing. First, migration rates decreases, 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 get richer, which improves risk sharing. The risk sharing measures therefore decreases, reflecting 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. However, changing the variance of the income process 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.

4.4 Moving from 2 to N households

The final computation issue is the approximation of a N household economy. The model presented in Section 2 was a two household model, but in reality the average village in my sample has approximately 400 households, of which I observe approximately 80 in the dataset. The model can be extended to N agents by including each agent's relative Pareto weight as an additional state variable. However, this is computationally intensive. I follow Ligon, Thomas and Worrall (2002) and other empirical applications of the limited commitment model (Laczo, 2011), and construct an aggregated "average rest of the village" household. The average rest of the village depends on the specific realization of the idiosyncratic shock for the household. For each state of the world s I construct the average village member by assigning the income realization such that the sum of household H and the rest of the village is equal to the average level of resources in the economy, taking into account how migration decisions change the total resources in the economy. I show how the pareto weight for the rest of the village agent relates to the weighted average of the pareto weights in Appendix C.

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. First, I show the implications of endogenous migration for estimating the returns to migration. I then use the model to quantify the comparative statics between migration, risk sharing and welfare. Finally, I show that the joint determination of migration and risk sharing has key implications for policy.

Table 5 shows the fit of the model to the data, averaged over the 5 village sample. The data fit the model well: average income, migration rates, and risk sharing behavior are all close. As a test of how well the model matches other characteristics in the data, I show the share of households that migrate this year if they migrated last year. This moment was not matched in the estimation. However, it is relatively close (43% vs 65%), a reassuring figure given that I only allow for two sources of heterogeneity in the model.

The area where there is the largest discrepancy between the model and the data is migrant consumption, a moment that was not explicitly targeted.[23] The model over predicts insurance for migrant households, and as a result migrant consumption is approximately 8% higher than the mean in the data. I do not allow the risk sharing technology to exogenously differ between migrant and non migrant households. However, the data seem to suggest that migrants are less insured than we would expect.

This raises the question about possible other mechanisms that may interact with migration and risk sharing. For example, it could be the case that instead of assuming all income is fully observable, households are able to hide income (Kinnan, 2010). If migrant households could more easily hide income from the rest of the village, this could generate an alternative mechanism constraining insurance. The key difference between a limited commitment framework and a hidden income framework is which agents are

[23]The model also slightly under predicts the mean of the migration income process. This is most likely due to discretization of the income process (I employ 3 points of support for the migration income distribution, compared with 5 points of support for the village distribution).

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. Other explanations for imperfect insurance include moral hazard (Ligon, 1998; Lim and Townsend, 1998; Townsend and Karaivanov, 2010), and ambiguity aversion (Bryan, 2010). In reality, the constraints faced by households are likely to be a function of several market imperfections. The key advantage about using the limited commitment framework is that there is a clear mechanism in the model that links migration to risk sharing, through the outside option. In terms of interpreting the following results, the fact that the model is over predicting migrant consumption means that the model likely over predicts the benefits of migrating, and so the estimated welfare results can be seen as an upper bound for the welfare gain of migration.

The parameter point estimates from the structural estimation are provided in Table 6. Migration has a higher mean return than village income (mean of the log-normal distribution is estimated to be 1.7 compared with 1.2), but is considerably riskier (standard deviation of 1.0 compared with 0.8). The model matches migration rates with expected income differentials through a utility cost of migrating. The mean cost, 0.18, is substantial, equivalent to 34% of mean household consumption. For households with many males, who face a lower utility cost, the cost is estimated to be approximately 22% of mean consumption (scaling factor of -0.48).

The estimated discount factor is 0.57. This is a low value, especially compared with literature in developed countries which estimate an annual discount factor closer to 0.9 (see, for example, Gourinchas and Parker (2002)). In the data, the correlation between income and consumption of 0.22. In order to generate this level of imperfect insurance, the discount factor needs to be low enough such that households do not value the future highly. As a result, the model fits a low optimal β. While the estimated value for β is low, it is not a priori clear what the discount factor should be for low income countries. The point estimate of 0.57 is at the upper end of the range of 0.4-0.6 elicited experimentally from individuals in the ICRISAT villages (Pender, 1996). A discount factor of 0.58 would be equivalent to an interest rate of 75% in a perfect market economy, which is reasonable with respect to interest rates charged by micro finance organizations.[24] To further explore the discount factor magnitude I reestimate the model allowing for an autoregressive income process for village income. This has very little effect on the estimated discount factor; the results are discussed below.

5.1 Selection and returns to migration

Both permanent heterogeneity and temporary income shocks affect migration. The selection of households into migration, as a function of their village income, is shown in Figure 3. The shaded area on each graph shows the selection of households into migration, and shows the amount of selection into migration on income. I separate out the income distribution for good aggregate shocks and for bad aggregate shocks. Migration depends on the realization of the aggregate shock. Migration allows the network to smooth aggregate shocks. Overall, mean migration is 16%, but is higher when there is a bad aggregate shock (22%) compared to a good aggregate shock (13%). Migration also depends on permanent characteristics of households. Landed households have a higher income in the village, and so migrate less. Households with many males have a lower cost of migrating, and so migrate more.

Table 7 shows the effect of migration on migration and village income. There are three results in the table. First, migration has a significant return. The mean income of migrant households is 5500 rupees per equivalent adult (approximately $110 USD). Households, on the whole, would have been considerably worse off had they not migrated. Counter-

[24] For example, micro finance APRs are 100% in Mexico Karlan and Zinman (2013), 60% in the Philippines Karlan and Zinman (2011), 30% in India Banerjee et al. (2013).

factual income (the income the household would have had in the village) is close to half of actual income, at 2300 rupees ($46 USD). Second, migration is risky. Ex-post, not all migrant households are better off migrating than they would have been staying in the village. I estimate 81% of migrant households have higher income from migrating than they would have if they had not migrated. However, 19% are ex-post worse off. This number is consistent with the experimental findings in Bryan, Chowdhury and Mobarak (2013) who estimate a 10-20% risk of "failure" from migration. The third result is that endogenous migration biases the observed returns to migration. The income of households who choose not to migrate is 5800 rupees per adult equivalent household member (approximately $116 USD). A naive estimate of the returns to migration would be to compare the income of non-migrants to income of migrants. This would yield a negative return to migration: non-migrants have a household income of 5800 rupees, compared with migrant income of 5500 rupees.[25] However, this is not the correct comparison. The true return to migration is the comparison of the income migrant households would receive if they did not migrate; in this case, 5500 rupees compared with 2300 rupees.

5.2 Theoretical comparative statics

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

1. Migration increases the correlation between income and consumption (i.e. decreases risk sharing) by 23%.
2. The welfare effect of migration is large (19.5% consumption-equivalent). However, comparing endogenously to exogenously incomplete markets, welfare is 7% lower.
3. Risk sharing reduces migration by 60%.

5.2.1 Migration reduces risk sharing

Theoretically, the effect of migration on risk sharing is ambiguous. On one hand, the option to migrate increases the outside option of households, decreasing risk sharing.

[25] This difference holds if the compositional effects (i.e. permanent characteristics) of non-migrants and migrants are controlled for.

On the other hand, migration allows the network to smooth aggregate shocks, increasing risk sharing. I show the effect of migration on risk sharing in Table 8. On average, the correlation between income and consumption is 21.5% before migration, whereas with migration, this correlation is 26.5%. With migration, households are more exposed to income risk, and I find the crowding-out effect of migration dominates. The net effect of introducing migration is to reduce risk sharing by 23%. Columns (3) and (4) make the same comparison with and without migration over the sample of agents who do not migrate. The households who do not migrate have the same income in both states of the world, so the only change that occurs is through the change in the distribution of consumption for these households. The same pattern holds.

The overall correlation masks a substantial degree of heterogeneity within group. The group that has the largest change in risk sharing is the households that have many males, and therefore can more easily migrate. For example, the correlation between income and consumption for landed households with many males increases from 16% to 26% with migration. Risk sharing actually improves for one group, landless households with few males. This group doesn't migrate very much, and is on average poor because they don't have much land. The overall effect is for this group to benefit from the increased income in the village, slightly reducing the correlation between income and migration.

5.2.2 Decomposition of the welfare effect of migration

Migration both changes the resources available to the village, but also endogenously changes risk sharing. The net welfare effect of migration 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 migration does not alter the structure of the insurance market if markets are exogenously incomplete as it does when markets are endogenously incomplete.[26] 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 9. The welfare benefits of migration are largest when households are in autarky and do not have access to any risk smoothing technology: introducing migration is equivalent to a 31.6% increase in average consumption. The benefit is positive with borrowing and saving, but smaller: households already could mitigate income shocks and hence the additional mechanism of migration is less valuable. I estimate the consumption equivalent gain to be a 20.9% increase in average consumption. Finally, when markets are endogenously incomplete, the welfare benefit of migration is smaller again. First, migration is an additional mechanism to informal risk sharing, so the level effect of migration is smaller than under autarky. Second, the option to migrate endogenously changes the outside option of households and reduces informal insurance, so the welfare benefit is smaller than under borrowing-savings. I estimate the benefit of migration under limited commitment to be a 19.5% increase in consumption. Contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain from migration is 7% lower.

The table also shows the heterogeneous effects of migration by subgroup. Overall, the net welfare gain is positive, equivalent to a 19.5% increase in consumption-equivalent terms. The largest relative benefits from migration are to the households with many males who are most easily able to migrate. Welfare (in consumption-equivalents) for the landless households with many males increases by 27.8%, and for landless households with many males, 21.3%.

5.2.3 Risk sharing reduces migration

With risk sharing, the migration decision no longer depends on the gross income differentials between the village and the city, but the post-transfer income differential. There are two potentially offsetting effects of transfers on migration: a home effect, that reduces migration, and a destination effect, increasing migration. Migration rates under alterna-

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

tive risk sharing regimes are presented in the first panel of Table 9. With endogenous risk sharing, the mean migration rate is 15.6%. Without risk sharing, migration rates would be 40.0%. The net effect of risk sharing is to reduce migration by 60%. Column (2) of the table estimates the migration rate under borrowing-saving; it is slightly higher than autarky, at 39.2%. Under this latter regime, agents are able to self-insure negative migration outcomes through asset accumulation, and can keep the full amount of migration-related earnings because they do not need to make risk-sharing transfers.

5.3 Robustness

I run several robustness tests for the model. First, I reestimate the model for different values of the coefficient of relative risk aversion. As discussed above, the coefficient of relative risk aversion and the discount factor are highly negatively correlated, making it difficult to separately identify the two parameters. The baseline results set the coefficient of relative risk aversion to 1.6. Increasing the correlation of relative risk aversion to either 2 or 2.5 decreases the estimated discount factor (to 48.2% and 43.9%, respectively) as expected. The results on risk sharing and welfare from introducing migration are robust, and are in fact larger in magnitude: risk sharing falls by 47% when gamma is 2.5. The second 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 with high income shocks, and so persistent shocks increases 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 slightly increases from 57% to 62%. However, I find little evidence in the data that income is in fact autoregressive.[27] The third robustness run of the model is to change the aggregate shock process. The baseline aggregate shock process is a process with a bad aggregate shock reducing income by 20%, which occurs with probability $\pi = 0.3$. I instead set the aggregate shock process to be less severe, and more common (based on the discussion in Section 4.3.1): a

[27] 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 in Appendix Table 3.

scaling factor of 10%, which occurs with probability $\pi = 0.5$. With this income shock process I estimate a discount factor of 60.4%. The relative benefit of migration is uniformally smaller: this aggregate shock process removes one of the main advantages of migration, namely the ability to smooth uninsurable aggregate risk. As a result, the benefit of migration under autarky is reduced (a gain equivalent to 17.0% increase in consumption, compared with 19.5% in the baseline).

5.4 Policy implications

I now consider the policy implications of the joint determination of migration and risk sharing. I first examine the Indian Government's National Rural Employment Guarantee Act (NREGA), a large-scale public works program. I then examine a set of separate policies that target migration itself: increasing economic growth in the city; decreasing the utility cost of migrating; and decreasing the variance of migration income.

5.4.1 Effect of the NREGA policy

The NREGA, introduced in 2005, is the largest rural employment scheme in the world, providing 55 million households with employment during 2010-11 (Government of India, 2011). The NREGA guarantees 100 days of work to each rural household. I model the scheme as a form of insurance, providing a minimum income level in the village, and examine the effect on migration and risk sharing.[28]

What is the welfare effect of the change in risk sharing and the change in migration? Other studies have documented how public transfers may crowd out informal risk sharing and hence reduce the welfare gains of policies (Attanasio and Rios-Rull, 2000; Albarran and Attanasio, 2002, 2003; Golosov and Tsyvinski, 2007; Thomas and Worrall, 2007; Krueger and Perri, 2010). I show this effect is present in my model. The break-down in informal risk sharing crowds out the welfare gain of the policy. However, in my model,

[28]What follows can be interpreted as an ex-ante evaluation of the NREGA policy. Ex-post there were many difficulties and irregularities in implementing the NREGA scheme. For a detailed discussion of the NREGA see Papp (2012). In addition, Imbert and Papp (2012) show that the NREGA has general equilibrium effects on wages. I abstract from this effect in the analysis.

there is an additional dimension that is crowded out. The rural employment scheme increases income in the village, directly substituting for migration. Comparing the effects of the policy under exogenously incomplete markets to the effect under endogenously incomplete markets, the welfare gain of the policy is 50-65% lower after household risk sharing and migration responses are considered. The key implication for policy is that households will adjust both risk sharing and migration, and it is necessary to consider both margins to fully understand the welfare effects of this development policy.

Table 10 shows the effect of the NREGA policy under alternative economic environments. I first consider the case when 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 NREGA will act as a targeted income transfer. Column (1) shows that under autarky and no migration the welfare benefit of the NREGA is equivalent to a 38.3% increase in average consumption. In comparison, if households are able to smooth income shocks, the marginal benefit of the NREGA income transfer is smaller. I examine this in two steps: a 'level' effect, by examining autarky to exogenously incomplete insurance, and then a 'crowding out' effect', comparing exogenously incomplete insurance to endogenously incomplete insurance. 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 autarky: 22.8%. 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 NREGA. The welfare effect of the policy is smaller than under exogenously incomplete markets, 10.8%, due to the crowd-out of informal insurance.

Table 10 shows the welfare effects under migration. The NREGA increases income in the village, reducing migration. The welfare effect of the NREGA policy is smaller, because migration is already a mechanism for households to smooth income shocks: households substitute away from migration towards the publicly provided insurance. The benefit of the scheme is 11.3% if households are autarkic. Note the difference in the effect of the NREGA when households are autarkic: 38.3% without migration, and 11.3% with migration. Accounting for endogenous migration is important, regardless of the insurance environment. Columns (5) and (6) repeat the analysis for exogenously incomplete and endogenously incomplete insurance. The same pattern as in the environment without migration holds. The benefit of the policy when households can borrow or save is 8.4%, and then once the endogenous change in insurance is taken into account, the final welfare benefit of the NREGA is 2.6% under limited commitment with migration.

The cost of the policy can be approximated from the migration response. If there is relatively less migration, this means that fewer people are migrating, as so more households will take up the NREGA work offer. The third panel of Table 10 shows that the largest drop in migration is when markets are endogenously incomplete. Under limited commitment, the overall migration rate is 30% of what it would have been without NREGA (i.e. a reduction of 70%) compared with 70% when markets are exogenously incomplete (i.e. a reduction of only 30%). Therefore, not only is the benefit smaller, but the cost is also larger.

5.4.2 Other migration policies

I consider the effects of three additional policies targeted toward migration: economic growth in the city, a decrease in the utility cost of migrating, and a decrease in the variance of migration income. All three policies increase the level of migration, but have different effects on risk sharing and welfare. Table 11 shows the results. The first policy experiment increases migration income of 20%, approximating the effect of economic growth in the city. Risk sharing increases, driven by an increase in net transfers from wealthier migrants to other members in the village. Welfare increases. The second experiment decreases the utility cost of migrating by 50%. Risk sharing decreases. This is because ex post income does not change, but the reduction of the utility cost increases the ex ante outside option of households, crowding out transfers. The welfare effect is positive, driven by the lower utility cost for those who migrate. The third experiment decreases the variance of migration income by 50%. This experiment can be thought of as provision of migration insurance. Here the effect of limited commitment risk sharing is the most striking: under endogenous risk sharing this policy actually causes welfare to decrease by 8.6% (compared with an increase of 5.8% under autarky). This is explained by the offsetting income and risk sharing effects. In this example, there is no positive income effect because the mean of the migration process is unchanged. However, the decrease in variance increases the outside option of households and crowds out risk sharing. As a result, the net effect is to decrease welfare.

6 Conclusion

Economists have long studied the complex systems of informal insurance between households in developing countries. Informal insurance is important because formal markets are generally absent in 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 migration decision of the household *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, hence changing the structure of endogenous risk sharing. I demonstrate how the welfare effect of migration can be decomposed into an income effect and a risk-sharing effect. I then show how risk sharing alters the returns to migration, and determines the migration decision.

Second, I estimate the model structurally on 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) migration reduces risk sharing by 23%; (2) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain of migration is 7% lower; (3) risk sharing reduces migration by 60%.

Third, the fact that households make both risk sharing and migration decisions jointly has 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 villages (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 NREGA 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 50-65% 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 migration, it is reasonable to think that many other decisions that poor households make may also be jointly determined with informal insurance. A fruitful avenue for future research may be to examine the the implications of the joint determination of informal risk sharing and investment or production decisions.

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Figures and Tables

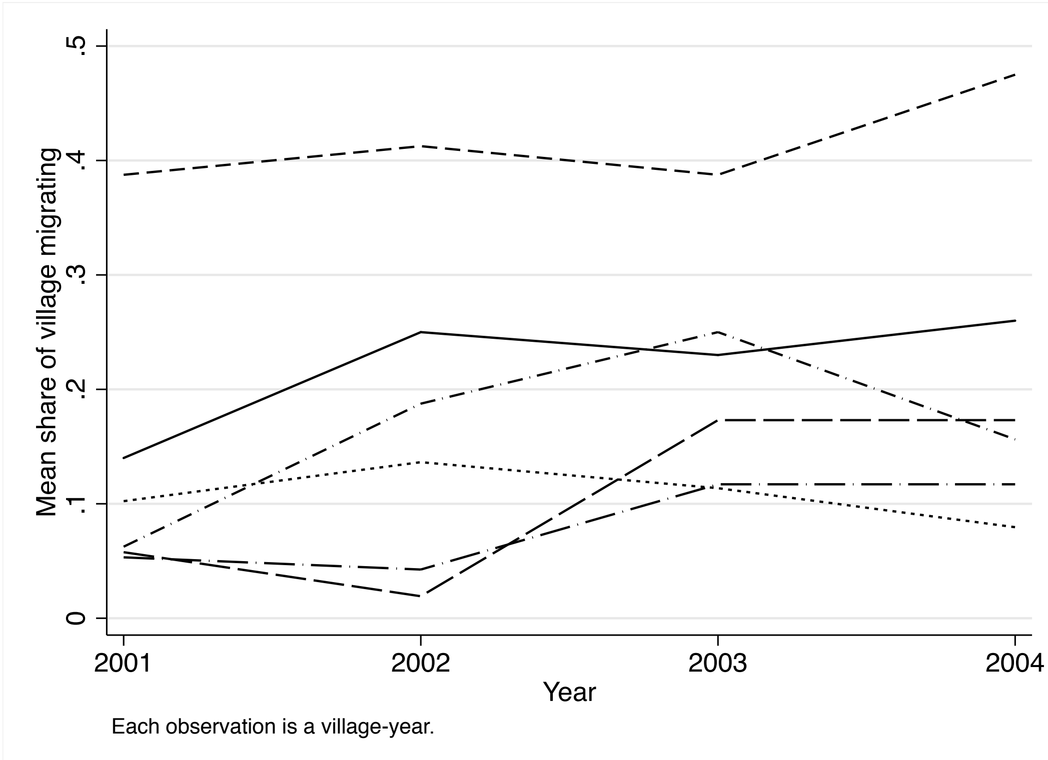


Figure 1: Migration varies over space and time: Temporary migration in the six ICRISAT villages over time.

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

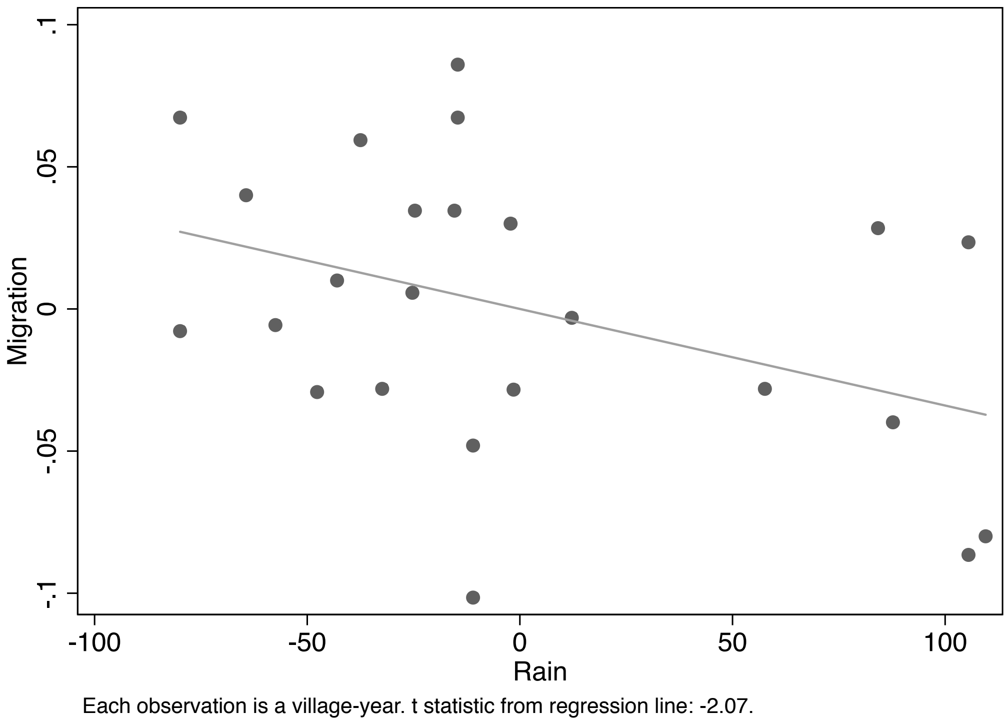


Figure 2: Verifying model assumptions: Temporary migration responds ex-post to income shocks.

Notes: The figure plots the relationship between de-meaned migration rate and de-meaned 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.

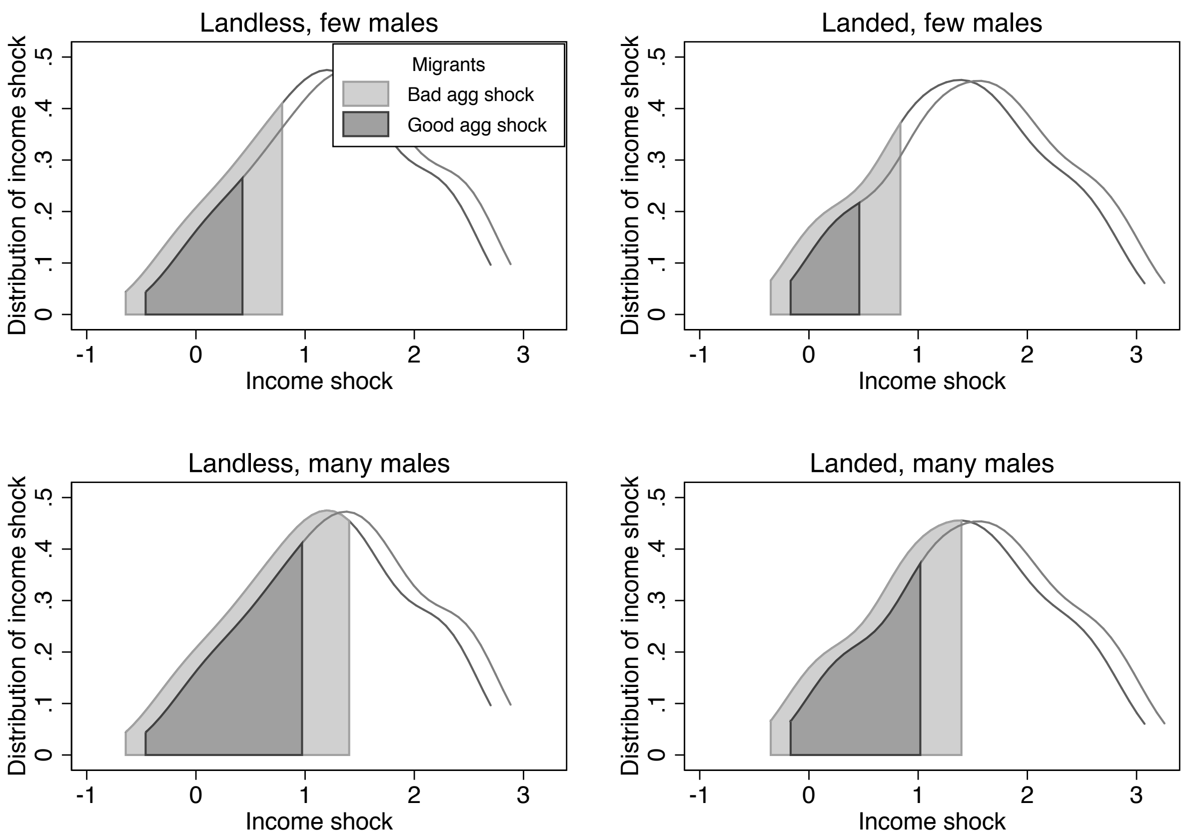


Figure 3: Structural estimation: Income distribution and selection into migration by population subgroup

Notes: The figure plots the migration and income distribution for each subgroup (males/land) for good and bad aggregate shocks. Computed from structural estimation results. The shaded area represents the agents who migrate in each period. Because the income process is discretized, I use the median income of migrants as the threshold to highlight the differences between aggregate and idiosyncratic shocks.

Table 1: Summary statistics

Mean/sd	(1) All	(2) Ever Migrate	(3) Never Migrate
Total income	22.66	23.50	22.12
	(18.27)	(17.68)	(18.63)
Non-migration income	21.49	18.72	23.24
	(22.66)	(22.16)	(22.82)
Migration income	2.38	6.15	0.00
	(6.10)	(8.54)	(0.00)
Total consumption	26.81	26.91	26.74
	(16.33)	(15.85)	(16.63)
Per capita consumption	6.79	6.29	7.11
	(4.26)	(4.47)	(4.09)
Owned land	4.83	4.45	5.08
	(5.61)	(5.96)	(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)	(1.64)	(1.56)
Number adult males	1.91	2.23	1.72
	(1.08)	(1.07)	(1.03)
Number migrants		1.77	
		(0.96)	
Share household migrating		0.33	
		(0.19)	
Migration length (days)		191.02	
		(103.97)	
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: Transfers are insurance

Dep. variable: Transfers	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Total Income	-0.951***	-0.832***	-0.967***	-0.847***
	(0.032)	(0.034)	(0.031)	(0.033)
Stock of transfers		-0.249***		-0.256***
		(0.024)		(0.024)
Village-Year FE	No	No	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
r2	0.698	0.718	0.731	0.752
N	1449	1238	1449	1238

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 3: 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	1492	606	393	336	1277
	(483)	(524)	(311)	(487)	(891)
Household FE	Yes	Yes	Yes	Yes	Yes
Mean dep. variable	5828	6856	-598	292	6231
R-squared	0.652	0.515	0.215	0.304	0.369
Number observations	1449	1449	1493	1493	1513
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 4: Test for perfect risk sharing

	Combined sample		VLS2 only	
	(1)	(2)	(3)	(4)
Dep. variable: Consumption	b/se	b/se	b/se	b/se
Income	0.207***	0.206***	0.071***	0.028
	(0.031)	(0.031)	(0.016)	(0.022)
VLS2 *X* Income	-0.099***	-0.141***		
	(0.036)	(0.037)		
Mean village migration *X* Income		0.236**		0.243*
		(0.117)		(0.121)
Village-Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
R-squared	0.685	0.686	0.627	0.630
Number observations	2422	2422	1446	1446

Notes: OLS regressions of log income on log consumption. Standard errors clustered at village-year level for all columns. Combined sample is VLS1 and VLS2. VLS1 is ICRISAT data 1975-1983. VLS2 is ICRISAT data 2001-2004. Mean village migration interacts the average village level of temporary migration with individual income.

Table 5: Goodness of fit of model to data

	(1) Data	(2) Model
Moments targeted during estimation		
Mean of non-migrant income	5.837	5.849
Std dev non-migrant income	4.261	4.128
Mean of non-migrant income: own land	6.525	6.383
Mean of migrant income	5.802	5.531
Std dev migrant income	3.736	3.571
Mean migration rate	0.197	0.170
Mean migration rate: male hh	0.306	0.259
Correlation of consumption and income	0.223	0.235
Mean non-migrant consumption	5.962	5.850
Mean migrant consumption	5.289	5.673
Percent nonmigrants receiving transfer	0.548	0.604
Percent migrants receiving transfer	0.427	0.627
Moments not targeted during estimation		
Percent migrating this year if migrated last year	0.654	0.428

Notes: Table reports how well the model matches the data by moment. All monetary values are 000's of rupees per adult equivalent in household.

Table 6: Structural point estimates (by village)

	A b/se	B b/se	C b/se	D b/se	E b/se	Average b/se
Village income						
Mean of village shock process	1.411	1.156	1.207	1.000	1.028	1.160
	(0.075)	(0.252)	(0.177)	(0.004)	(0.173)	(0.072)
Std. dev of village shock process	0.677	0.619	0.851	0.959	0.747	0.771
	(0.031)	(0.300)	(0.087)	(0.124)	(0.019)	(0.068)
Migration income						
Mean of migration income process	1.844	1.594	1.591	1.952	1.439	1.684
	(0.016)	(0.067)	(0.439)	(0.038)	(0.143)	(0.094)
Std. dev of migration income process	0.933	0.932	1.156	0.713	1.300	1.007
	(0.029)	(0.015)	(0.214)	(0.152)	(0.353)	(0.088)
Utility cost of migrating						
Utility cost of migrating	0.142	0.074	0.132	0.396	0.177	0.184
	(0.348)	(0.088)	(0.001)	(0.070)	(0.275)	(0.092)
Preference parameters						
Discount factor	0.619	0.656	0.556	0.432	0.585	0.570
	(0.092)	(0.074)	(0.031)	(0.104)	(0.118)	(0.040)
Heterogeneity parameters						
Scaling utility cost for male	-0.843	-0.477	-0.240	-0.244	-0.581	-0.477
	(0.417)	(0.064)	(0.361)	(1.290)	(0.585)	(0.304)
Scaling mean for land	0.514	0.054	0.001	0.340	0.422	0.266
	(0.221)	(0.133)	(0.166)	(0.110)	(0.316)	(0.091)
Exogenous parameters						
Coefficient of relative risk aversion	1.600	1.600	1.600	1.600	1.600	1.600
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). Three parameters are set exogenously: the coefficient of relative risk aversion, the share of household income from migration and the scaling effect of a good aggregate shock.

Table 7: Effect of migration on village income and income of migrants

	(1) Data	(2) Model
Income of Migrants		
Observed mean income	5.802	5.531
Mean income if stayed in village		2.279
Share of migrants with income gain		0.814
Village Income		
Observed mean income of non-migrants	5.837	5.849
Mean of untruncated village income distribution		5.240

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 8: Effect on risk sharing of introducing 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	0.215	0.265	0.204	0.260
Landless, few males	0.283	0.275	0.277	0.274
Landed, few males	0.163	0.194	0.161	0.195
Landless, many males	0.283	0.346	0.279	0.368
Landed, many males	0.163	0.260	0.160	0.263

Notes: Table compares risk sharing in an economy with migration to the same economy without migration. 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 9: Effect of allowing migration under different risk sharing regimes

	(1) Autarky	(2) Exogenous incomplete	(3) Endogenous incomplete
Migration rate			
Overall	0.400	0.392	0.156
Landless, few males	0.409	0.357	0.091
Landed, few males	0.291	0.262	0.053
Landless, many males	0.490	0.527	0.307
Landed, many males	0.409	0.423	0.172
Welfare gain relative to no migration			
Overall	1.165	1.084	1.073
Landless, few males	1.183	1.084	1.087
Landed, few males	1.108	1.051	1.043
Landless, many males	1.232	1.124	1.106
Landed, many males	1.137	1.075	1.056
Consumption equivalent gain relative to no migration			
Overall	0.316	0.209	0.195
Landless, few males	0.313	0.191	0.213
Landed, few males	0.218	0.130	0.120
Landless, many males	0.432	0.309	0.278
Landed, many males	0.299	0.207	0.168

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 10: 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	0.383	0.228	0.108	0.113	0.084	0.026
Landless, few males	0.453	0.270	0.132	0.153	0.112	0.016
Landless, many males	0.314	0.185	0.084	0.111	0.080	0.031
Landed, few males	0.453	0.270	0.132	0.106	0.082	0.034
Landed, many males	0.314	0.185	0.084	0.080	0.062	0.021
Correlation between income and consumption with NREGA relative to pre-NREGA						
Overall			2.879			1.768
Landless, few males			3.022			3.270
Landless, many males			2.735			1.462
Landed, few males			3.022			1.084
Landed, many males			2.735			1.257
Migration rate with NREGA relative to pre-NREGA						
Overall				0.700	0.702	0.317
Landless, few males				0.600	0.501	0.000
Landless, many males				0.600	0.511	0.000
Landed, few males				0.800	0.911	0.359
Landed, many males				0.800	0.886	0.501

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.

Table 11: Migration policy experiments

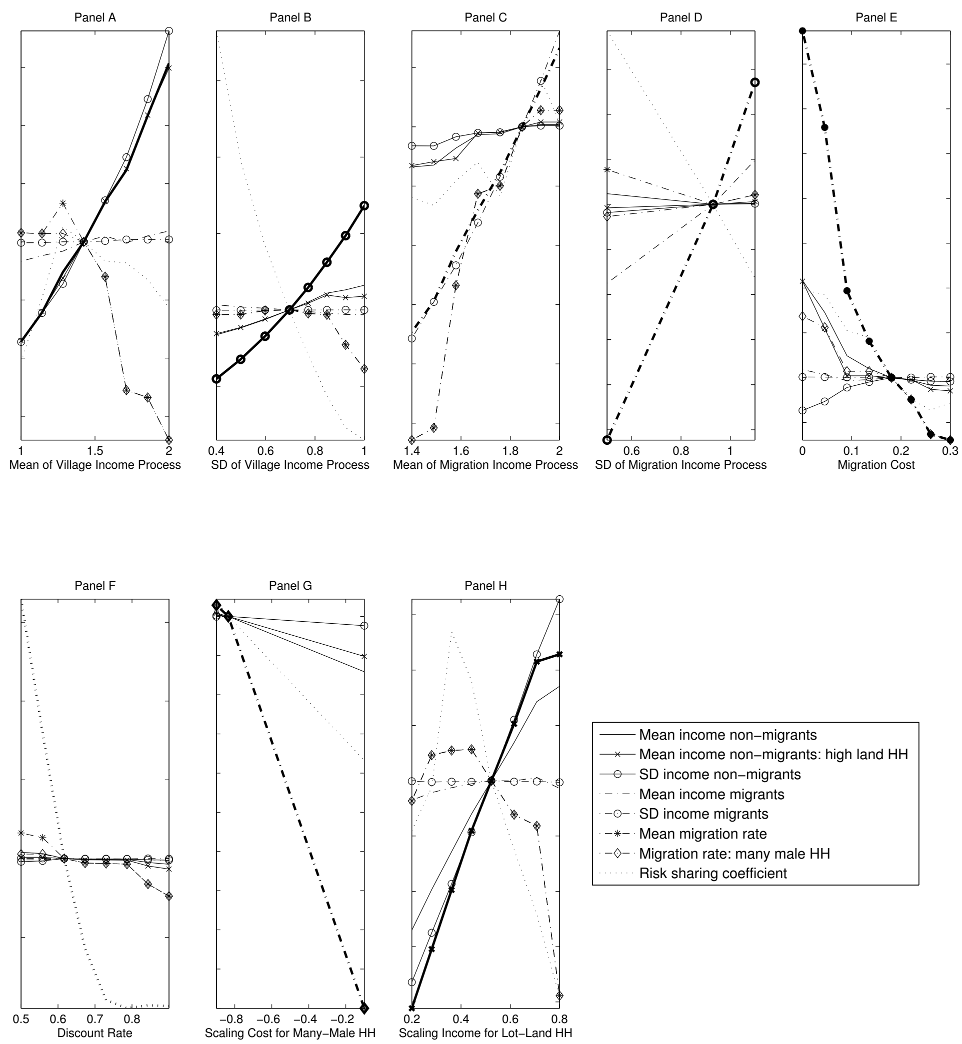
	(1) Full model	(2) No risk sharing
Increase migration income by 20%		
Relative migration rate	0.355	1.336
Relative correlation between income and consumption	0.375	
Consumption-equivalent gain	0.134	0.046
Decrease migration cost by 50%		
Relative migration rate	2.673	1.224
Relative correlation between income and consumption	1.546	
Consumption-equivalent gain	0.036	0.034
Decrease migration variance by 50%		
Relative migration rate	1.594	1.039
Relative correlation between income and consumption	2.129	
Consumption-equivalent gain	-0.086	0.058

Notes: Policy shows the change from the baseline estimates for three separate policy experiments.

NOT FOR PUBLICATION

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: 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 3: No evidence of income persistence

	(1)	(2)
	OLS	Arellano-Bond estimator
Dep. variable: Log Income	b/se	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.

B Theoretical appendix

B.1 Proof of Proposition 2.1

Under autarky, migration is perfectly negatively selected on income realization in the village. Under perfect risk sharing, migration is perfectly negatively selected on income realization in the village, conditional on the time invariant pareto weights.

Proof:

Let $Y(s)$ denote total income if agent i doesn't migrate, and $Y(s,q)$ denote total income if i migrates and the outcome is q. Let $\Delta Y(q) = m^i(q_t) - e^i(s_t)$ be the change in total income if household i migrates and their income in the village is $e^i(s^t)$. Under autarky, agent i migrates if the expected utility gain is positive:

$$\begin{aligned} \text{Migrate} &= \mathbb{I}\{\sum_q \pi(q)u(m(q)) - d \geq u(e(s))\} \\ &= \mathbb{I}\{\sum_q \pi(q)u'(e(s))\Delta Y(q) \geq d\} \\ &= \mathbb{I}\{h(q,e(s)) \geq d\} \end{aligned} \tag{10}$$

The selection equation $h(q,e(s))$ is strictly decreasing in $e(s)$, so agents with the lowest incomes will have the highest returns to migration. Under perfect risk sharing i consumes a constant share α^i, of total resources. Agent i migrates if the joint expected utility gain is positive:

$$\begin{aligned} \text{Migrate} &= \mathbb{I}\{\sum_q \pi(q)[\lambda^A u'(\alpha^A Y(s))\alpha^A \Delta Y(q) + \lambda^B u'(\alpha^B Y(s))\alpha^B \Delta Y(q)] \geq \lambda^i d\} \\ &= \mathbb{I}\{h(q,e^i(s),\lambda^A,\lambda^B) \geq \lambda^i d\} \end{aligned} \tag{11}$$

The selection equation $h(q,e^i(s),\lambda^A,\lambda^B)$ is strictly decreasing in $e^i(s)$. Conditional on the time invariant pareto weights λ^i, agents with the lowest incomes will migrate.

B.2 Proof of Proposition 4.1

For a given 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*

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

Further, the partial derivatives of α^c with respect to its arguments are signed as following: $\alpha^c_1(\alpha^\Omega,\beta,\gamma) < 0, \alpha^c_2(\alpha^\Omega,\beta,\gamma) < 0$, 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).

C Computational appendix

The computational appendix discusses the assumptions required to move from 2 to N households in the estimation procedure and the algorithm to solve the limited commitment game with endogenous migration.

C.1 Moving from 2 to N households

The model presented above was for two households. 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 (2011)) 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:

$$\frac{u'(c^i)}{u'(c^H)} = x^i \ \forall i \neq H$$

Then, by CRRA utility, for all $i \neq H$

$$\frac{\tilde{c}^i}{\tilde{c}^H} = (x^i)^{-1/\gamma}$$

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

$$\frac{\sum_{i \neq H} \tilde{c}^i}{\tilde{c}^H} = \sum_{i \neq H} (x^i)^{-1/\gamma}$$

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

$$\frac{\tilde{c}^{-H}}{\tilde{c}^H} = \frac{1}{N-1} \sum_{i \neq H} (x^i)^{-1/\gamma}$$

Then:

$$(\frac{\tilde{c}^{-H}}{\tilde{c}^H})^{\gamma} = (\frac{1}{N-1} \sum_{i \neq H} (x^i)^{-1/\gamma})^{\gamma} = x^{-H}$$

$$\frac{u'(\tilde{c}^H)}{u'(\tilde{c}^{-H})} = x^{-H}$$

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 of the rest of the village.

The weighted average pareto weight comes from the first order conditions for N households, taking N participation constraints into account. When the 2 household approximation is used, the participation constraints for all the other households are collapsed into one participation constraint. The approximation error is the difference in the value of the endogenous pareto weight computed with N relative pareto weights and N realizations of this period income, compared with the relative pareto weight computed with only one relative weight.

$$x_t^{-H}(x_{t-1}^1, x_{t-1}^2, ..., x_{t-1}^N, s_1, s_2, ..., s_N) - \hat{x}_t^{-H}(x_{t-1}^{-H}, s)$$

C.2 Algorithm to solve the limited commitment problem

I consider two agents: agent A and agent B (the rest of the village). We solve for the migration decision of person A, taking into account that migration must be consistent with the total resources available to the network (i.e. on the endowments of person B). I base the ex-post component of the algorithm on Laczo (2011).

To solve the algorithm I work with a recursive form. Let s define the state of the world in the village, and q define the state of the world in the migration destination. Let the pareto weight at the start of the period be given by x. The social planner's value function, $V(x,s)$ is a weighted average of the value function for household A and household B:

$$\begin{aligned} V(x,s) &= V^A(x,s) + xV^B(x,s) \\ V^A(x,s) &= u(c^A(x',s)) + \beta V^A(x',s') \\ V^B(x,s) &= u(c^B(x',s)) + \beta V^B(x',s') \end{aligned}$$

We look to find V_A and V_B by value function iteration.

The algorithm is solved in several steps:

1. Outer loop on total resources: migration affects the total resources available to the network. We need to find the fixed point of the migration decision such that the migration decision is consistent with the implied total resources in the network.

2. Ex-post decision: for each state in the village and possible migration outcome, we solve the ex-post constrained problem to find efficient transfers.

3. Ex-ante decision: choose the optimal migration decision, making sure to satisfy ex-ante participation constraint

Define the following, all computed recursively:

- The ex-ante participation constraint

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

- The ex-post participation constraint

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

- First-best risk-sharing (no migration)

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

We are now ready to begin the algorithm.

1. Guess the migration rule for household A and construct the rest-of-village resources for household B
2. Define two grids: a no-migration grid on s (state of the world) by x (value of pareto weight), and a migration grid on q (migration outcome) by x
3. Guess an initial value for the value function: $V^i_0(s) = \max(V^i_{\text{first-best}}(s), \Omega^i_{\text{ex-ante}}(s))$
4. Solve the ex-post problem for each point on the no-migration grid
   - Examine the grid point (s_t, x_{t-1})
   - Set $x_t = x_{t-1}$
   - Check whether the participation constraints are satisfied for each agent at this point:

   $$u(c^i(s_t, x_t)) + \beta \mathrm{E}V^i_{t-1}(x_t, s_{t+1}) \geq \Omega^i_{\text{ex-post}}(s_t)$$

     If not, find x^*_t such that participation constraints are satisfied for both agents, and the resource constraint is satisfied
   - Set $x_t = x^*_t$
   - Update the value function

   $$V^i_{\text{no mig},t}(s_t, x_t) = u(c(s_t, x_t)) + \beta \mathrm{E}V^i_{t-1}(x_t, s_{t_1})$$

5. Solve the ex-post problem for each possible migration outcome on the migration grid
   - Examine the grid point (s_t, q_t, x_{t-1})
   - Set $x_t = x_{t-1}$
   - Check whether the participation constraints are satisfied for each agent at this point:

     $$u(c^i(s_t, q_t, x_t)) + \beta \mathrm{E} V^i_{t-1}(x_t, s_{t+1}) \geq \Omega^i_{\text{ex-post}}(s_t, q_t)$$

     If not, find x^*_t such that participation constraints are satisfied for both agents, and the resource constraint is satisfied
   - Set $x_t = x^*_t$
   - Update the value function

     $$V^i_{\text{migration}}(s_t, q_t, x_t) = u(c(s_t, q_t x_t)) + \beta \mathrm{E} V^i_{t-1}(x_t, s_{t_1})$$

6. Find the expected value of migrating

   $$V^i_{\text{migration}}(s_t, x_t) = \mathrm{E} V^i_{\text{migration}}(s_t, q_t, x_t)$$

7. Solve for the optimal migration decision

   $$\mathbb{I} = 1 \text{ if } \sum_i V^i_{\text{migration}}(s_t, x_t) \geq \sum_i V^i_{\text{no mig},t}(s_t, x_t)$$

   - Check that the ex-ante participation constraint is satisfied

     $$\mathbb{I}(V^i_{\text{migration}}(s_t, x_t)) + (1 - \mathbb{I})(V^i_{\text{no mig},t}(s_t, x_t)) \geq \Omega^i_{\text{ex-ante}}(s_t)$$

     If the ex-ante condition is not satisfied, set $\mathbb{I} = (1 - \mathbb{I})$

8. Update the value function for period t

   $$V^i_t(s_t, x_t) = \mathbb{I}(V^i_{\text{migration}}(s_t, x_t)) + (1 - \mathbb{I})(V^i_{\text{no-mig,t}}(s_t, x_t))$$

9. Iterate Steps 2-8 until convergence on $V^i_t(s_t, x_t)$

10. Update Step 1 with vector of migration outcomes

11. Iterate Steps 1-10 until the vector of migration outcomes converges