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. I study a dynamic model of risk sharing with limited commitment frictions and endogenous temporary migration. First, I characterize the model. I demonstrate theoretically how migration may decrease risk sharing. I decompose the welfare effect of migration into changes in income and 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 55%; (2) migration reduces risk sharing by 38%; (3) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain from migration is 12% lower. Third, I introduce a rural employment scheme. The policy reduces migration and decreases risk sharing. The welfare gain of the policy is 20-40% lower after household risk sharing and migration responses are considered.

Keywords: Internal migration, Risk Sharing, Limited Commitment, Dynamic Contracts, India, Urban, Rural
JEL Classification: D12, D91, D52, O12, R23

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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, and 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 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 37%; (2) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain in welfare from migration is 12% lower; (3) risk sharing reduces migration by 55%. 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 20-40% lower after household risk sharing and migration responses are considered.

The joint model of migration and risk sharing is a novel contribution. I discuss how the theoretical findings from my model relate to the broader literature on migration and risk sharing. The three theoretical results are as follows.

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).1 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

1Of course, there are many other explanations for imperfect risk sharing, including moral hazard (Ligon, 1998; Lim and Townsend, 1998; Townsend and Karaivanov, 2010), ambiguity aversion (Bryan, 2010), and hidden income (Kinnan, 2010).
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; Chandrasekhar, Kinnan and Larreguy, 2010).

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 (Golosov and Tsyvinski, 2007; Townsend and Karaivanov, 2010). When markets are exogenously incomplete, migration does not alter the structure of the insurance market. Specifically, I consider a model where households can borrow and save a risk-free asset (as in 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.

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. 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, 2011; 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.\footnote{Other household surveys in India find widespread temporary migration of up to 50\% \cite{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 (2011) (Bangladesh).} I establish four empirical facts relating migration to risk sharing in these data. 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 38\% 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 16\% 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 12% 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 55%.

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 20-40% 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 exit the risk sharing network if they migrate (Banerjee and Newman, 1998; Munshi and Rosenzweig, 2009). Rather than take the decision between participating in informal risk sharing and migration to be a binary one, 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. This complements literature examining the effects of migration on the income distribution of origin communities (Barham and Boucher, 1998; McKenzie and Rapoport, 2007; Giles, 2006, 2007). In addition, because migration may generate an externality through reduced risk sharing, the framework differentiates between private returns and social returns. Many studies,
both in developing and developed countries, find high private returns to migration (Gibson, McKenzie and Stillman, 2010; Beegle, de Weerdt and Dercon, 2011; Clemens, 2011; Kennan and Walker, 2011; Bryan, Chowdhury and Mobarak, 2011). If risk sharing is reduced as a result of migration, the welfare gain from migration is lower. In other words, the rural-urban wage differential may overstate the benefits of migration.

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

This section presents the model of risk sharing with endogenous temporary migration. The model is a model of inter-household risk sharing. I construct this model in three steps. Section 2.1 presents a model of migration with exogenous risk sharing transfers. Section 2.2 presents the limited commitment model of risk sharing without migration. Section 2.3 merges the first two components together to present the full model of limited commitment risk sharing with endogenous temporary migration. I use the model to derive three theoretical results: the effect of risk sharing on migration; the effect of migration on risk sharing; and the decomposition of the welfare effect of migration.

2.1 Migration with exogenous risk sharing

This section develops a model of temporary migration with exogenous risk sharing transfers. I use a reduced-form model to derive comparative statics for the effect of risk sharing on migration. I show that an increase in risk sharing will have two potentially offsetting effects on migration.

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3The 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).
I model agents migrating in respond to income differences between the village and a city. Agents face a utility cost if they migrate. This 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). Because of the utility cost of migrating, households may not find it optimal to migrate, even if there is a positive rural-urban wage differential. Agents observe the amount of income in the village and make a decision about whether to migrate. Migration is temporary: if a household sends out a migrant, the migrant returns to the village at the end of the period. Assume that the agent has income $e$ in the village, and expects to earn income $m$ if they migrate. If an agent migrates, they pay a utility cost $d$. The agent will migrate if the expected utility gain of doing so is positive:

$$Eu(m) - d > u(e).$$

Now, consider that the agent also receives transfers (either positive or negative), denoted by $\tau$, from a risk-sharing network. The agent remains part of the network if they migrate. Transfers are made ex-post of the migration decision. Assume that the transfers depend on the agent’s income, and a penalty $p$ levied by the network if agents do not make transfers. The key attribute of risk sharing transfers is that they provide insurance against bad income shocks. Agents receive transfers when they have low income and make transfers when they have high income. This is captured by assuming $\frac{\partial \tau(y, p)}{\partial y} < 0$. Assume also that the degree of risk sharing depends on the exogenous penalty. This is captured by assuming that the absolute value of transfers is a function of the penalty: $\frac{\partial |\tau(y, p)|}{\partial p} > 0$.

With risk sharing, the agent considers post-transfer, instead of gross, income differen-

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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’i where per capita income is $21,000.

5 In this paper I examine temporary migration as a household response to income shocks. There are many other reasons why households migrate. For example, migration may be an ex-ante income diversification strategy (Rosenzweig and Stark, 1989; Stark and Bloom, 1985; Hoddinott, 1994). Because I analyze the temporary migration decision itself, I also do not consider how remittances from migrants already outside the village may respond to income shocks of the household, as in Rosenzweig (1988), Yang and Choi (2007) and Yang (2008).
tials. The agent migrates if the expected utility gain is positive:

\[ Eu(m + \tau(m, p)) - d > u(e + \tau(e, p)). \]

We want to derive the effect of risk sharing on migration. To do this, consider the effect of an exogenous increase in the penalty \( p \). An increase in \( p \) will increase the magnitude of the risk sharing transfer because it becomes more costly to not participate fully in risk sharing. As a result, agents who receive a positive transfer receive a larger transfer, and agents who make a transfer make a larger transfer.

Consider an agent who is indifferent between migrating and staying:

\[ Eu(m + \tau(m, p)) - d = u(e + \tau(e, p)). \]

An increase in the penalty will have two offsetting effects on migration. For a small increase in \( p \), the agent will now migrate if:

\[
\underbrace{E \frac{\partial \tau(m, p)}{\partial p} u'(m + \tau(m, p))}_\text{Destination effect: change to expected migration income} > \underbrace{\frac{\partial \tau(e, p)}{\partial p} u'(e + \tau(e, p))}_\text{Home effect: change to village income}
\]

The overall effect of an improvement in risk sharing on migration depends on the relative magnitude of the destination and home effects. With respect to the home effect, the expected gain from migration is not the gross income difference between the village and the migration destination, but the post-transfer difference. The agents with the highest expected utility gain from migrating are the agents with low income realizations. However, 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. Regarding the destination effect, 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, increasing the expected utility of migrating, and
increasing migration.

Next, I consider how the risk sharing transfers are determined.

### 2.2 Limited commitment risk sharing without migration

This section presents the limited commitment risk sharing without migration (Kocherlakota, 1996; Ligon, Thomas and Worrall, 2002). The following section adds temporary migration to this model.\(^6\)

The risk sharing problem is to find transfers that maximize the joint utility of both households, subject to the constraint that households can walk away from the agreement.\(^7\)

In other words, risk sharing is constrained by a condition that households must gain as much utility from participating in the network as not participating. The first-best allocation of resources is perfect risk sharing, where each agent receives a constant share of total resources. Under perfect risk sharing, the correlation between income and consumption is zero. However, with limited commitment, a positive correlation between income and consumption can arise because households with high income shocks have a relatively desirable outside option of walking away from the risk-sharing network. As a result, agents with a high income have higher consumption, generating a positive correlation between income and consumption.

Consider a two household economy. Households have identical preferences.\(^8\) Households receive a draw from an income distribution each period. There are no financial markets: agents cannot save or borrow. The state of the world in the village is indexed by \(s\), which takes a finite number of values, \(s = \{1, 2, ..., S\}\). The realization of the state of the world determines the endowment income for each household. The endowments for the two households, \(A\) and \(B\), in state \(s\) are given by the vector \(e(s) = \{e^A(s), e^B(s)\}\).

Let \(s_t\) be the realization of the state of the world in period \(t\), and \(s^t\) denote the history

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\(^6\)See also Coate and Ravallion (1993); Kehoe and Levine (1993); Attanasio and Rios-Rull (2000); Dubois, Jullien and Magnac (2008) for other limited commitment models.

\(^7\)In this paper, 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.

\(^8\)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).
of the realizations of the state of the world up to time $t$, $s^t = \{s_0, s_1, ..., s_t\}$. The state of the world is governed by a Markov transition matrix $\Pi$, with $\pi_{s',s} = \pi(s_{t+1} = s' | s_t = s)$.

Slightly modifying the notation, I will refer to the vector $e$ in place of $s$. The key component of the limited commitment problem is the value of each household’s outside option. This is given by the present discounted value of consuming their endowment stream:

$$\Omega^i(e) = E \sum_{t=0}^{\infty} \beta^t u(e_t).$$

I present the recursive formulation of the limited commitment problem using the techniques of Marcet and Marimon (1998) and following Attanasio and Rios-Rull (2000). The equivalent date-zero problem is presented in Appendix A. The problem is recursive in two state variables: the current state of the world, $e$, and a summary measure, $x$, of the binding participation constraints up until that period. This summary measure $x$ is equivalent to the ratio of marginal utilities, and is referred to as an endogenous Pareto weight. The endogenous Pareto weight is updated at time $t$ to reflect the current period’s binding participation constraints.

The value function for household $A$ is expressed by $V^A(x,e)$ and similarly $V^B(x,e)$ for agent $B$. The social planner’s value function is a weighted sum which takes into account the endogenous weight of household $B$: $V(x,e) = V^A(x,e) + xV^B(x,e)$.

The social planner solves for transfers to maximize joint utility:

$$V(x,e) = \max_{\tau,x'} u(e^A + \tau) + xu(e^B - \tau) + \beta E \underbrace{V(x',e')}_{V^A(x',e') + x'V^B(x',e')} \quad (1)$$

subject to:

$$u(c^i) + \beta E V^i(x',e') \geq u(e^i) + \beta E \Omega^i(e'), \quad (2)$$

and:

$$c^A + c^B \leq e^A + e^B. \quad (3)$$

where (2) is the participation constraint that requires the utility gained from participating in the agreement to be as high as the outside option, and (3) is the budget constraint for
the economy.

**Definition 1.** A **constrained efficient allocation** is defined by two functions:

1. An updating rule for the endogenous Pareto weight \( x' = x'(x, e) \).

2. Transfer function \( \tau(e, x') = \{\tau^A, \tau^B\} \).

such that (1) is maximized subject to the participation constraints (2) and resource constraint (3).

The solution to this problem is a simple updating rule for the endogenous Pareto weight \( x \). *Ligon, Thomas and Worrall (2002)* show that the constrained efficient contract is a state-specific range of Pareto weights (and hence consumption shares) that simultaneously satisfy the participation constraints of both households. Specifically,

**Proposition 2.1** (Proposition 1, *Ligon, Thomas and Worrall (2002)*). The constrained efficient contract can be characterized as follows. There exist \( S \) state-dependent intervals \( [x_r, \bar{x}_r], r = 1, 2, \ldots, S \) such that \( x(e_t) \) evolves according to the following rule. Let \( e_t \) be given and let \( r \) be the state which occurs at time \( t + 1 \); then

\[
x(e_{t+1}) = \begin{cases} 
\bar{x}_r & \text{if } x(e_t) < \bar{x}_r \\
x(s_t) & \text{if } x(e_t) \in [x_r, \bar{x}_r] \\
x_r & \text{if } x(e_t) > \bar{x}_r 
\end{cases}
\]

### 2.3 Limited commitment with migration

I now bring together the separate models of (1) limited commitment risk sharing and (2) migration, to construct a model of limited commitment risk sharing with endogenous temporary migration. The key mechanism in the limited commitment model is the value of walking away and consuming the endowment stream. It is therefore a natural model with which to study the effect of migration because migration opportunities will change a household’s outside option: instead of consuming only the endowment in the village, the household will now have the opportunity to migrate.
Temporary migration is the option to work in the city for one period and return back to the village at the end of the period. To introduce temporary migration, I allow a household to make a decision about whether to migrate once they see what their income will be in the village for the year. 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 may change.

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. The timing in the model is as follows. Households observe their endowment in the village, and decide whether to send a migrant to the city. If a household sends out a migrant, they then realize their migration income. 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. The incentive compatibility constraints map to the two separate stages at which households can decide to walk away from any risk sharing agreement: ex-ante and ex-post of the migration decision. The ex-post participation constraint binds at the time when transfers are made, after all migration decisions have been made and final income is revealed (for example, a rich migrant does not want to transfer too much back to others in the village). The ex-ante participation constraint binds at the time migration decisions are made (for example, a household would rather not migrate even if it would be optimal for the network as a whole to migrate). 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.

The economic environment is as described above in Section 2.2, with the addition of an income process for migration. Migration income for each agent is an i.i.d. draw from a discrete migration income distribution. The state of the world in the migration destination is indexed by \( q \), which takes a finite number of values. The migration state is not realized until after migration decisions have been made. The migration income for each household in state \( q \) is given by \( m(q) = \{m^A(q), m^B(q)\} \), although this vector is only observed for agents who migrate. Slightly modifying the notation, I will refer to the
vector $m$ in place of $q$. Agents pay a direct utility cost $d$ if they migrate.

The option to migrate changes the outside option for households. The new value of autarky, $\Omega_m^i(e_i)$, incorporates the option to migrate:

$$\Omega_m^i(e_i) = E \sum_{t=0}^{\infty} \beta^t \max\{u(e_i^t), u(m_i) - d\}.$$  

We are now ready to solve for constrained efficient transfers and migration. The problem is solved recursively in two stages. First, conditional upon migration decisions ($\{I^A, I^B\}$) and the realization of migration outcome $m$, transfers are chosen to maximize joint utility such that the ex-post incentive compatibility constraints of both agents are satisfied. This yields the intermediate optimized value function $\tilde{V}(x, e, m, I^A, I^B)$. Second, given constrained-efficient transfers, migration is chosen to maximize expected joint utility such that the ex-ante incentive compatibility constraints of both agents are satisfied. The value function for the combined problem is given by $V(x, e)$.

The ex-post problem, conditional upon the migration decisions and migration outcome, is to choose transfers to maximize total utility:

$$\tilde{V}(x, e, m, I^A, I^B) = \max_{\tau} u(y^A + \tau) - I^A d + x(u(y^B - \tau) - I^B d) + \beta E V(x', e'),$$  \hspace{1cm} (1')

subject to

$$u(c^i) + \beta EV^i(x', s') \geq I^i u(m^i) + (1 - I^i)u(e^i) + \beta E \tilde{\Omega}_m^i(e'),$$  \hspace{1cm} (2')

and

$$c^A + c^B = (1 - I^A)e^A + I^A m^A + (1 - I^B)e^B + I^B m^B,$$  \hspace{1cm} (3')

where ex-post income for agent $i$ is given by $y^i = I^i m^i + (1 - I^i)e^i$, (2') represents the ex-post participation constraints, and (3') is the ex-post resource constraint for the economy.

The ex-ante problem takes the optimized ex-post value function, $\tilde{V}(x, e, m, I^A, I^B)$, and chooses migration in order to maximize expected joint utility, such that the ex-ante incen-
tive compatibility constraints of both agents are satisfied:

\[
V(x, e) = \max_{I^A, I^B} \int \tilde{V}(x, e, m, I^A, I^B) dF_m,
\]

subject to an ex-ante participation constraint:

\[
Eu(e^i) + \beta EV^i(x', e') \geq \max(u(e^i), E(u(m^i) - d)) + \beta E\tilde{\Omega}^i_m(e'). \tag{5}
\]

**Definition 2.** A constrained efficient allocation with temporary migration is defined by three policy functions:

1. Migration rule \( i(e) = \{I^A, I^B\} \)

2. Updating rule for Pareto weight \( x' = x'(e, m, i, x) \)

3. Transfer function \( \tau(e, m, i, x') = \{\tau^A, \tau^B\} \)

such that the social planner’s problem (4) is maximized, subject to the ex-ante incentive compatibility constraints (5), ex-post incentive compatibility constraints (2’), and ex-post resource constraints (3’).

A similar updating rule for the relative Pareto weight \( x \) holds in the model with temporary migration. There exist \( S \) states in the village and \( Q \) possible states in the migration destination. Denote the combined state of the world by the vector \( \{s_t, q_t\} \). Then,

**Proposition 2.2** (Adapted from Proposition 1, Ligon, Thomas and Worrall (2002)). The constrained efficient contract can be characterized as follows: For each possible migration outcome, indexed by \( i \), there exist \( S \times Q \) state-dependent intervals \( [x^i_{r,n}, \bar{x}^i_{r,n}] \), \( r = 1, 2, ...S; n = 1, 2, ...Q \), such that \( x(s_t, q_t) \) evolves according to the following rules. Let \( x(s_t, q_t) \) be given, let \( \{r, n\} \) be the state which occurs at time \( t + 1 \), and let \( i(r) \) be the migration rule at time \( t + 1 \), then

\[
x(r_{t+1}, n_{t+1}) = \begin{cases} 
\bar{x}_{r,n} & \text{if } x(s_t, q_t) < \bar{x}^{i(r)}_{r,n} \\
x(s_t, q_t) & \text{if } x(s_t, q_t) \in [x^{i(r)}_{r,n}, \bar{x}^{i(r)}_{r,n}] \\
x^{i(r)}_{r,n} & \text{if } x(s_t, q_t) > \bar{x}^{i(r)}_{r,n}
\end{cases}
\]
Proof: Refer to Appendix A.

We now derive comparative statics of migration on risk sharing and welfare.

2.3.1 Comparative statics on risk sharing, consumption, and welfare

This section derives two theoretical comparative statics: the effect of migration on risk sharing, and the effect of migration on welfare. I then present a simple numerical example to illustrate the channels for these effects.

Throughout this section, I consider the cross-sectional income distribution in the village. At the start of each period, households receive an income draw from the village income distribution $F_{\text{no migration}}$. When households migrate they receive a new income draw. As a result, the cross-sectional distribution of income in the village changes. I refer to the resulting income distribution, ex-post of the realization of all migration decisions and income, as $F_{\text{migration}}$.

I allow for a common aggregate shock in the village. This introduces cross-sectional correlation between household income. Assume that at time $t$, the state of the world is either good ($H$) with probability $\pi$, or bad ($B$) with probability $1 - \pi$. Conditional upon the aggregate state of the world, each household receives an i.i.d. income draw. Village income is a draw from the no-migration distribution: $e_i \sim F_{\text{no migration}}(\mu, \sigma)$, where $\mu$ is the vector of the mean for bad and good years, $\mu = [\mu_B, \mu_G]$, and $\sigma$ is the vector of the variance in bad and good years, $\sigma = [\sigma_B, \sigma_G]$.

Now, consider what happens when we introduce migration. This will change both total income and the distribution of income. Migration may increase total income in the economy. This is captured by a change in the mean of the income distribution, $\mu$. Migration offers a mechanism for smoothing aggregate shocks. As a result, it may affect the mean income in the economy differentially in good years ($\mu(G)$) and bad years ($\mu(B)$). What about the variance of income? Migration may provide households with low income shocks with a way to self-insure, which would reduce the ex-post cross-sectional variance. However, it may also introduce income risk, because migration itself is uncertain, increasing the cross-sectional variance of income. Again, the effect on the variance of income may differ by the aggregate shock. The overall effect of migration on the income process
is captured by the ex-post distribution \( \tilde{F}_{\text{migration}}(\tilde{\mu}, \tilde{\sigma}) = \tilde{F}_{\text{no migration}}(\mu + \Delta \mu, \sigma + \Delta \sigma) \).

### 2.3.2 The effect of migration on risk sharing

I show here that 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.

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

**Definition 3.** 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.

Consider the effect of migration on risk sharing, captured by a change in the ex-post mean \( \mu \) and standard deviation \( \sigma \) 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: an incentive effect and a self-insurance effect:

\[
\Delta RS_t = \frac{\partial RS_t}{\partial \sigma(c_t)} \left( \frac{\partial \sigma(c_t)}{\partial \sigma} \Delta \sigma + \frac{\partial \sigma(c_t)}{\partial \mu} \Delta \mu \right) + \frac{\partial RS}{\partial \sigma(e_t)} \Delta \sigma
\]

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

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. We 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, $\mu$):

$$
\Delta W = \frac{\partial W}{\partial \sigma(c_t)} \left( \frac{\partial \sigma(c_t)}{\partial \sigma} \Delta \sigma + \frac{\partial \sigma(c_t)}{\partial \mu} \Delta \mu \right) + \frac{\partial W}{\partial \mu} \Delta \mu
$$

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.

2.3.4 A simple numerical example

To illustrate these effects I work through a simple numerical example. Consider an economy with a deterministic income process and symmetric endowments. In even periods household $A$ receives a positive income shock; in odd periods $B$ receives a positive shock. The total resources in this economy are equal to 2, with the agent who has a positive shock receiving 1.3 (65% of the total resources), and the other agent 0.7 (35% of the total resources).
resources). Assume logarithmic utility and a discount rate of 0.7.\footnote{In Appendix A I prove that this economy converges to an asymptotic distribution of consumption and I show that risk sharing is determined by the distribution of income.}

I model migration as a risk-free opportunity where the guaranteed income is 0.8. I assume no utility cost to migrating. Under these parameters, the agent with the bad shock will migrate, but the agent with the good shock will not. Migration changes the income process in two ways. First, total resources available to the network increase to 2.1 from 2.0. Second, the share of total resources that the rich agent receives decreases to 0.62 from 0.65.

Figure 1 shows the effect of migration on consumption and risk sharing in this economy. The incentive compatibility curve (the net present value of the endowment stream) for the agent with the binding participation constraint is drawn through each endowment point. The intersection of the incentive compatibility curve and budget set for the economy yields the risk-sharing allocation. Pre-migration, the risk-sharing allocation is for the rich agent to consume 1.04 (52% of total resources), and the poor agent to consume 0.96 (48% of total). Post-migration, the incentive compatibility curve shifts, reflecting an increase in the net present value of income. As a result, the initial allocation rule is no longer incentive compatible. The new allocation is for the rich agent to consume 1.16 (56% of total resources), and the poor agent to consume 0.94 (44% of the total). Risk sharing is reduced.

Figure 2 decomposes the welfare effect of introducing migration. There are two offsetting effects. Migration increases the total resources available to the economy, increasing welfare. However, it also endogenously decreases risk sharing. This causes a shift along the welfare curve, reducing welfare. Without the change in risk sharing, the economy would have a welfare level of 0.089. Taking the change in risk sharing into account, actual welfare is 0.0718. The change in risk sharing reduces potential welfare by 20%.

\subsection*{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 compara-
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.\textsuperscript{10} 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\textsuperscript{11}. 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. Figure 3 plots its prevalence by village and year, using the VLS2 data. 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.

40% of households have a migrant at least one of the four years of the survey. The main household-level determinants of temporary migration are landholdings and the number of males.\textsuperscript{12} These results are reported in Appendix Table 1. 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. To match these differences in propensity to migrate across households, I allow for heterogeneity by landholdings and household composition when estimating

\textsuperscript{10}For more information about the initial ICRISAT panel, refer to Walker and Ryan (1990)).
\textsuperscript{11}The majority of migration in VLS1 is due to marriage, with the woman migrating to her husband’s home (Rosenzweig and Stark, 1989).
\textsuperscript{12}Overall, 28% of temporary migrants are women. However, these women are almost always accompanied 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.
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 4, 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.

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 $\beta_i$ is a household fixed effect and $\gamma_{vt}$ 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 2 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 1 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. The key feature of the model is the joint determination of risk sharing and migration. In order to quantify this interaction, I estimate the model structurally. The following section explains the estimation procedure.
4 Structural estimation

This section describes the structural estimation procedure. Section 4.1 discusses the simulated method of moments estimator; Section 4.2 the specific moments matched; Section 4.3 model identification; 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).\textsuperscript{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 $\theta$ 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:

$$\hat{\theta}_{SMM} = \arg\min_{\theta} (Q(\theta) - q_s)'W^{-1}(Q(\theta) - q_s)$$

where $W$ is a positive definite weighting matrix. 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, $\theta$, 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:

\textsuperscript{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.
1. Construct the vector of data moments $q_s$.

2. For the given $\theta$ 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 $t = 0$ 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 following section details the exact moments matched in the data during this algorithm.

### 4.2 Moments matched in data

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:* I estimate the discount rate and the coefficient of relative risk aversion. The preference parameters determine both risk sharing and migration.
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.

Table A shows the parameters that are estimated and how these are matched to the data. The model is over-identified, meaning that I match more moments than parameters. In addition to structurally estimating parameters, I set two of them exogenously. I set the scaling parameter for the good shock to 0.2. This matches the mean difference in the data between a good and bad aggregate shock. I set the income share from migration to 0.6, matching the share of household income from migration for households with a temporary migrant observed in the data.

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 9 parameters for each village, yielding a total of 45 parameters to be estimated, and set 2 exogenously. The parameter vector \( \theta = \{\theta_{\text{estimated}}, \theta_{\text{exogenous}}\} \) is a vector of 47 parameters which fully characterizes the risk sharing and migration model.
Table A: Parameter vector for structural model

<table>
<thead>
<tr>
<th>Type of parameter</th>
<th>Symbol</th>
<th>Main source of variation in data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income distribution in village</td>
<td>$\mu_v$</td>
<td>Mean income of non migrants</td>
</tr>
<tr>
<td></td>
<td>$\sigma_v$</td>
<td>Standard deviation of income for non-migrants</td>
</tr>
<tr>
<td>Income distribution if migrating</td>
<td>$\mu_{mig,v}$</td>
<td>Mean income of migrants</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{mig,v}$</td>
<td>Standard deviation of income for migrants</td>
</tr>
<tr>
<td>Utility cost of migrating</td>
<td>$d_v$</td>
<td>Mean households migrating</td>
</tr>
<tr>
<td>Preference parameters</td>
<td>$\beta_v$</td>
<td>Share of non-migrants receiving a transfer</td>
</tr>
<tr>
<td></td>
<td>$\gamma_v$</td>
<td>Share of migrants receiving a transfer</td>
</tr>
<tr>
<td></td>
<td>$\alpha^\mu_{\text{land},v}$</td>
<td>Mean income of non-migrant land owners</td>
</tr>
<tr>
<td></td>
<td>$\alpha^d_{\text{male},v}$</td>
<td>Mean male households migrating</td>
</tr>
<tr>
<td>Heterogeneity parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameters set exogenously</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaling parameter good agg shock</td>
<td>$\mu$</td>
<td>1.2</td>
</tr>
<tr>
<td>Income share from migration</td>
<td></td>
<td>0.6</td>
</tr>
</tbody>
</table>

Notes: The parameters with a $v$ subscript are estimated at the village level. Parameters without a $v$ subscript are estimated across the entire sample. The estimation sample is 5 villages. The total vector size is 47 (9 parameters estimated separately for each village and 2 parameters estimated across the entire sample).

4.3 Identification of parameters

This section details the identification of each group of parameters. Dynamic structural models are not non-parameterically identified (Rust, 1994). I outline the specific parametric assumptions I employ, and discuss the sources of variation within the data.

4.3.1 Household income

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.
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 ($\varepsilon$) and aggregate ($\nu$) component:

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

The aggregate state is either high or low, each with equal probability. The idiosyncratic shock is an iid draw from a village-specific log-normal distribution with mean $\mu$ and variance $\sigma_{\text{idio},v}^2$:

$$\log(\varepsilon) \sim \mathcal{N}(\mu_v, \sigma_{\text{idio},v}^2).$$

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

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 $\sigma_{\text{mig},v}^2$. I assume that all agents face the same ex-ante income distribution if they migrate:\footnote{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 (refer to Appendix Table 2). I abstract from any learning about migration. For papers that consider learning and migration see Pessino (1991) and Bryan, Chowdhury and Mobarak (2011).}

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

To implement the estimation I discretize the 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.

4.3.2 Utility parameters

I assume CRRA preferences. The discount rate $\beta$ and the coefficient of relative risk aversion $\gamma$ 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. I identify $\beta$ and $\gamma$ by matching risk sharing moments: the correlation between income and consumption and the mean consumption of migrants and non-migrants.

There are two challenges. The first is that it is difficult to empirically identify both $\beta$ and $\gamma$. Many studies find they are highly negatively correlated (see Guvenen and Smith (2010)). The second challenge is that with CRRA preferences there is no distinction between risk aversion and the elasticity of inter-temporal substitution. This is particularly important in my model because migration, an intra-temporal choice, is risky. I currently estimate the model using CRRA preferences, but will extend the analysis to incorporate Epstein-Zin preferences (Epstein and Zin, 1989, 1991) to address this issue.

4.3.3 Utility 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 $I_{\text{male}}$ if the household has more males than the median for all households, and estimate a scaling parameter $\alpha_{\text{male}}$ 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.

4.4 Moving from 2 to N households

The model presented in Section 2 was a two household model. 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 ($\overline{H}$) is equal to the average level of resources in the economy, taking into account how migration decisions change the total resources in the economy. For further discussion, and the specific algorithm used to solve the model, please refer to Appendix B.

5 Structural Results

This section presents the structural estimation results and performs a counterfactual policy analysis. First, I show that is is quantitatively important to consider migration and risk sharing jointly. I estimate that (1) risk sharing reduces migration by 55%, (2) migration reduces risk sharing by 38%, and (3) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain from migration is 12% lower. Second, I use these quantitative results to show how key policy parameters may be affected if migration and risk sharing are not considered jointly. Third, I show that the joint determination of migration and risk sharing has key implications for policy.

Section 5.1 discusses the fit between the model and the data. Section 5.2 presents the key empirical results, and Section 5.3 the implications for model parameters. Section 5.4.1 examines policy counterfactuals.
5.1 Model results

This section discusses model fit, selection into migration, and the identification of the returns to migration.

5.1.1 Model fit

The data fit the model well. Table 3 shows the moments targeted during the estimation procedure, averaged over the 5 village sample.\footnote{The model over-predicts the share of migrants receiving risk-sharing transfers from the network. This is most likely due to the small number of discrete states used to estimate the migration process (I allow for three possible migration outcomes); a finer grid would provide a better match on this.} 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 (54% vs 65%), a reassuring figure given that I only allow for two sources of heterogeneity in the model.

The parameter point estimates from the structural estimation are provided in Table 4. Migration has a higher mean return than village income (mean of the log-normal distribution is estimated to be 1.7 viz. 1.3), but is considerably riskier (standard deviation 0.98 viz. 0.69). The model matches migration rates with expected income differentials through a utility cost of migrating. The mean cost, 0.08, is substantial - equivalent to 30% of mean household consumption. For households with many males, who face a lower utility cost, the cost is estimated to be approximately 15% of mean consumption (scaling factor of -0.58).

I estimate a coefficient of relative risk aversion of 1.89 and a discount rate of 0.55.\footnote{As a comparison, the discount rate in Ligon, Thomas and Worrall (2002) is estimated to be between 0.7-0.9, also relatively low.} In my model, households are making both risky intertemporal and risky intratemporal decisions. As discussed in Section 4.3.2, a constraint with CRRA utility is that risk aversion is not separately identified from the elasticity of intertemporal substitution. The low value of the discount rate is necessary to match the observed risk sharing behavior; matching this with a lower risk aversion parameter instead would then overestimate the migration rate. One possibility is to re-estimate the model with Epstein-Zin preferences, where the
elasticity of intertemporal substitutability is separately identified to the coefficient of risk aversion. This is currently in progress.

5.1.2 Selection into migration

There are two dimensions that govern migration: permanent heterogeneity, and temporary income shocks. The selection of households into migration is shown in Figure 5. The figure plots the distribution of the idiosyncratic income shock for each group of households. I separate out the income distribution for good aggregate shocks and for bad aggregate shocks.

The shaded area on each graph shows the selection of households into migration. Migration is endogenous: households with the lowest income realizations choose to migrate. Migration also depends on permanent characteristics of households: landholdings and household composition. 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. In addition, 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 (19%) compared to a good aggregate shock (14%).

5.1.3 Returns to migration

Table 5 shows the effect of migration on migration and village income. In addition, I show how endogenous migration causes naive estimates of the return to migration to be downward biased.

There are three key results in the table. First, migration has a significant return: mean income of migrant households is 5250 rupees per equivalent adult (approximately $104 USD). Households, on the whole, would have been considerably worse off had they not migrated. Counterfactual income (the income the household would have had in the village) is approximately half of actual income, at 2700 rupees ($50 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 74% of migrant households have higher income from migrating than they would have if they had not migrated. However, 26% are ex-post worse off. This number is consistent with the experimental findings in Bryan, Chowdhury and Mobarak (2011) who estimate a 10-20% risk of “failure” from migration. Third, endogenous migration biases the observed returns to migration. The income of households who choose not to migrate is 5900 rupees per adult equivalent household member (approximately $118 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 5900 rupees, compared with migrant income of 5250 rupees.\footnote{This difference holds if the compositional effects (i.e. permanent characteristics) of non-migrants and migrants are controlled for.} 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, 2700 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 38%.

2. The welfare effect of migration is large (16% consumption-equivalent). However, comparing endogenously to exogenously incomplete markets, welfare is 12% lower.

3. Risk sharing reduces migration by 55%.

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. On the other hand, migration allows the network to smooth aggregate shocks, increasing risk sharing.

I summarize risk sharing in terms of the correlation between income and consumption. A higher correlation means that household consumption tracks income more closely,
and so risk sharing is lower.\footnote{Results are robust to defining risk sharing using $1 - \frac{\sigma(c)}{\sigma(y)}$, the correlation yields an easier comparison so is used here.} Migration causes risk sharing to decrease: on average, the correlation between income and consumption is 14.6% before migration, whereas with migration, this correlation is 20.1%. With migration, households are more exposed to income risk. The change in the relationship between income and consumption is plotted in Figure 6. I estimate that the net effect of introducing migration is to reduce risk sharing by 38%. That is, the crowding-out effect of migration dominates.

This overall correlation masks a substantial degree of heterogeneity within group. Table 6 shows the change in risk sharing by group. The largest change in risk sharing is for the agents who can migrate easily, and hence experience the greatest change in their outside option: i.e., households with many males. 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. Here, the same pattern holds.

5.2.2 Decomposition of the welfare effect of migration

The welfare effect of migration can be decomposed into an income effect and a risk sharing effect. Table 7 considers the welfare implications of introducing migration, comparing average welfare in the economy without migration and average welfare with migration. For ease of comparison, the mean migration rate for each group in included in the table. I estimate that the net welfare gain is positive, equivalent to a 15.6% increase in consumption-equivalent terms. The largest relative benefits from migration are to the poor (landless) households: welfare (in consumption-equivalents) for the landless households with few males increases by 18.0%, and for landless households with many males, 26.4%.

However, migration also causes risk sharing to decrease. 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. Specifically, I consider a model where households can borrow and save a risk-free asset (as in 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. I estimate that the welfare gain with endogenously incomplete markets is 12% lower than the welfare gain from migration with exogenously incomplete markets.

Table 8 shows the effect of migration under three economic environments: endogenously incomplete markets (limited commitment), exogenously incomplete markets (borrowing and savings), and autarky. 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 28.2% 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 17.6% 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 15.6% increase in consumption. Contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain from migration is 12% lower.

5.2.3 Risk sharing reduces migration

With respect to risk sharing, the migration decision depends on post-transfer income differentials between the village and the city. Theoretically, I show that risk sharing can either increase or decrease migration. There are two potentially offsetting effects of transfers on migration: a home effect, that reduces migration, and a destination effect, increas-

\footnote{I set the risk free interest rate to 0.10 and an exogenous borrowing constraint of approximately 50% of average annual income.}
Migration rates under alternative risk sharing regimes are presented in the first panel of Table 8. The mean migration rate is 16% with risk sharing; I estimate the counterfactual migration rate to be 36%. I estimate the net effect of risk sharing to be a 55% reduction in migration. The second column estimates the migration rate under borrowing-saving; it is slightly higher than autarky, at 37%. 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 Implications for key parameters

The estimation results show the joint determination of migration and risk sharing is quantitatively important. For each theoretical result, I consider how the joint interaction of migration and risk sharing affects the estimation of key parameters.

Effect of migration on risk sharing: Within the structural model, I estimate the net effect of introducing migration to be a 38% reduction in risk sharing. The key policy-relevant parameters affected are the utility parameters (the coefficient of relative risk aversion and the discount rate). With migration, risk sharing is lower because households have a higher outside option, which constrains risk sharing. Without migration, but with the same estimated coefficient of relative risk aversion and discount rate, risk sharing is more complete, which appears as households being more averse to risk. To estimate a model of risk sharing without accounting for migration we would overestimate the coefficient of relative risk aversion. This overestimate will affect analysis of any policy that addresses household risk, such as public insurance.

Decomposition of the welfare effect of migration: I estimate that the welfare gain from migration is 12% lower when markets are endogenously incomplete compared when markets are exogenously incomplete. Migration induces a negative externality on the village because it decreases informal risk sharing. As a result, the rural-urban wage gap overstates the welfare benefit of migration.
Effect of risk sharing on migration: Within the structural model, I estimate the net effect of risk sharing is to reduce migration by 55%. The key policy-relevant parameter affected is the utility cost of migrating. With risk sharing, households do not migrate as often because they have informal insurance against bad income shocks. Without risk sharing, but with the same estimated cost of migrating, households would migrate more often in order to self-insure. Therefore, in order to match a model of migration without risk sharing to the observed data, we would estimate a higher utility cost of migrating. This overestimate will affect analysis of any policy that changes the cost of migration, such as infrastructure development.

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.\(^\text{20}\) Comparing the effects of the policy under exogenously incomplete markets to the effect under endogenously incomplete markets, the welfare gain of the policy is 20-40% lower after household risk sharing and migration responses are considered.

Table 9 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

\(^{20}\)For a detailed discussion of the NREGA see Papp (2012). Imbert and Papp (2012) show that the NREGA has general equilibrium effects on wages. I abstract from this effect in the analysis.
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 (6) shows that under autarky and no migration the welfare benefit of the NREGA is equivalent to a 29% 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 (5) 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: 17%. This is because households were already able to smooth some of the welfare fluctuations of the income shocks. Column (4) 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, 9.8%, due to the crowd-out of informal insurance.

Now consider the effect of the policy allowing for 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 6.5% if households are autarkic. Note the difference in the effect of the NREGA when households are autarkic: 28.6% without migration, and 6.5% with migration. Accounting for endogenous migration is important, regardless of the insurance environment. Columns (2) and (1) 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 5.6%, and then once the endogenous change in insurance is taken into account, the final welfare benefit of the NREGA is 4.5% under limited commitment with migration.

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; Albar-
ran 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, there is an additional dimension that is crowded out. The rural employment scheme increases income in the village, directly substituting for migration. 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.

5.4.2 Other migration policies

I consider the effects of three 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 10 shows the results. The first row considers an increase in 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 row 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 row decreases the variance of migration income. 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. 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. 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 37%; (2) contrasting endogenous to exogenous risk sharing, the consumption-equivalent gain of migration is 12% lower; (3) risk sharing reduces migration by 55%.

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 20-40% lower after household risk sharing and migration responses are considered.

One limitation of this paper is that the environment does not consider the general equilibrium effects on wages from migration. Future work could extend this environment to consider these broader impacts of migration, as in Card (2001) and Borjas (2003).
References


Badiani, Reena and Abla Safir, “Coping with Aggregate Shocks: Temporary Migration and Other Labor Responses to Climatic Shocks in Rural India,” 2009.


Figure 1: Effect on consumption from migration under limited commitment.

Notes: This figure plots autarky and consumption for a simple limited commitment economy with a deterministic income process with two states of the world and constant aggregate resources. The initial autarky point is \( \{y_{\text{rich}} = 1.3, y_{\text{poor}} = 0.7\} \). Under limited commitment, the amount of risk-sharing is constrained by the outside option of the agent with the binding participation constraint (here: the current rich agent). The risk-sharing equilibrium is a consumption allocation that yields the same utility to the rich agent as autarky. In the graph this is the point closest to equal allocation of resources, where the indifference curve intersects the budget constraint for the economy: \( \{c_{\text{rich}} = 1.05, c_{\text{poor}} = 0.95\} \). In this example, there is imperfect risk-sharing: the rich agent consumes more than half of total resources, but the allocation is more equitable than autarky. Consider the introduction of a migration opportunity that yields a guaranteed income of 0.8. The current poor agent will migrate but the current rich agent will not migrate. This changes the income process to \( \{y_{\text{rich}} = 1.3, y_{\text{poor}} = 0.8\} \). The outside option for all agents has increased, which shifts out the indifference curve for the current rich agent. The new limited commitment consumption equilibrium is the bundle: \( \{c_{\text{rich}} = 1.17, c_{\text{poor}} = 0.93\} \). Thus, the initial degree of risk-sharing is no longer incentive compatible and the share of total resources consumed by the rich agent increases. The result is that risk-sharing is crowded out by the increase in the outside option due to migration.
Figure 2: Effect on welfare from migration: income effect and incentive effect

Notes: This figure plots the two effects on welfare from migration: an income effect due to extra resources, and an incentive effect due to crowding out of risk-sharing. The dashed portion of the graph shows the consumption allocations which are not incentive compatible. Total welfare is maximized when the consumption share is equal to 0.5. However this consumption allocation is not incentive compatible. The shift in autarky from \( \{y_{\text{rich}} = 1.3, y_{\text{poor}} = 0.7\} \) to \( \{y_{\text{rich}} = 1.3, y_{\text{poor}} = 0.8\} \) increases the total resources available to the network but decreases risk-sharing. The income effect shows the welfare gain from higher income, holding the consumption share constant. The incentive effect shows the reduction in welfare due to decreased risk-sharing.
Each observation is a village-year.

Figure 3: 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 4: 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 5: 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.
Figure 6: Structural estimation: Relationship between income and consumption (both de-meaned)

Notes: The figure plots a kernel-weighted local regression line of de-meaned consumption on de-meaned income, comparing no-migration to migration. Computed from structural estimation results.
### Table 1: Change in Household Income and Expenditure When Migrate

<table>
<thead>
<tr>
<th>Dep. variable:</th>
<th>(1) Income b/se</th>
<th>(2) Consumption b/se</th>
<th>(3) Δ Fin. Assets b/se</th>
<th>(4) Δ Phy. Assets b/se</th>
<th>(5) Expenditure b/se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dummy if migrate</td>
<td>1492 (483)</td>
<td>606 (524)</td>
<td>393 (311)</td>
<td>336 (487)</td>
<td>1277 (891)</td>
</tr>
<tr>
<td>Household FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean dep. variable</td>
<td>5828</td>
<td>6856</td>
<td>-598</td>
<td>292</td>
<td>6231</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.652</td>
<td>0.515</td>
<td>0.215</td>
<td>0.304</td>
<td>0.369</td>
</tr>
<tr>
<td>Number observations</td>
<td>1449</td>
<td>1449</td>
<td>1493</td>
<td>1493</td>
<td>1513</td>
</tr>
<tr>
<td>Number households</td>
<td>438</td>
<td>438</td>
<td>437</td>
<td>437</td>
<td>438</td>
</tr>
</tbody>
</table>

**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 2: Test for Perfect Risk Sharing

<table>
<thead>
<tr>
<th>Dep. variable: Consumption</th>
<th>Combined sample (VLS1 and VLS2)</th>
<th>VLS2 only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) b/se</td>
<td>(2) b/se</td>
</tr>
<tr>
<td>Income</td>
<td>0.198*** (0.029)</td>
<td>0.199*** (0.029)</td>
</tr>
<tr>
<td>VLS2 X Income</td>
<td>-0.090** (0.034)</td>
<td>-0.133*** (0.036)</td>
</tr>
<tr>
<td>Mean village migration X Income</td>
<td>0.239** (0.116)</td>
<td></td>
</tr>
<tr>
<td>Village-Year FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Household FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.685</td>
<td>0.687</td>
</tr>
<tr>
<td>Number observations</td>
<td>2429</td>
<td>2429</td>
</tr>
</tbody>
</table>

**Notes:** OLS regressions of log income on log consumption. Standard errors clustered at village-year level for all columns. 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 3: Goodness of Fit of Model to Data

<table>
<thead>
<tr>
<th></th>
<th>(1) Data</th>
<th>(2) Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moments targeted during estimation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of non-migrant income</td>
<td>5.837</td>
<td>5.935</td>
</tr>
<tr>
<td>Std dev non-migrant income</td>
<td>4.261</td>
<td>3.701</td>
</tr>
<tr>
<td>Mean of non-migrant income: own land</td>
<td>6.525</td>
<td>6.539</td>
</tr>
<tr>
<td>Mean of migrant income</td>
<td>5.802</td>
<td>5.249</td>
</tr>
<tr>
<td>Std dev migrant income</td>
<td>3.736</td>
<td>3.440</td>
</tr>
<tr>
<td>Mean migration rate</td>
<td>0.197</td>
<td>0.171</td>
</tr>
<tr>
<td>Mean migration rate: male hh</td>
<td>0.306</td>
<td>0.248</td>
</tr>
<tr>
<td>Correlation of consumption and income</td>
<td>0.223</td>
<td>0.210</td>
</tr>
<tr>
<td>Mean non-migrant consumption</td>
<td>5.962</td>
<td>5.971</td>
</tr>
<tr>
<td>Mean migrant consumption</td>
<td>5.289</td>
<td>5.410</td>
</tr>
<tr>
<td>Percent nonmigrants receiving transfer</td>
<td>0.548</td>
<td>0.584</td>
</tr>
<tr>
<td>Percent migrants receiving transfer</td>
<td>0.427</td>
<td>0.661</td>
</tr>
</tbody>
</table>

**Moments not targeted during estimation**

|                                |          |           |
| Percent migrating this year if migrated last year | 0.654    | 0.536     |

*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 4: Structural Point Estimates (by Village)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th></th>
<th>B</th>
<th></th>
<th>C</th>
<th></th>
<th>D</th>
<th></th>
<th>E</th>
<th></th>
<th>Average</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
</tr>
<tr>
<td><strong>Village income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of village shock process</td>
<td>1.487</td>
<td>(0.061)</td>
<td>1.084</td>
<td>(0.253)</td>
<td>1.260</td>
<td>(0.258)</td>
<td>1.260</td>
<td>(0.312)</td>
<td>1.207</td>
<td>(0.388)</td>
<td>1.260</td>
<td>(0.124)</td>
</tr>
<tr>
<td>Std. dev of village shock process</td>
<td>0.630</td>
<td>(0.004)</td>
<td>0.616</td>
<td>(0.257)</td>
<td>0.762</td>
<td>(0.147)</td>
<td>0.768</td>
<td>(0.044)</td>
<td>0.687</td>
<td>(0.068)</td>
<td>0.693</td>
<td>(0.061)</td>
</tr>
<tr>
<td>Utility cost of migrating</td>
<td>0.081</td>
<td>(0.007)</td>
<td>0.031</td>
<td>(0.016)</td>
<td>0.085</td>
<td>(0.055)</td>
<td>0.148</td>
<td>(0.002)</td>
<td>0.169</td>
<td>(0.011)</td>
<td>0.103</td>
<td>(0.012)</td>
</tr>
<tr>
<td><strong>Migration income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of migration income process</td>
<td>1.852</td>
<td>(0.166)</td>
<td>1.328</td>
<td>(0.425)</td>
<td>2.099</td>
<td>(0.571)</td>
<td>1.888</td>
<td>(0.655)</td>
<td>1.475</td>
<td>(0.056)</td>
<td>1.728</td>
<td>(0.197)</td>
</tr>
<tr>
<td>Std. dev of migration income process</td>
<td>0.887</td>
<td>(0.151)</td>
<td>1.199</td>
<td>(0.426)</td>
<td>0.787</td>
<td>(0.276)</td>
<td>0.804</td>
<td>(0.463)</td>
<td>1.223</td>
<td>(0.097)</td>
<td>0.980</td>
<td>(0.142)</td>
</tr>
<tr>
<td><strong>Heterogeneity parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaling utility cost for male</td>
<td>-0.945</td>
<td>(0.163)</td>
<td>-0.855</td>
<td>(0.292)</td>
<td>-0.443</td>
<td>(0.551)</td>
<td>-0.599</td>
<td>(0.702)</td>
<td>-0.036</td>
<td>(0.124)</td>
<td>-0.575</td>
<td>(0.192)</td>
</tr>
<tr>
<td>Scaling mean for land</td>
<td>0.527</td>
<td>(0.120)</td>
<td>0.395</td>
<td>(0.066)</td>
<td>0.232</td>
<td>(0.148)</td>
<td>0.232</td>
<td>(0.392)</td>
<td>0.315</td>
<td>(0.465)</td>
<td>0.340</td>
<td>(0.128)</td>
</tr>
<tr>
<td><strong>Preference parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of relative risk aversion</td>
<td>1.837</td>
<td>(0.221)</td>
<td>1.874</td>
<td>(0.667)</td>
<td>2.228</td>
<td>(0.232)</td>
<td>2.228</td>
<td>(0.302)</td>
<td>1.271</td>
<td>(0.163)</td>
<td>1.888</td>
<td>(0.163)</td>
</tr>
<tr>
<td>Discount factor</td>
<td>0.602</td>
<td>(0.022)</td>
<td>0.577</td>
<td>(0.317)</td>
<td>0.457</td>
<td>(0.025)</td>
<td>0.411</td>
<td>(0.251)</td>
<td>0.702</td>
<td>(0.099)</td>
<td>0.550</td>
<td>(0.084)</td>
</tr>
<tr>
<td><strong>Exogenous parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaling factor good aggregate shock</td>
<td>0.200</td>
<td></td>
<td>0.200</td>
<td></td>
<td>0.200</td>
<td></td>
<td>0.200</td>
<td></td>
<td>0.200</td>
<td></td>
<td>0.200</td>
<td></td>
</tr>
<tr>
<td>Share of household income from migration</td>
<td>0.550</td>
<td></td>
<td>0.550</td>
<td></td>
<td>0.550</td>
<td></td>
<td>0.550</td>
<td></td>
<td>0.550</td>
<td></td>
<td>0.550</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Table gives point estimates and standard errors from simulated method of moment estimation. Columns (1)-(5) yield village-specific estimates. Column (6) averages across villages (note: standard error for the average does not take into account covariance across village as this was not estimated). Two parameters are set exogenously: the share of household income from migration and the scaling effect of a good aggregate shock.
Table 5: Effect of Migration on Village Income and Income of Migrants

<table>
<thead>
<tr>
<th></th>
<th>(1) Data</th>
<th>(2) Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income of Migrants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed mean income</td>
<td>5.802</td>
<td>5.249</td>
</tr>
<tr>
<td>Mean income if stayed in village</td>
<td>2.714</td>
<td></td>
</tr>
<tr>
<td>Share of migrants with income gain</td>
<td>0.736</td>
<td></td>
</tr>
<tr>
<td><strong>Village Income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed mean income of non-migrants</td>
<td>5.837</td>
<td></td>
</tr>
<tr>
<td>Mean of untruncated village income distribution</td>
<td>5.385</td>
<td></td>
</tr>
</tbody>
</table>

*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 6: Effect on Risk Sharing of Introducing Migration

<table>
<thead>
<tr>
<th>Risk sharing: corr(y, c)</th>
<th>Whole sample</th>
<th>Only non-migrants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) No migration mean</td>
<td>(2) With migration mean</td>
</tr>
<tr>
<td>Overall</td>
<td>0.146</td>
<td>0.201</td>
</tr>
<tr>
<td>Landless, few males</td>
<td>0.190</td>
<td>0.206</td>
</tr>
<tr>
<td>Landed, few males</td>
<td>0.110</td>
<td>0.142</td>
</tr>
<tr>
<td>Landless, many males</td>
<td>0.190</td>
<td>0.266</td>
</tr>
<tr>
<td>Landed, many males</td>
<td>0.110</td>
<td>0.198</td>
</tr>
</tbody>
</table>

*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>
<thead>
<tr>
<th>Mean welfare</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No migration</td>
<td>Migration</td>
<td>Welfare gain</td>
<td>Cons eq. gain</td>
<td>Migration rate</td>
</tr>
<tr>
<td>Overall</td>
<td>2.191</td>
<td>2.305</td>
<td>1.046</td>
<td>0.156</td>
<td>0.160</td>
</tr>
<tr>
<td>Landless, few males</td>
<td>2.065</td>
<td>2.216</td>
<td>1.061</td>
<td>0.180</td>
<td>0.116</td>
</tr>
<tr>
<td>Landed, few males</td>
<td>2.316</td>
<td>2.374</td>
<td>1.020</td>
<td>0.074</td>
<td>0.043</td>
</tr>
<tr>
<td>Landless, many males</td>
<td>2.065</td>
<td>2.245</td>
<td>1.079</td>
<td>0.264</td>
<td>0.316</td>
</tr>
<tr>
<td>Landed, many males</td>
<td>2.316</td>
<td>2.385</td>
<td>1.025</td>
<td>0.106</td>
<td>0.165</td>
</tr>
</tbody>
</table>

Notes: Table shows mean welfare for whole sample and by subgroup. Column 1 computes welfare with no migration. Column 2 computes welfare with migration. Column 3 is welfare gain (Col 2/Col 1). Column 4 computes the consumption equivalent welfare gain (computed as per Lucas(1987)). Column 5 is mean migration rate.
<table>
<thead>
<tr>
<th>Migration rate</th>
<th>(1) Endogenous incomplete</th>
<th>(2) Exogenous incomplete</th>
<th>(3) Autarky</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.160</td>
<td>0.372</td>
<td>0.359</td>
</tr>
<tr>
<td>Landless, few males</td>
<td>0.116</td>
<td>0.370</td>
<td>0.376</td>
</tr>
<tr>
<td>Landed, few males</td>
<td>0.043</td>
<td>0.209</td>
<td>0.254</td>
</tr>
<tr>
<td>Landless, many males</td>
<td>0.316</td>
<td>0.546</td>
<td>0.475</td>
</tr>
<tr>
<td>Landed, many males</td>
<td>0.165</td>
<td>0.365</td>
<td>0.332</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welfare gain relative to no migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
</tr>
<tr>
<td>Landless, few males</td>
</tr>
<tr>
<td>Landed, few males</td>
</tr>
<tr>
<td>Landless, many males</td>
</tr>
<tr>
<td>Landed, many males</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumption equivalent gain relative to no migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
</tr>
<tr>
<td>Landless, few males</td>
</tr>
<tr>
<td>Landed, few males</td>
</tr>
<tr>
<td>Landless, many males</td>
</tr>
<tr>
<td>Landed, many males</td>
</tr>
</tbody>
</table>

Notes: Table shows change in welfare with migration compared to no migration for whole sample and by subgroup. Endogenous incomplete markets is the limited commitment model. No risk sharing is autarky. Exogenous incomplete markets considers a Hugget (1993) economy where agents can buy and sell a risk-free asset.
### Table 9: Effect of NREGA under different regimes

<table>
<thead>
<tr>
<th></th>
<th>With migration</th>
<th>Without migration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>Endog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autarky</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Migration rate with NREGA relative to pre-NREGA

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.295</td>
<td>0.827</td>
<td>0.789</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landless, few males</td>
<td>0.010</td>
<td>0.748</td>
<td>0.600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landless, many males</td>
<td>0.297</td>
<td>0.749</td>
<td>0.600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landed, few males</td>
<td>0.246</td>
<td>0.912</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landed, many males</td>
<td>0.645</td>
<td>0.918</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Correlation between income and consumption with NREGA relative to pre-NREGA

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>1.265</td>
<td>2.616</td>
</tr>
<tr>
<td>Landless, few males</td>
<td>1.629</td>
<td>2.789</td>
</tr>
<tr>
<td>Landless, many males</td>
<td>1.374</td>
<td>2.358</td>
</tr>
<tr>
<td>Landed, few males</td>
<td>0.928</td>
<td>3.044</td>
</tr>
<tr>
<td>Landed, many males</td>
<td>1.064</td>
<td>2.358</td>
</tr>
</tbody>
</table>

#### Consumption equivalent gain with NREGA

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.045</td>
<td>0.056</td>
<td>0.065</td>
<td>0.098</td>
<td>0.165</td>
<td>0.286</td>
</tr>
<tr>
<td>Landless, few males</td>
<td>0.037</td>
<td>0.079</td>
<td>0.096</td>
<td>0.125</td>
<td>0.207</td>
<td>0.355</td>
</tr>
<tr>
<td>Landless, many males</td>
<td>0.026</td>
<td>0.051</td>
<td>0.060</td>
<td>0.066</td>
<td>0.116</td>
<td>0.205</td>
</tr>
<tr>
<td>Landed, few males</td>
<td>0.080</td>
<td>0.061</td>
<td>0.078</td>
<td>0.143</td>
<td>0.235</td>
<td>0.405</td>
</tr>
<tr>
<td>Landed, many males</td>
<td>0.044</td>
<td>0.033</td>
<td>0.028</td>
<td>0.066</td>
<td>0.116</td>
<td>0.205</td>
</tr>
</tbody>
</table>

**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 10: MIGRATION POLICY EXPERIMENTS

<table>
<thead>
<tr>
<th></th>
<th>(1) Full model</th>
<th>(2) No risk sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increase migration income by 20%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative migration rate</td>
<td>1.170</td>
<td>1.366</td>
</tr>
<tr>
<td>Relative correlation between income and consumption</td>
<td>0.539</td>
<td>0.036</td>
</tr>
<tr>
<td>Consumption-equivalent gain</td>
<td>0.147</td>
<td>0.036</td>
</tr>
<tr>
<td><strong>Decrease migration cost by 50%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative migration rate</td>
<td>2.255</td>
<td>1.267</td>
</tr>
<tr>
<td>Relative correlation between income and consumption</td>
<td>1.567</td>
<td>0.001</td>
</tr>
<tr>
<td>Consumption-equivalent gain</td>
<td>0.048</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Decrease migration variance by 50%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative migration rate</td>
<td>1.412</td>
<td>1.113</td>
</tr>
<tr>
<td>Relative correlation between income and consumption</td>
<td>2.215</td>
<td>0.045</td>
</tr>
<tr>
<td>Consumption-equivalent gain</td>
<td>-0.049</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Notes: Policy shows the change from the baseline estimates for three separate policy experiments.
### Appendix Table 1: Characteristics of Migrant Households

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

*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 Education on Migration and Wage Rate

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dep. variable:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Migration/Wage</td>
<td>Probability of migrating</td>
<td>Wage rate if migrate</td>
</tr>
<tr>
<td></td>
<td>b/se</td>
<td>b/se</td>
</tr>
<tr>
<td>Years Education</td>
<td>0.008**</td>
<td>28.451*</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(16.459)</td>
</tr>
<tr>
<td>Village-Year FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean dep. variable</td>
<td>0.110</td>
<td>205.835</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.081</td>
<td>0.353</td>
</tr>
<tr>
<td>Number observations</td>
<td>2562</td>
<td>284</td>
</tr>
</tbody>
</table>

*Notes:* OLS regressions of probability of ever migrating on education and wage rate if migrate on education. Standard errors clustered by village-year.
Appendices

A Theoretical appendix

This appendix discusses the date-zero limited commitment problem, provides the proof of Proposition 2.2, and proves results for the deterministic economy discussed in Section 2.3.4.

A.1 Date-zero problem

This section describes the equivalent date-zero limited commitment problem.

Consider two households, household \( A \) and household \( B \). Each household has an initial pareto weight of \( \lambda_i \). The key mechanism in limited commitment models is the value of a household’s outside option: the utility from consuming their income today and the expected value of their future income. Define this value as \( \Omega(s_t) \):

\[
\Omega(s_t) = u(e(s_t)) + E \sum_{r=1}^{\infty} \beta^r u(e(s^r)|s^t)/
\]

The social planner’s problem is to find constrained efficient allocations that maximize the sum of utilities:

\[
\max_{(c^t_i)_{t=0}^\infty} \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t) \left\{ \lambda_A u(c^A(s_t)) + \lambda_B u(c^B(s_t)) \right\},
\]

subject to a set of incentive compatibility constraints for each agent \( i \) that hold for every time \( t \):

\[
\sum_{r=1}^{\infty} \sum_{s^r} \beta^{r-t} \pi(s^r|s^t) u(c^i(s_r)) \geq \Omega^i(s^t),
\]

and a standard resource constraint. Denote the lagrange multiplier on the incentive compatibility constraint for household \( i \) at state \( s^t \) by \( \gamma_i(s^t) \).

The first order condition for this problem at time \( t \), as a function of the participation constraints for each period until \( t \) is given by:

\[
\frac{u'(c^A(s^t))}{u'(c^B(s^t))} = \frac{\lambda^B + \gamma^B(s^0) + \gamma^B(s^1) + \ldots + \gamma^B(s^t)}{\lambda^A + \gamma^A(s^0) + \gamma^A(s^1) + \ldots + \gamma^A(s^t)}.
\]

Using the techniques of Marcet and Marimon (1998), and following Attanasio and Rios-Rull (2000) and Kehoe and Perri (2002) we can write this problem recursively. Define a variable \( M_i(s^t) \) which captures the history of binding participation constraints up to and including time \( t \). This variable is defined recursively: \( M_i(s^t) = M_i(s^{t-1}) + \gamma_i(s^t), \) with \( M_i(s^{-1}) = \lambda_i \). The time-zero problem can then be rewritten in terms of a participation constraint in terms of this period’s consumption (omitting the resource constraint):
\[
\sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t) \sum_i M_i(s^{t-1})u(c_i^t(s_t)) + \gamma_t(s^t)[u(c^t(s^t)) - \Omega_i(e(s^t))].
\]

Incentive compatibility HH i

The first order condition for the recursive problem yield first order conditions of the form:

\[
\frac{u'(c^A(s^t))}{u'(c^B(s^t))} = \frac{M^B_{t-1} + \gamma^B_t}{M^A_{t-1} + \gamma^A_t} = x.\]

This first order condition shows clearly how relative consumption adjusts to satisfy participation constraints. If agent A has a binding participation constraint then \(\gamma^A > 0\), and so the endogenous pareto weight in period \(t\) is lower than in period \(t - 1\), resulting in household A receiving a larger share of total consumption. The reverse holds for household B: if household B’s participation constraint binds then \(\gamma^B > 0\), and so \(x_t > x_{t-1}\), increasing B’s consumption share.

We can show that the relative pareto weight, \(x\) has a simple updating rule. Define \(\phi_t = \frac{\gamma_t}{M^A_{t-1}}\), and then the endogenous pareto weight for period \(t\) is the previous value of the endogenous weight, adjusted in the direction of which, if any, household has a binding participation constraint in period \(t\):

\[
x_t = \frac{1 + \phi^B(s^t)}{1 + \phi^A(s^t)} x_{t-1}.
\]

If agent A has a binding participation constraint then \(\phi^A > 0\), and so the endogenous pareto weight in period \(t\) is lower than in period \(t - 1\), resulting in household A receiving a larger share of total consumption. The reverse holds for household B: if household B’s participation constraint binds then \(\phi^B > 0\), and so \(x_t > x_{t-1}\), increasing B’s consumption share.

We can now write the problem recursively as an endogenously weighted sum of household A’s utility and household B’s utility. All of the information of past binding constraints is contained in \(x_{t-1}\). The state of the world, \(s_t\) and the value of \(x_{t-1}\) will determine which agent has a binding participation constraint, if any, and generates the updated endogenous pareto weight \(x_t\). \(x_t\) then determines the consumption allocation. The problem is recursive with the incoming pareto weight \(x\) and state of the world \(s\) the two state variables.

\[
V(x, s) = \max_{c^A, c^B, x'} u(c^A) + xu(c^B) + \beta \mathbb{E} [V(x', s') | V(x', s') + x'V^A(x', s') + x'V^B(x', s')]
\]

A.2 Proof of Proposition 2.2

Let \(s\) be the state of the world in the village, and \(q\) be the state of world in the migration destination.
**Proposition 2.2:** The constrained efficient contract can be characterized as follows: For each possible migration outcome, indexed by $i$, there exist $S \times Q$ state-dependent intervals $[x_{r,n}^i, \bar{x}_{r,n}^i]$, $r = 1, 2, ...; Q; n = 1, 2, ...Q$, such that $x(s_t, q_t)$ evolves according to the following rules. Let $x(s_t, q_t)$ be given, let $\{r,n\}$ be the state which occurs at time $t + 1$, and let $i(r)$ be the migration rule at time $t + 1$, then

$$x(r_{t+1}, n_{t+1}) = \begin{cases} x_{r,n}^i & \text{if } x(s_t, q_t) < x_{r,n}^{i(r)} \\ x(s_t, q_t) & \text{if } x(s_t, q_t) \in [x_{r,n}^{i(r)}, \bar{x}_{r,n}^{i(r)}] \\ \bar{x}_{r,n}^i & \text{if } x(s_t, q_t) > \bar{x}_{r,n}^{i(r)} \end{cases}$$

**Proof.** The optimal transfer, determined by $x(r_{t+1}, n_{t+1})$, is made ex-post of the realization of all migration income. For every possible combination of migration decisions, indexed by $i$, Proposition 2.1 applies, yielding an updating rule $x(r_{t+1}, n_{t+1})^i, i = \{1,..., \dim(i)\}$. The optimal migration rule is $i(r)$. Therefore the updating rule is given by the updating rule for $x(r_{t+1}, n_{t+1})^i(r)$. \qed

### A.3 Theoretical results from a deterministic economy

The section presents that risk-sharing only depends on the degree of inequality in endowment, for the deterministic economy considered in Section 2.3.4.

Assume the economy is deterministic economy with constant aggregate resources and symmetric endowments. There are two states of the world: in even periods agent A receives a good shock, and in odd periods agent B receives a good shock. The total endowment is constant and equal to $y$. The agent who has the good shock in period $t$ receives an endowment $\alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha \alpha 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Assuming log utility the participation constraint simplifies to a function only of the share of income and consumption, not the level:

\[
\log \alpha^c + \beta \log(1 - \alpha^c) = \log \alpha^\Omega + \beta \log(1 - \alpha^\Omega)
\]

(6)

The value of endowment is a concave function of \( \alpha \). For low levels of inequality the benefit of consuming more today is higher than the discounted effect of consuming less tomorrow, but as inequality increases this reverses. At high levels of inequality a mutually beneficial transfer from rich agent to poor agent is possible.

### A.3.2 Risk-sharing determined by allocation

Consider the effect on the distribution of consumption from a change in the distribution of endowment: \( \frac{\partial \alpha^c}{\partial \alpha^\Omega} \). Term this the incentive effect.

**Proposition A.1** (The incentive effect is negative if inequality is high). Assume that \( \alpha > \frac{1}{1+\beta} \). Then, the incentive effect is negative: as income becomes more unequal, consumption becomes more unequal.

**Proof:** Using the implicit function theorem, \( \frac{\partial \alpha^c}{\partial \alpha^\Omega} < 0 \).

Intuitively, as the allocation becomes more unequal, the gains from sharing risk increase. The economy can move closer towards the first-best allocation of perfect risk-sharing.

### B Computational appendix

The computational appendix presents the algorithm to solve the limited commitment game, and discusses the assumptions required to move from 2 to \( N \) households in the estimation procedure.

### 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.

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21 Log utility is not necessary to remove the level effect: the same equation with CRRA utility is

\[
(\alpha^c)^{1-\sigma} + \beta (1 - \alpha^c)^{1-\sigma} = (\alpha^\Omega)^{1-\sigma} + \beta (1 - \alpha^\Omega)^{1-\sigma}
\]
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 \( H \):

\[
\frac{u'(c_i)}{u'(c^H)} = x^i \quad \forall i \neq H
\]

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 \( i \neq H \)

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

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

Then:

\[
\left( \frac{\tilde{c}^{-H}}{\tilde{c}^H} \right)^\gamma = \left( \sum_{i \neq H} (x^i)^{-1/\gamma} \right)^\gamma = x^{-H}
\]

\[
\frac{u'(<c^H)}{u'(\tilde{c}^{-H})} = x^{-H}
\]

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.

B.1 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).

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 \( B \):

\[
V(x, s) = V^A(x, s) + xV^B(x, s)
\]

\[
V^A(x, s) = u(c^A(x', s)) + \beta V^A(x', s')
\]

\[
V^B(x, s) = u(c^B(x', s)) + \beta V^B(x', s')
\]
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
  \[ \Omega^i_{\text{ex-ante}}(s) = \max \{ u(e^i(s)), Eu(m^i(q)) - d \} + \beta E \Omega^i_{\text{ex-ante}}(s') \]

- The ex-post participation constraint
  \[ \Omega^i_{\text{ex-post}}(s, q, I^i) = I^i u(m^i(q)) + (1 - I^i) u(e^i(s)) + \beta E \Omega^i_{\text{ex-ante}}(s') \]

- First-best risk-sharing (no migration)
  \[ V^i_{\text{first-best}}(s) = u\left(\frac{e^A(s) + e^B(s)}{2}\right) + V^i_{\text{first-best}}(s) \]

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:
     \[ u(e^i(s_t, x_t)) + \beta EV^i_{t-1}(x_t, s_{t+1}) \geq \Omega^i_{\text{ex-post}}(s_t) \]
     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

$$V_{no\ mig,t}^i(s_t, x_t) = u(c(s_t, x_t)) + \beta EV_{t-1}^i(x_t, s_{t1})$$

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:

$$u(c^i(s_t, q_t, x_t)) + \beta EV_{t-1}^i(x_t, s_{t1}) \geq \Omega_{ex-post}^i(s_t, q_t)$$
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

$$V_{migration}^i(s_t, q_t, x_t) = u(c(s_t, q_t x_t)) + \beta EV_{t-1}^i(x_t, s_{t1})$$

6. Find the expected value of migrating

$$V_{migration}^i(s_t, x_t) = EV_{migration}^i(s_t, q_t, x_t)$$

7. Solve for the optimal migration decision

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

• Check that the ex-ante participation constraint is satisfied

$$\mathbb{1}(V_{migration}^i(s_t, x_t)) + (1 - \mathbb{1})(V_{no\ mig,t}^i(s_t, x_t)) \geq \Omega_{ex-ante}^i(s_t)$$
If the ex-ante condition is not satisfied, set $\mathbb{1} = (1 - \mathbb{1})$

8. Update the value function for period $t$

$$V_t^i(s_t, x_t) = \mathbb{1}(V_{migration}^i(s_t, x_t)) + (1 - \mathbb{1})(V_{no-mig,t}^i(s_t, x_t))$$

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

10. Update Step 1 with vector of migration outcomes

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