*Migration in Rural Mexico: Strategic Interactions, Dynamic Behavior, and the Environment**

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Abstract

Understanding international migration is important from both an economic and policy perspective. In this paper, we add to the literature on the determinants of migration by proposing a methodological framework that incorporates strategic interactions and dynamic behavior and use this framework to examine the effects of the environment on migration decisions and welfare. In particular, we apply a structural econometric model of the dynamic game between households in a village making decisions about migration to detailed household-level data from rural Mexico. The structural econometric model enables us to examine how environmental factors, such as changes in precipitation affect the migration decisions of households. We use the parameters we estimate to simulate the effects of counterfactual scenarios regarding climate and the environment on migration decisions and welfare.

JEL Codes O15, O54

Keywords: Migration, Mexico, Strategic Interactions, Dynamic Behavior, Dynamic Game, Structural Econometric Model, Environment

Introduction

Understanding the factors that affect migration is important from the perspective of both economics and public policy. This is particularly important for migration from Mexico to the U.S., which represents one of the largest migration flows in the world, and which is both economically important and relevant for policy (Rojas Valdes, Lin Lawell, and Taylor, 2017a). For example, some authors estimate that 13 % of household total income and 16 % of per capita income in Mexico come from

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migrant remittances (Taylor et al., 2008).[1]

There is an increasing number of academic studies that have focused their attention on the relationships between the movements of people for economic and environmental reasons. In this paper, we propose a new methodological approach to analyzing the relationships that occur between environmental factors and migration decisions. Our model of household migration decisions incorporates economic factors, environmental factors, strategic interactions, and dynamic behavior.

We model migration as a dynamic decision, similar to that of investment under uncertainty, where payoffs are uncertain and where there is leeway over the timing of the migration decisions, generating an option value to waiting. As in investment under uncertainty problems, players make decisions based not only on the current state of economic factors but also on the prospects of economic opportunities in other areas and the potential streams of net benefits (or payoffs) from migrating (Rojas Valdes, Lin Lawell, and Taylor, 2017b).

We also model migration as a strategic decision and thus allow for strategic interactions between households. These 'strategic interactions' arise when the migration decisions of other households in their village affect a household's payoffs from migration and, therefore its decisions to have a member migrate. There are several reasons why a household's migration decisions may depend on the migration decisions of its neighbors, including migration networks and information externalities (Rojas Valdes, Lin Lawell, and Taylor, 2017a).

To examine strategic interactions, dynamic behavior, and the effects of the environment on migration decisions, we apply a structural econometric model of the dynamic game between households in a village making decisions about migration we have developed in Rojas Valdes, Lin Lawell and Taylor (2017b) to detailed household-level data from rural Mexico. The structural econometric model enables us to examine how natural factors, economic factors, institutions, government policies, and strategic interactions affect the migration decisions of households in rural Mexico. We use this model to simulate the effects of counterfactual scenarios regarding climate and the environment on migration decisions and welfare. In our model of a dynamic game, players make decisions to maximize the present discounted value of

[1] Castelhano et al. (2017) find that migrant remittances are not associated with increases in rural investment in agricultural production in Mexico, however.

their stream of expected per-period payoffs, and their actions affect not only their own payoffs but also the payoffs of other players. These strategic interactions occur in a dynamic context because individuals make decisions based not only on what they see today and expect other individuals to do today but also on what they expect the state of the economy to be and what they expect other agents to do in the future.

Structural econometric models of dynamic and strategic decision-making enable one to answer the following questions. First, how do natural factors, economic factors, government policies, and strategic interactions affect the strategic and dynamic decision-making behavior of households in rural Mexico? Second, how do different institutions and policies affect this behavior and its outcome? Third, how should we design institutions and policies so that the decision-making behavior and outcome that are realized increase social welfare?

The balance of the paper is as follows. In the next section, we review the related literature. The following section describes our data, then we present our methodological framework, and the results, and the last section concludes the paper.

LITERATURE REVIEW

Determinants of migration

The use of a structural econometric model is motivated by a large amount of economic research on the determinants of migration. As in the literature of the new economics of labor migration, we use the household as the relevant analysis unit, which responds to several observed features of migration that cannot be captured by individualistic models, such as the presence of remittances and the existence of extended households (see, e.g., Stark and Bloom, 1985; Taylor and Martin, 2001). Rojas Valdes, Lin Lawell, and Taylor (2017a) provide a detailed survey of the literature on determinants of migration, including the literature on the new economics of labor migration.

We also build on the literature examining the relationship between migration and the environment. Jessoe, Manning, and Taylor (2016) use a 28-year panel on individual employment and find that years with a high occurrence of heat lead to a reduction in local employment, particularly for wage work and non-farm labor. They also find that extreme heat also increases migration domestically from rural to urban areas and internationally to the U.S.

Maystadt, Mueller, and Sebastian (2016) investigate the impact of weather-driven internal migration on labor markets in Nepal. They find that an increase of 1 percentage point in net migration reduces wages in the formal sector by 5.7%. A similar change in migration augments unemployment by one percentage point. The unskilled bear greater consequences. Understanding entrepreneurial constraints and drivers of labor market exits will inform pathways to resilience (Maystadt, Mueller and Sebastian, 2016).

Mason (2016) analyzes climate change and migration using a dynamic model. In particular, he develops a model in which citizens of a country vulnerable to damages from climate change may migrate to a second country, from which a steady stream of greenhouse gases occurs. If this migration imposes costs on the emitting country, then migration induces a sort of pseudo carbon tax via political, economic forces. This pseudo tax creates an incentive for the country receiving the flow of immigrants to lower its emissions, offering an offset to the costs incurred as a result of climate change. Mason (2016) shows that the long run carbon stock, and the entire time path of production (and hence emissions), is smaller in the presence of migration. He also discusses various comparative dynamics for both the path of production and the long run atmospheric carbon stock.

Mahajan and Yang (2017) examine migration responses to hurricanes, which reduce the attractiveness of origin locations. Restricted-access U.S. Census data allows precise migration measures and analysis of more migrant-origin countries. They find that hurricanes increase

U.S. immigration, with the effect increasing in the size of prior migrant stocks. Results show that large migrant networks reduce fixed costs by facilitating legal immigration from hurricane-affected source countries.

Strategic interactions

"Strategic interactions" arise whenever the migration decisions of other households in their village affect a household's payoffs from migration and, therefore, its decisions to have a member migrate. Based on the literature, there are several reasons why households make take into account the actions of other households in their village when making their migration decisions (Rojas Valdes, Lin Lawell, and Taylor, 2017a).

The first source of strategic interactions is migration networks. Migration networks may affect migration decisions because they may reduce the financial, psychological, and/or informational costs of moving out of the community. Contacts in the source economy lower financial or information costs and reduce the utility loss from living and working away from home (Rojas Valdes, Lin Lawell, and Taylor, 2017a). The role of migration networks has been studied by Du, Park, and Wang (2005) on China; Bauer and Gang (1998) on Egypt; Battisti, Peri and Romiti (2016) on Germany; and several others on Mexico, including Massey and Espinosa (1997) and Massey, Goldring and Durand (1994). These papers find a positive effect of migration networks on the probability of migration. In his analysis of job networks among Mexican immigrants in the U.S. labor market, Munshi (2003) finds that the same individual is more likely to be employed and to hold a higher paying nonagricultural job when his network is exogenously higher. Orrenius and Zavodny (2005) show that the probability of migrating for young males in Mexico increases when their father or siblings have already migrated. McKenzie and Rapoport (2010) lower average schooling in migrants from Mexican communities with a larger presence in the United States. Networks and the presence of relatives or friends in the host country are consistently found to be significant in studies such as those of Greenwood (1971) and Nelson (1976), among others. Wahba and Zenou (2005) show that conditional on being employed, the probability of finding a job through social networks, relative to other search methods, increases and is concave with the size of the network.

A second source of strategic interactions is information externalities between households in the same village that may have a positive effect on migration decisions. When a household decides to send a migrant outside the village, other households in the village may benefit from learning information from their neighbor. This information may include information about the benefits and costs of migration, as well as information that enables a household to increase the benefits and reduce the costs of migration (Rojas Valdes, Lin Lawell, and Taylor, 2017a).

A third source of strategic interactions may be relative deprivation. Models of relative deprivation (see, e.g., Stark and Taylor, 1989; Stark and Taylor, 1991) consider that a household's utility is a function of its relative position in the wealth distribution of all the households in the community. Individuals who migrate remain attached to their household and remit to improve the position of their household with respect to the reference group. The relative deprivation motive helps to explain why local migration is different from international migration because when a migrant moves within the same country it is more likely that she changes her relative group since it is easier to adapt in the host economy (where maybe the same language is spoken, and the cultural differences are not as dramatic as in the case of international migration). Also, the relative deprivation concept would predict that those individuals from a household that is relatively deprived might decide to engage in international migration rather than domestic migration even though the former is more costly because by migrating locally her position in the most likely new reference group would be even worse than the position she would have if she did not migrate (Stark and Taylor, 1989; Stark and Taylor, 1991; Rojas Valdes, Lin Lawell, and Taylor, 2017a).

A fourth source of strategic interactions is risk sharing (Rojas Valdes, Lin Lawell, and Taylor, 2017a). Chen, Szolnoki and Perc (2012) argue that migration can occur in a setting when individuals share collective risk. Cheng et al. (2011) show that migration might promote cooperation in the prisoner's dilemma game. Lin et al. (2011) show that aspirations also promote cooperation in the prisoner's dilemma game. Morten (2016) develops a dynamic model to understand the joint determination of migration and endogenous temporary migration in rural India and finds that improving access to risk sharing reduces migration.

A fifth source of strategic interactions is a negative competition effect whereby the benefits of migrating to the U.S. or within Mexico would be reduced if others from the same village also migrate to the U.S. or within Mexico (Rojas Valdes, Lin Lawell and Taylor, 2017a). Having a limited number of employers at the destination site who do not discriminate against migrants from elsewhere (Carrington, Detragiache and Vishwanath, 1996) may exacerbate this competition effect (Rojas Valdes, Lin Lawell, and Taylor, 2017b).

Owing to migration networks, information externalities, relative deprivation, risk sharing, competition effects (Rojas Valdes, Lin Lawell and Taylor, 2017a), and a limited number of employers at the destination site who do not discriminate against migrants from elsewhere (Carrington, Detragiache and Vishwanath, 1996), households may take into account the migration decisions of neighboring households when making their migration decisions (Rojas Valdes, Lin Lawell, and Taylor, 2017a).

We build on our work in Rojas Valdes, Lin Lawell and Taylor (2017a), or 'neighborhood effects,' in which we study the strategic interactions in migration decisions using reduced-form models. We analyze whether the fraction of neighbors who engage in migration to the U.S. and the fraction of neighbors who engage in migration within Mexico affect a household's decision to have a member migrate to the U.S. and/or a household's decision to have a member migrate within Mexico.

Measuring neighbors' effects is difficult, owing to two sources of endogeneity. One source is the simultaneity of the strategic interaction: if household *i* is affected by its neighbor *j*, then household *j* is affected by its neighbor *i*. The other arises from spatially correlated unobservable variables (Manski, 1993; Manski, 1995; Brock and Durlauf, 2001; Conley and Topa, 2002; Glaeser, Sacerdote and Scheinkman, 1996; Moffitt, 2001; Irwin and Bockstael, 2002; Munshi, 2003; Lin, 2009; Robalino and Pfaff, 2012; Pfeiffer and Lin, 2012; Topa and Zenou, 2015; Morrison and Lin Lawell, 2016). It is, therefore important to address these endogeneity problems in order to identify any strategic interactions (Rojas Valdes, Lin Lawell, and Taylor, 2017a).

To address the endogeneity of neighbors' migration decisions, Rojas Valdes, Lin Lawell and Taylor (2017a) use instruments for the fraction of neighbors that engage in migration that are correlated the neighbors' migration decisions but do not affect a household's own-migration decision except through their effect on the neighbors' migration decisions.

Structural econometric models

The methodology we use in this paper follows the literature of structural econometric models initiated by Rust (1987), who develops an econometric method for estimating single-agent dynamic discrete choice models and is considered the seminal work in dynamic structural econometric models. Structural econometric models of dynamic behavior have been ap- plied to model bus engine replacement (Rust, 1987), nuclear power plant shutdown decisions (Rothwell and Rust, 1997), water management (Timmins, 2002), air conditioner purchase behavior (Rapson, 2014), wind turbine shutdowns and upgrades (Cook and Lin Lawell, 2017), agricultural disease management (Carroll et al., 2017b), supply chain externalities (Carroll et al., 2017a), agricultural productivity (Carroll et al., forthcoming), pesticide spraying decisions (Sambucci, Lin Lawell and Lybbert, 2017), and decisions regarding labor supply, job search, and occupational choices (see Keane, Todd and Wolpin, 2011).

More recently, burgeoning literature using structural models in development economics has also been used to tackle problems related to migration. Shenoy (2016) estimates the cost of migration and migration-related supply elasticity in Thailand using the structural model of location choice. He finds that the costs of migration are 0.3 to 1.1 times as high as average annual earnings. He also finds that migration contributes 8.6 percentage points to local labor supply elasticity. We build on Shenoy's (2016) work by explicitly modeling the dynamic and strategic components of international migration.

To explain the large spatial wage disparities and low male migration in India, Munshi and Rosenzweig (2016) develop and estimate a structural econometric model of the trade-off between consumption smoothing, provided by caste-based rural insurance networks, and the income gains from migration. We build on Munshi and Rosenzweig's (2016) work by explicitly modeling the dynamics of international migration, by allowing for multiple channels of strategic interactions in addition to networks, and by applying our model to migration from rural Mexico.

Morten (2016) develops and estimates a dynamic structural model of risk sharing with limited commitment frictions and endogenous temporary migration to understand the joint determination of migration and risk sharing in rural India. We build on Morten's (2016) work by allowing for multiple channels of strategic interactions in addition to risk sharing, and by applying our model to migration from rural Mexico.

As many migrations are temporary (Dustmann and Gorlach, 2016), Kennan and Walker (2011) estimate a dynamic structural econometric model of optimal sequences of migration decisions in order to analyze the effects of expected income on individual migration decisions. They apply the model to interstate migration decisions within the United States. The model is estimated using panel data from the National Longitudinal Survey of Youth on white males with a high-school education. Their results suggest that the link between income and migration decisions is driven both by geographic differences in mean wages and by a tendency to move in search of a better locational match when the income realization in the current location is unfavorable.

While most of the dynamic structural econometric models in development economics model single-agent dynamic decision-making (see, e.g., Todd and Wolpin, 2010; Duflo, Hanna, and Ryan, 2012; Mahajan and Tarozzi, 2011), we model a dynamic game between decision- makers and thus allow for both dynamic and strategic decision-making. Structural econometric models of dynamic games incorporate not only dynamic behavior but also strategic interactions as well. These models allow researchers to answer questions that cannot be addressed using static settings and that account for the effect of players decisions on other players' payoffs and state variables.

The structural econometric model of a dynamic game we use builds on a model developed by Pakes, Ostrovsky and Berry (2007), which has been applied to the multi-stage investment timing game in offshore petroleum production (Lin, 2013), to ethanol investment decisions (Thome and Lin Lawell, 2017), and to the decision to wear and use glasses (Ma, Lin Lawell and Rozelle, 2017); a model developed by Bajari et al. (2015) and applied to ethanol investment (Yi and Lin Lawell 2017a; Yi and Lin Lawell, 2017b); as well as on a model developed by Bajari, Benkard and Levin (2007), which has been applied to the cement industry (Ryan, 2012; Fowlie, Reguant and Ryan, 2016), the ethanol industry (Yi, Lin Lawell and Thome, 2017), the world petroleum industry (Kheiravar, Lin Lawell and Jaffe, 2017), and climate change policy (Zakerinia et al., 2017). Huang and Smith (2014) model the dynamics of common-pool fisheries exploitation in North Carolina.

DATA

Our primary source of data is the National Survey of Rural Households in Mexico (ENHRUM) in its three rounds (2002, 2007, and 2010)[2]. The survey is a nationally representative sample of Mexican rural households across 80 villages and includes information on household characteristics such as productive assets and production decisions. It also includes retrospective employment information: individuals report their job history back to 1980. With this information, we construct an annual household-level panel data set that runs from 1990 to 2010[3] and that includes household composition variables such as household size, household head age, and the number of males in the household. For each individual, we have information on whether they are working in the same village, in some other state within Mexico (internal migration), or the United States.

The survey also includes information about the plots of land owned by each household, including slope (flat, inclined, or very inclined), quality (good, regular, or bad), irrigation status, and land area.[4]We reconstruct the information for the complete panel using the date at

[2] The sample of 2010 is smaller than the sample of the two previous rounds because it was impossible to access some villages during that round due to violence and budget constraints

[3] Since retrospective data from 1980 to 1989 included only some randomly selected individuals in each village who reported their work history, we begin our panel data set in 1990

[4] We use information on plots of land which are owned by the household because our data set does not include comparable information on plots of land that are rented or borrowed.

which each plot was acquired. Since a plot's slope and quality are unlikely to change over time (unless investments were taken to considerably change the characteristics of the plots, which we do not observe very often in the data), we interact the plot variables with a measure precipitation at the village level (Jessoe, Manning and Taylor, 2016) so the characteristics vary across households and along time. Rain data is available only for the subperiod of 1990 to 2007.

We use information from the National Statistics Institute (INEGI) to control for the urbanization and education infrastructure at the municipality level, including the number of basic schools and the number of indigenous schools. We also include the number of registered cars and buses. These data cover the period 1990 to 2010.

We also include aggregate variables that represent the broad state of the institutional and economic environment relevant to migration. We use data from the INEGI on the fraction of the labor force employed in each of the three productive sectors (primary, secondary, and tertiary)[5] at the state level, from 1995 to 2010. We use INEGI's National Survey of Employment and the methodology used in Campos-Vazquez, Hincapie, and Rojas-Valdes (2012) to calculate the hourly wage at the national level from 1990 to 2010 in each of the three productive sectors and the average wage across all three sectors.

METHODOLOGICAL FRAMEWORK

We model the migration decisions of households in a village as a dynamic game in which each household optimally decides how to allocate its members across distinct activities, taking into account dynamic considerations about the future and strategic considerations about what neighbors in the village are doing.

Migration decisions are dynamic because these decisions can be viewed as forms of investment, there is leeway over the timing of these decisions, and the payoffs from these decisions are uncertain; as a consequence, there may be an option value to waiting before making these decisions that make these decisions dynamic rather than static. Migration decisions are also dynamic because households consider the future when making these decisions,

[5] The primary sector includes agriculture, livestock, forestry, hunting, and fisheries. The secondary includes the extraction industry and electricity, manufacturing, and construction. The tertiary sector includes commerce, restaurants and hotels, transportation, communication and storage, professional services, financial services, corporate services, social services, and government and international organizations.

basing them not only on the current state of economic factors but also on the prospects of economic opportunities in other areas and the potential streams of net benefits (or payoffs) from migrating.

The structural econometric model of a dynamic game we develop and estimate in Rojas Valdes, Lin Lawell and Taylor (2017b) enables us to examine how natural factors, economic factors, institutions, government policies, and strategic interactions affect the migration decisions of households in rural Mexico. In this paper, we use the estimated parameters from a structural econometric model of a dynamic migration game to simulate the effects of counterfactual scenarios regarding climate and the environment on migration decisions and welfare. In Rojas Valdes, Lin Lawell and Taylor (2017b), we build on this framework to develop and estimate an expanded and more sophisticated structural econometric model of the dynamic migration game and use it to simulate the effects of counterfactual policy scenarios, including those regarding schooling, land quality, climate, institutions, and government policy, on migration decisions and welfare.

There are several advantages to using a dynamic structural econometric model. First, a dynamic structural model explicitly models the dynamics of migration decisions. Second, a dynamic structural model incorporates continuation values that explicitly model how expectations about future affect current decisions. Third, a structural econometric model of a dynamic game enables us to estimate structural parameters of the underlying dynamic game with direct economic interpretations. These structural parameters include parameters that measure the effects of state variables on household payoffs (utility) and the net effect of the strategic interactions. These parameters account for the continuation value. Fourth, the parameter estimates can be used to calculate welfare. Fifth, the parameter estimates can be used to simulate the effects of counterfactual scenarios on decisions and welfare.

Dynamic migration game

The players in our dynamic migration game are households within a village. Assume that there are $i = 1,...,N$ players. The planning horizon is discretized into an infinite number of years $t = 1, ...,\infty$.

Each year t, each household chooses an action from a discrete finite set $a_{it} \in A_i$, and all households choose their time-t actions a_{it} simultaneously, such that $\mathbf{a}_t = (a_{1t}, ..., a_{Nt}) \in A$ summarizes the actions played at t. In our model, the actions are whether to engage in new migration to the U.S., and whether to engage in new migration within Mexico. New migration to the U.S. is equal to 1 for household *i* in year *t* if a household has a member migrate to the U.S. for the first time in year *t* and did not have a member migrate to the U.S. last year. Similarly, new migration within Mexico is equal to 1 for household *i* in year *t* if a household has a member migrate within Mexico for the first time in year *t* and did not have a member migrate within Mexico last year.

The decisions of each household *i* in year *t* depend on the vector of state variables $\mathbf{s}_t \in S \subset \mathrm{R}^{L}$ at time *t*. For state variables, we include the household head age, the household head schooling, the maximum level of schooling of any member of the household, the slope of plots of land owned by the household interacted with rain, the quality of plots of land owned by the household interacted with rain, and whether the household engaged in migration in the past 5 years.

The decisions of each household *i* in year *t* also depend on private information shocks to household *i*. Each period *t*, each household *i* receives an idiosyncratic shock $\varepsilon_{it} \in E_i$ independent of other players' private shock with distribution $G_i(\cdot|\mathbf{s}_t)$ such that the collection of idiosyncratic shocks is $\varepsilon_t = (\varepsilon_{1t},...,\varepsilon_{Nt})$. The private information shocks may represent, for example, shocks to household costs, health, and/or income.

Each household's *i* per-period payoff depends on the actions played by household *i*, the actions played by other households (denoted $-i$), the state variables $\mathbf{s}_t$, and household *i*'s private shock. For the actions of neighbors, we include the fraction of neighbors with new migration to the U.S. and the fraction of neighbors with new migration within Mexico. We also include squared terms of the state variables; interactions between a household's own action and each of the state variables; and interactions between a household's own action and the actions of its neighbors. We denote the per-period payoff function as $\pi_i(\mathbf{a}_t, \mathbf{s}_t, \varepsilon_{it})$.

At each time *t*, each household *i* makes its decisions in order to maximize the present discounted value of the entire stream its expected per-period payoffs, without knowing what the future realizations of its idiosyncratic shocks and the state vector will be, and without knowing what other households will decide to do at time *t*.

The dynamic optimization problem of agent i at a given period $t = s$ is given by:

$$\max_{\{a_{it}\}} \quad E\left[\sum_{t=0}^{\infty} \beta^t \pi_i(\mathrm{a}_t, \mathrm{s}_t, \varepsilon_{it}) | \mathrm{s}_t\right].$$

The policy functions describe the behavior of households as functions of other households' actions and the values of the state vector. For purposes of analyzing the behavior of households in equilibrium, we follow Bajari, Benkard, and Levin (2007) and focus on a particular type of policy function: those consistent with pure strategy Markov perfect equilibria. A Markov strategy of player i is a function $\sigma_i : S \times E_i \rightarrow A_i$ that maps combinations of state-shocks into actions such that $\sigma : S \times E_1 \times ... \times E_N \rightarrow A$ is the profile of strategies, and where $E_i \subset \mathrm{R}^M$ is the support of G_i. For a realization of the state vector **s**, the expected payoff of player i from playing strategy σ_i is:

$$V_i(\mathrm{s}; \sigma) = E_\varepsilon\left[\pi_i(\sigma(\mathrm{s}, \varepsilon), \mathrm{s}, \varepsilon_i) + \beta \int V_i(\mathrm{s}'; \sigma) dP(\mathrm{s}'|\sigma(\mathrm{s}, \varepsilon), \mathrm{s})|\mathrm{s}\right].$$

This expression gives the expected payoff for player i when the state vector is realized at **s**, before she receives the idiosyncratic shock. This payoff has two terms: the current payoff, which is a function of the set of strategies being played, the state vector, and the individual-specific shock; and the discounted stream of payoffs that the player expects given that state **s** was realized and the probabilities of ending up at state **s** in the next period, which in turn depend on the profile of strategies, the set of idiosyncratic shocks, and the current state vector.

The assumption of a Markov Nash Perfect Equilibrium means that for all players, states and strategies, each player's set of decisions is the best response to the rest of the players' decisions:

$$V_i(\mathrm{s}; \sigma) \geq V_i(\mathrm{s}; \sigma'_i, \sigma_{-i}).$$

We describe our dynamic migration game in more detail in Rojas Valdes, Lin Lawell, and Taylor (2017b).

Econometric Estimation

The parameters θ to be estimated are the coefficients on the terms in the per-period pay- off function, which include terms that are functions of action variables, strategic variables, demographic characteristics of the household, natural factors, economic factors, and government policies. Even in problems with simple structure, finding a single equilibrium is computationally costly. In more complex problems, as in the case of the dynamic game of migration, where many agents and decisions are involved, the computational burden is even more important. Bajari, Benkard, and Levin (2007) propose a method for recovering the dynamic parameters of the payoff function without having to compute any single equilibrium. Their estimation builds on the algorithm of Hotz and Miller (1993) but allows for continuous and discrete choice variables, so their approach is more general and can be implemented in a broader array of research questions. We follow Bajari, Benkard, and Levin (2007) and estimate our structural econometric model in two stages.

In the first stage, we estimate the parameters of the policy function, the transition densities, and the value function. We estimate the policy functions as an empirical relationship between the observed actions and the state variables. In particular, we regress a household's decisions to engage in new migration to the U.S. and new migration within Mexico on the state variables, using instruments similar to those we use in Rojas Valdes, Lin Lawell and Taylor (2017a) to address the endogeneity of the neighbors' decisions. We estimate the transition densities for the state variables, which describe how these state variables evolve over time, as linear functions of each variable and its lags, and the lags of other relevant variables.

We use forward simulation to estimate the value function. The procedure consists of simulating many paths of play for each individual given distinct draws of the idiosyncratic shocks and then averaging over the paths of play to get an estimate of the expected value function. Our methodological innovation is that we address the endogeneity of neighbors' decisions using a fixed point calculation, as described in detail in Rojas Valdes, Lin Lawell, and Taylor (2017b).

The second stage consists of estimating the parameters of the payoff function that are consistent with the observed behavior. This is done by appealing to the assumption of Markov

Perfect Nash Equilibrium, so each observed decision is every agent's best response to the actions of the rest of the players. Following Bajari, Benkard and Levin (2007), we use a minimum distance estimator to find the parameters that minimize profitable deviations from the optimal strategy.

We describe our structural econometric model in more detail in Rojas Valdes, Lin Lawell, and Taylor (2017b).

RESULTS

Table 1 (See Appendix) presents the parameter estimates from our structural econometric model. We find that the payoff to migrating to the U.S. decreases when neighbors migrate to the U.S. as well. Similarly, the payoff to migrating within Mexico decreases when neighbors migrate within Mexico as well. These negative effects on welfare possibly occur through the effect of neighbors migrating today on expected future strategic interactions. That is, households perceive that their future benefits from neighbors engaging in migration in the future might decrease if their neighbors engage in migration today instead.

We also find that the payoff to migrating is affected by schooling. In addition, the payoff to migrating is affected by land quality and precipitation.

To examine the effects of the environment on migration decisions, we use the parameter estimates from the structural econometric model to simulate the effects of different counterfactual scenarios for precipitation. Specifically, we simulate changes in precipitation of -50%, -25%, -15%, -10%, 10%, 15%, 25%, and 50%. The simulated data is compared to the base case scenario of no changes in precipitation to examine changes in welfare and migration that may result from changes in precipitation.

In *Table* 2 (See Appendix) we present the results of a two-sample *t*-test of differences in average welfare per household-year under each precipitation scenario when compared to the base case scenario of no change in precipitation. None of the counterfactual precipitation scenarios results in a change in welfare that is statistically significant.

Table 3 (See Appendix) shows the counterfactual number of migrants under each of the counterfactual precipitation scenarios. In contrast to the welfare measures, for which we do not observe any statistically significant change, under some moderate to extreme changes in precipitation, both the number of households with migrants to the U.S. and the number of households with migrants within Mexico is different from the base case scenario of no change in precipitation, and this difference is statistically significant. For example, an increase of 10% in precipitation leads to an increase of 1.3% in the number of households with migrants to the U.S., and an increase of 0.6% in the number of households with migrants within Mexico. Furthermore, these changes in the number of households with migrants are not monotonic with the change in precipitation. Our results suggest that households may be using migration as a means to smooth their welfare when exogenous conditions change.

We also examine the effects of precipitation changes on welfare and number of households with migrants at the village level. Figure 1a presents the results of the simulation of a 25% decrease in precipitation on the average welfare per household-year in each village. Red dots denote villages with a statistically significant decrease in welfare, green dots denote villages statistically with a statistically significant increase in welfare, and black dots denotes villages with no significant changes. Only few villages show a statistically significant change in welfare.

Figures 1b and 1c (See Appendix) present the changes in the number of households with migration to the U.S. and within Mexico due to a decrease of 25% in precipitation. Red dots represent villages with a statistically significant decrease in the number of households with migrants, green dots represent villages with a statistically significant increase in the number of households with migrants, and black dots represent villages with no change in the number of households with migrants. Villages respond differently to decreases in precipitation: more households in the center and north of Mexico respond to these new scenarios, sending more migrants to the U.S.; and only a few villages have fewer households sending migrants to the U.S. In contrast, only a few villages have more households sending migrants within Mexico, and many of them have fewer households sending migrants within Mexico. This could be to a reallocation of labor: since the changes in precipitation are expected to happen in a broad area - possibly the entire country - households diversify their labor force by sending migrants to a more remote location, the U.S.

We also analyze the effects of a 25% increase in welfare and migration by village. Figure 2a presents the results of the simulation of a 25% increase in precipitation on the average welfare per household-year in each village. Once again, only a few villages have a statistically significant change in welfare.

Figures *2b* and *2c* (See Appendix) present the results of our simulations of a 25% increase in precipitation on migration. Now, for both migration to the U.S. and within Mexico, there are more villages with more households sending migrants to the U.S. and within Mexico than villages with fewer households sending migrants to these locations.

Conclusion

Strategic interactions among households in a village have an important role in household migration decisions that have previously been neglected in the literature. Dynamic behavior is an important aspect of household migration decision-making as well.

Our analysis of the effects of the environment on migration shows that changes in precipitation affect migration decisions but has less of an effect on household welfare, and these effects vary across villages. Our results suggest that households may be using migration as a means to smooth their welfare when exogenous environmental conditions change. Strategic interactions, dynamic behavior, and environmental conditions are, therefore important considerations that affect migration decisions.

We have presented a framework that can be extended to analyze the effects of government policies, natural factors, and economic factors on migration decisions, which we do in Rojas Valdes, Lin Lawell, and Taylor (2017b). This framework is particularly timely, as migration and the movement of labor, in general, have regained the attention of researchers in light of its political relevance. The decisions of people to move depend on complex trade-offs and expectations that are difficult to capture in static settings of agents making individualistic decisions; one must thus account for both strategic interactions and dynamic behavior. One potential drawback of this approach is its reliance on detailed data that might not be available in every context. As reduced-form models and structural econometric models each have their advantages and disadvantages, it is often a good idea to tackle problems using both approaches.

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APPENDIX

Table 1 Parameter Estimates

	Estimate	Standard error	
Coefficient in per-period payoff on:			
Own new migration to US	0.000680	0.000017	***
Own new migration within Mexico	0.000665	0.000004	***
Own migration to US	0.000680	0.000017	***
Own migration within Mexico	0.000665	0.000004	***
Fraction of neighbors with new migration to US -	0.001406	0.00004	***
Fraction of neighbors with new migration within Mexico -	0.000319	0.000004	***
Household head age (years) -	0.001000	0.000000	***
Household head schooling (years) -	0.000429	0.000000	***
Household maximum schooling (years) -	0.000625	0.000001	***
Plot's slope interacted with rain -	0.000722	0.000000	***
Plot's quality interacted with rain -	0.000040	0.000001	***
US migration in past 5 years -	0.000411	0.000016	***
Mexico migration in past 5 years -	0.000469	0.000003	***
Household head age (years), squared	0.000010	0.000000	***
Household head schooling (years), squared	0.000562	0.000001	***
Household maximum schooling (years), squared	0.000319	0.000002	***
Plot's slope interacted with rain, squared	0.000156	0.000000	***
Plot's quality interacted with rain, squared	0.000607	0.000001	***
US migration in past 5 years, squared	0.000598	0.000016	***
Mexico migration in past 5 years, squared	0.000540	0.000003	***
Own new migration to US, squared	0.000781	0.000017	***
Own new migration within Mexico, squared	0.000766	0.000004	***
Fraction of neighbors with new migration to US * Own new migration to US -	0.002292	0.000012	***
Fraction of neighbors with new migration within Mexico * Own new migration to US	0.001336	0.000001	***
Household head age * Own new migration to US	0.000013	0.000049	
Household head schooling * Own new migration to US -	0.000051	0.000004	***
Household maximum schooling (years) * Own new migration to US	0.000100	0.000005	***
Plot's slope interacted with rain * Own new migration to US	0.000492	0.000003	***
Plot's quality interacted with rain * Own new migration to US	0.000488	0.000003	***
Mexico migration in past 5 years * Own new migration to US -	0.000156	0.000003	***
Fraction of neighbors with new migration to US * Own new migration within Mexico -	0.000733	0.000001	***
Fraction of neighbors with new migration within Mexico * Own new migration within Mexico -	0.002581	0.000004	***
Household head age * Own new migration within Mexico -	0.000025	0.000026	
Household head schooling * Own new migration within Mexico -	0.000067	0.000002	***
Household maximum schoooling (years) * Own new migration within Mexico -	0.000086	0.000006	***
Plot's slope interacted with rain * Own new migration within Mexico -	0.000506	0.000001	***
Plot's quality interacted with rain * Own new migration within Mexico -	0.000519	0.000001	***
US migration in past 5 years * Own new migration within Mexico -	0.000402	0.000002	***

Note: Bootstrap standard errors using 100 repetitions.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01

Table 2: Effects of Changes in Precipitation on Welfare: Two-sample t-test of the change in average welfare per household-year

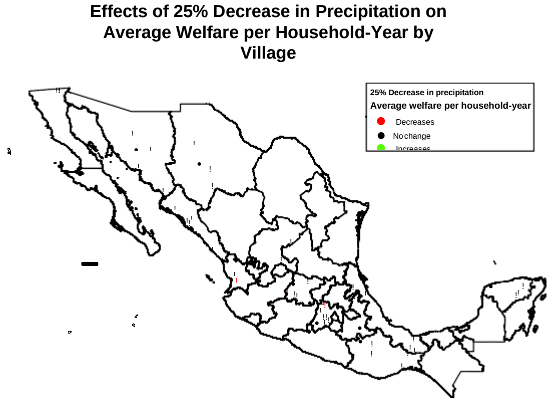
	Base case	Simulated	Percentage change from base case
-50% precipitation	-0.0028	-0.0028	-0.1596
	(0.0000)	(0.0000)	
-25% precipitation	-0.0028	-0.0028	-0.0834
	(0.0000)	(0.0000)	
-15% precipitation	-0.0028	-0.0028	-0.0508
	(0.0000)	(0.0000)	
-10% precipitation	-0.0028	-0.0028	-0.0508
	(0.0000)	(0.0000)	
+10% precipitation	-0.0028	-0.0028	-0.0036
	(0.0000)	(0.0000)	
+15% precipitation	-0.0028	-0.0028	0.0327
	(0.0000)	(0.0000)	
+25% precipitation	-0.0028	-0.0028	0.0435
	(0.0000)	(0.0000)	
+50% precipitation	-0.0028	-0.0028	0.0871
	(0.0000)	(0.0000)	

Significance codes: * p<0.10, ** p<0.05, *** p<0.01

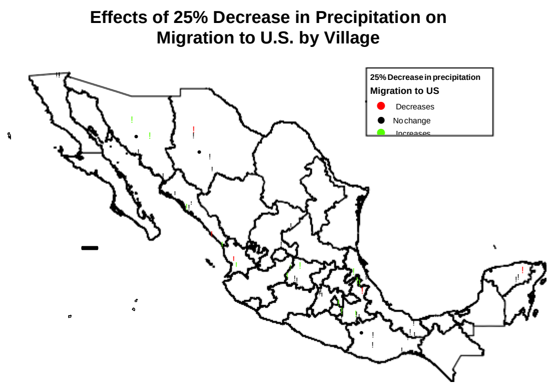
Table 3 Effects of changes in precipitation on migration: Two-sample t-test of the change in the number of households with migrants

	To US			Within Mexico		
	Base case	Simulated	Percentage change from base case	Base case	Simulated	Percentage change from base ca
-50% precipitation	742.13	762.28	2.72***	1062.42	1055.51	0.65**
	(31.79)	(25.78)		(41.55)	(33.65)	
-25% precipitation	742.13	755.07	1.74***	1062.42	1062.87	0.04
	(31.79)	(29.79)		(41.55)	(36.11)	
-15% precipitation	742.13	757.06	2.01***	1062.42	1064.74	0.22
	(31.79)	(26.94)		(41.55)	(35.21)	
-10% precipitation	742.13	744.01	0.25	1062.42	1061.08	− 0.13
	(31.79)	(31.84)		(41.55)	(41.5)	
+10% precipitation	742.13	740.44	− 0.23	1062.42	1063.76	0.13
	(31.79)	(31.71)		(41.55)	(41.59)	
+15% precipitation	742.13	751.89	1.32***	1062.42	1068.83	0.60**
	(31.79)	(27.04)		(41.55)	(35.22)	
+25% precipitation	742.13	746.53	0.59*	1062.42	1069.68	0.68**
	(31.79)	(29.23)		(41.55)	(35.87)	
+50% precipitation	742.13	734.25	−1.06***	1062.42	1069.2	0.64**
	(31.79)	(31.56)		(41.55)	(41.96)	

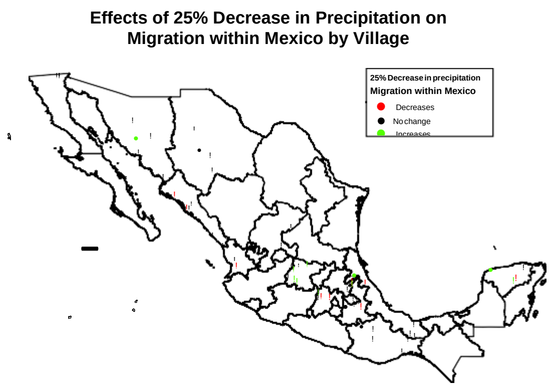
Significance codes: * p<0.10, ** p<0.05, *** p<0.01



(a)

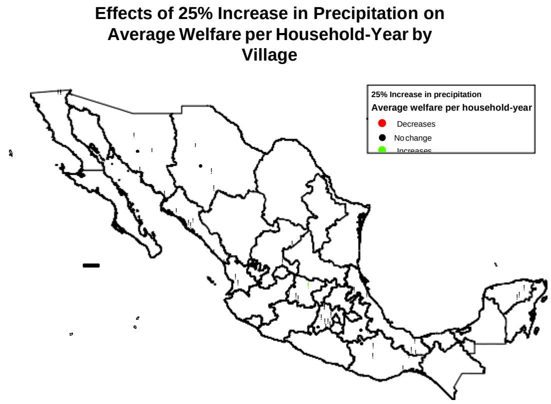


(b)

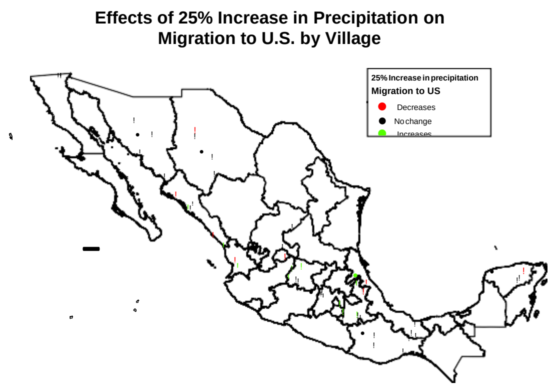


(c)

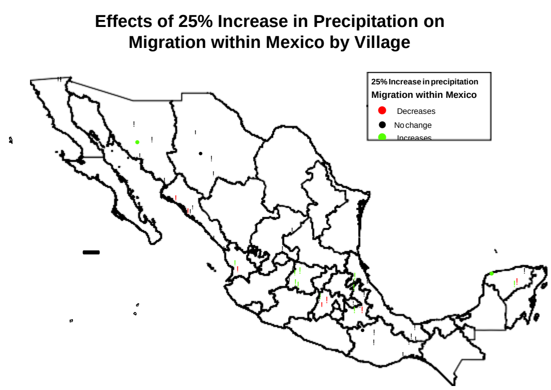
Figure 1 Sign of changes in selected variables by villages that are significant at a 10% level under a 25% decrease in precipitation



(a)



(b)



(c)

Figure 2: Sign of changes in selected variables by villages that are significant at a 10% level under a 25% increase in precipitation