The Dynamic Migration Game:
A Structural Econometric Model and Application to Rural Mexico*

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Abstract

The migration decisions of households in a village can be thought of as a dynamic game in which each household makes decisions about 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. We develop and estimate a structural econometric model of this dynamic migration game, and apply it to households in rural Mexico. We use the estimated parameters to simulate the effects of counterfactual policy scenarios, including those regarding wages, government policy, schooling, crime rates at the border, and precipitation, on migration decisions and welfare. Results show that analyses that ignore the possibility of strategic interactions or dynamic behavior lead to misleading results. In addition, owing in part to strategic interactions and dynamic behavior, a cap on total migration to the US decreases migration not only to the US but also within Mexico as well, causes migration to the US to decrease by more than what is required by the policy, and decreases average welfare per household-year.

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1 Introduction

According to estimates from the World Bank (2010a), around 3 percent of the world population live in a country different from the one in which they were born. The US is the country with the highest immigrant population in the world, with more than 46 million people who were foreign born (United Nations, 2013), of which about 11 million are from Mexico (World Bank, 2010b). These trends are considerably changing demographic portraits, reshaping patterns of consumption, and altering the cultures of both sending and receiving countries (Rojas Valdes, Lin Lawell and Taylor, 2018).

Given the economic significance of migration and its relevance for policy (Rojas Valdes, Lin Lawell and Taylor, 2018), it is important to understand the factors that cause people to migrate. We add to the literature on the determinants of migration by incorporating two important features of migration decisions: strategic interactions and dynamic behavior.

Migration decisions are dynamic because households consider the future when making these decisions, 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. Migration decisions are also dynamic because these decisions can be viewed as forms of investment that are made under uncertainty. Migration decisions are at least partially irreversible, 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 makes these decisions dynamic rather than static (Dixit and Pindyck, 1994).

In addition to being dynamic, migration decisions are also strategic. We define 'strategic interactions' as arising whenever the migration decisions of other households in the 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, information externalities, relative deprivation, risk sharing, competition effects (Rojas Valdes, Lin Lawell and

Taylor, 2018), a limited number of employers at the destination site who do not discriminate against migrants from elsewhere (Carrington, Detragiache and Vishwanath, 1996), and the marriage market (Riosmena, 2009). Our structural model is general enough to capture multiple possible sources of strategic interactions, and enables us to analyze their net effect.[1]

Owing to strategic interactions and dynamic behavior, the migration decisions of households in a village can be thought of as a dynamic game in which each household makes decisions about 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. We develop and estimate a structural econometric model of this dynamic migration game.

We build on the previous literature on the determinants of migration by estimating a structural econometric model that incorporates strategic interactions and dynamic behavior, and that enables us to calculate welfare and to analyze the effects of counterfactual scenarios on decisions and welfare. Furthermore, the previous literature on migration externalities focuses primarily on externalities that arise at the destination site, including, for example, migration networks. Our research fills a gap in the literature by accounting for migration externalities that occur in the source country in the form of strategic interactions, and by incorporating these strategic interactions in a dynamic setting.

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

[1] We choose to use the term 'strategic interactions' instead of 'peer effects' for two main reasons. First, the term 'peer' often connotes an individual; in contrast; the decision-makers we examine are households rather than individuals. Second, a possible source of strategic interactions we allow for in our analysis is a competition effect, which is an effect that is potentially more accurately described as a 'strategic interaction' rather than a 'peer effect'. Nevertheless, our concept of 'strategic interactions' is very similar to that of 'peer effects'.

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.

Our structural econometric model of the dynamic migration game 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 the estimated parameters to simulate the effects of counterfactual policy scenarios, including those regarding wages, government policy, schooling, crime rates at the border, and precipitation, on migration decisions and welfare. In order to disentangle the effects of strategic interactions and dynamic behavior in our model, we also simulate counterfactual scenarios in which remove strategic interactions, and counterfactual scenarios in which we remove dynamic behavior.

Results show that analyses that ignore the possibility of strategic interactions or dynamic behavior lead to misleading results. In addition, owing in part to strategic interactions and dynamic behavior, a cap on total migration to the US decreases migration not only to the US but also within Mexico as well, causes migration to the US to decrease by more than what is required by the policy, and decreases average welfare per household-year. Thus, not only do barriers to migration from Mexico to the U.S. have no positive effect on U.S. agricultural wages or employment (Clemens, Lewis and Postel, 2017), but our results show that such barriers to migration decrease the average welfare of households in rural Mexico.

The balance of the paper is as follows. Section 2 reviews the related literature on migration and structural econometric models. Section 3 presents our model of the dynamic migration game. Section 4 describes the econometric estimation. Section 5 provides background information on the importance of migration in rural Mexico and describes the data. Section 6 presents the results of the structural econometric model. Section 7 presents the results of our counterfactual simulations. Section 8 concludes.

2 Literature Review

2.1 Determinants of Migration

The first strand of literature upon which our paper builds is the literature on determinants of migration. The new economics of labor migration posits the household as the relevant unit of analysis. Using the household as the relevant unit of analysis addresses several observed features of migration that are ignored by individualistic models, including the enormous flows of remittances and the existence of extended families which extend beyond national borders. Most applications of the new economics of labor migration assume that the preferences of the household can be represented by an aggregate utility function and that income is pooled and specified by the household budget constraint.

For example, Stark and Bloom (1985) assume that individuals with different preferences and income not only seek to maximize their utility but also act collectively to minimize risks and loosen constraints imposed by imperfections in credit, insurance, and labor markets. This kind of model assumes that there is an informal contract among members of a family in which members work as financial intermediaries in the form of migrants. The household acts collectively to pay the cost of migration by some of its members, and in turn migrants provide credit and liquidity (in form of remittances), and insurance (when the income of migrants is not correlated with the income generating activities of the household). In this setting, altruism is not a precondition for remittances and cooperation, but it reinforces the implicit contract among household members (Taylor and Martin, 2001). In their analysis of how migration decisions of Mexican households respond to unemployment shocks in the US, Fajardo, Gutiérrez and Larreguy (2017) emphasize the role played by the household, as opposed to individuals, as the decision-making unit at the origin. Garlick, Leibbrandt and Levinsohn (2016) provide a framework with which to analyze the economic impact of migration when individuals migrate and households pool income.

In the new economics of labor migration, individual characteristics and human capital variables are also very important because they influence both the characteristics of the migrants and the impacts that migration has on the productive activities of the remaining household. Human capital theory à la Sjaastad (1962) suggests that migrants are younger than those who stay because younger migrants would capture the returns from migration over a longer time horizon. The role of education depends on the characteristics of the host and the source economy. Education is positively related to rural-urban migration but has a negative effect on international migration (Taylor, 1987). The reason is that education is not equally rewarded across different host economies. For example, agricultural work in the United States requires only low-skilled labor, so education has a negative effect on the selection of migrants for this type of work.

Changes in labor demand in the United States has modified the role of migrant characteristics in determining who migrates. Migrants from rural Mexico, once mainly poorly educated men, more recently have included female, married, and better educated individuals relative to the average rural Mexican population (Taylor and Martin, 2001). Borjas (2008) finds evidence that Puerto Rico migrants to the United States have lower incomes, which is consistent with Borjas' (1987) prediction that migrants have incomes lower than the mean income in both the source and host economies when the source economy has low mean wages and high inequality. On the other hand, Feliciano (2001), Chiquiar and Hanson (2005), Orrenius and Zavodny (2005), McKenzie and Rapoport (2010), Cuecuecha (2005), and Rubalcaba et al. (2008) find that Mexican migrants come from the middle of the wage or education distribution. McKenzie and Rapoport (2007) show that migrants from regions with communities of moderate size in the United States come from the middle of the wealth distribution, while migrants from regions with bigger communities in the United States come from the bottom of the wealth distribution.

The financial costs of migration can be considerable relative to the income of the poorest households in Mexico.[2] Angelucci (2015) finds that financial constraints to international

[2]Data from the National Council for the Evaluation of the Social Policy in Mexico (CONEVAL) show that the average income of the poorest 20 per cent of rural Mexican households was only 456 dollars a year

migration are binding for poor Mexicans, some of whom would like to migrate but cannot afford to. Migration costs reflect in part the efforts of the host country to impede migration, which might explain why migration flows continue over time and why we do not observe enormous flows of migrants (Hanson, 2010). Migration costs for illegal crossing from Mexico to the United States are estimated to be 2,750 to 3,000 dollars (Mexican Migration Program, 2014). Estimates reported in Hanson (2010) suggest that the cost of the "coyote" increased by 37 percent between 1996-1998 and 2002-2004, mainly due to the increase of border enforcement due to the terrorist attacks of 9/11. Nevertheless, Gathmann (2008) estimates that even when the border enforcement expenditure for the Mexico-United States border almost quadrupled between 1986 and 2004, the increase in expenditure produced an increase the cost of the coyote of only 17 percent, with almost zero effect on coyote demand.

Migration decisions may also be affected by weather and climate. Jessoe, Manning and Taylor (2018) evaluate the effects of annual fluctuations in weather on employment in rural Mexico to gain insight into the potential labor market implications of climate change, and find that extreme heat increases migration domestically from rural to urban areas and internationally to the U.S. Feng, Krueger and Oppenheimer (2010) find a significant effect of climate-driven changes in crop yields on the rate of migration from Mexico to the United States. Maystadt, Mueller and Sebastian (2016) investigate the impact of weather-driven internal migration on labor markets in Nepal. Mason (2016) analyzes climate change and migration using a dynamic model, and shows that the long run carbon stock, and the entire time path of production (and hence emissions), is smaller in the presence of migration. Mahajan and Yang (2017) find that hurricanes in source countries increase migration to the U.S., with the effect increasing in the size of prior migrant stocks.

The previous literature on migration externalities focuses primarily on externalities that arise at the destination site, including, for example, migration networks. Our research fills a gap in the literature by accounting for migration externalities that occur in the source country

in 2012.

in the form of strategic interactions, and by incorporating these strategic interactions in a dynamic setting.

We build on our analysis in Rojas Valdes, Lin Lawell and Taylor (2018), in which we estimate reduced-form models to analyze strategic interactions, or 'neighborhood effects', in migration decisions. Using instrumental variables to address the endogeneity of neighbors' decisions, we empirically examine whether strategic interactions in migration decisions actually take place in rural Mexico, whether the interactions depend on the size of the village, and whether there are nonlinearities in the strategic interactions (Rojas Valdes, Lin Lawell and Taylor, 2018).

We build on the previous literature on the determinants of migration by estimating a structural econometric model that incorporates both dynamic behavior and strategic interactions, and that enables us to calculate welfare and to analyze the effects of counterfactual scenarios on decisions and welfare.

2.2 Structural econometric models

In addition to the literature on migration, our paper also builds on previous literature using structural econometric models.

There is a burgeoning literature using structural models in development economics. Shenoy (2016) estimates the cost of migration and migration-related supply elasticity in Thailand using 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.

The seminal work of Rust (1987), who develops an econometric method for estimating single-agent dynamic discrete choice models, is the cornerstone of dynamic structural econometric models. Structural econometric models of dynamic behavior have been applied 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), copper mining decisions (Aguirregabiria and Luengo, 2016), wind turbine shutdowns and upgrades (Cook and Lin Lawell, 2018), agricultural disease management (Carroll et al., 2018b), supply chain externalities (Carroll et al., 2018a), agricultural productivity (Carroll et al., forthcoming), pesticide spraying decisions (Sambucci, Lin Lawell and Lybbert, 2018), and decisions regarding labor supply, job search, and occupational choices (see Keane, Todd and Wolpin, 2011).

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 State. 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 include 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, 2018), and to the decision to wear and use glasses (Ma, Lin Lawell and Rozelle, 2018); and a model developed by Bajari et al. (2015), which has been applied to ethanol investment (Yi and Lin Lawell 2018a; Yi and Lin Lawell, 2018b). Structural econometric models of dynamic games have also been applied to fisheries (Huang and Smith, 2014), dynamic natural monopoly regulation (Lim and Yurukoglu, 2018), and Chinese shipbuilding (Kalouptsidi, forthcoming).

The structural econometric model of a dynamic game we use is based 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, 2018), the world petroleum industry (Kheiravar, Lin Lawell and Jaffe, 2018), climate change policy (Zakerinia and Lin Lawell, 2018), and the global market for solar panels (Gerarden, 2017).

3 Dynamic Migration Game

We model the migration decisions of households in a village as a dynamic game in which each household makes decisions about 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.

The players $i = 1, ..., N$ in our dynamic migration game are households within a village. Each year $t = 1, ..., \infty$, each household i chooses an action from a discrete finite set $a_{it} \in A_i$, and all households in the village 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 migration to the US, and whether to engage in migration within Mexico. We do not assume that the actions are mutually exclusive, so it is possible for a household to engage in both migration to the US and migration within Mexico at the same time. Thus, in each year t, each household i decides whether to send individual members to migrate to the US and/or to other areas within Mexico, while also keeping some members in the village.

The vector of state variables at time t is given by $\mathbf{s}_t \in S \subset \mathbb{R}^L$. State variables include natural factors, economic factors, and government policy.

The state variables at the household level in s_{it} include the number of males in the household, the age of the household head; the schooling of the household head; the maximum level of schooling achieved by any of the household members; the average level of schooling, measured as the number of years of education that have been completed, of household members 15 years old and above; a dummy if the household's first born was a male; the slope and quality of land owned by the household that is irrigated for agricultural purposes, interacted with village precipitation; whether the household engaged in migration to the US the previous year; and whether the household engaged in migration within Mexico in the previous year.

The state variables at the municipality level in s_{it} include the number of schools in the basic system, the number of schools in the indigenous system, the number of cars, and the number of buses. The state-level variables in s_{it} include employment by sector. The national variables in s_{it} are aggregate variables that represent the broad state of the institutional and economic environment relevant for migration, including the average hourly wage, and wage by sector. The border crossing variables in s_{it} includes variables that measure crime, deaths, and border enforcement at nearby border crossing points.

Each period t, each household i receives an idiosyncratic private information 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.

The per-period payoff to each household i, which measures the household i's utility in a given period t, depends on the actions a_{it} played by household i, the actions a_{-it} played by other households, the state variables $\mathbf{s}_t$, and household i's private shock ε_{it}. The per-period payoff (or utility) to a household includes anything and everything the household may care about, including both economic and non-economic sources of utility. Our model therefore captures both economic and non-economic motives for migration.

Our action variables are whether to engage in migration to the US, and whether to engage in migration within Mexico. For the actions of neighbors, we include the fraction of neighbors with migration to the US and the fraction of neighbors with migration within Mexico.

The state variables we use in the per-period payoff function include the number of household members; the household head age; a dummy whether the first born child of the household was male; household head schooling; household average schooling; household land quality interacted with rain; the number of basic schools; the hourly wage; the distance to the closest border crossing point; and the crime rate at the closest, second closest, and third closest border crossing points.

We assume that the payoff function is indexed by a finite parameter vector θ, so that the payoff function is given by $\pi_i(\mathbf{a}, \mathbf{s}, \varepsilon_i; \theta)$. The parameters θ to be estimated are the coefficients on the terms in the per-period payoff function, which include terms that are functions of action variables, strategic variables, demographic characteristics of the household, natural factors, economic factors, and government policies. In particular, the terms in the per-period payoff function include terms for each of the state variables; terms for the state variables squared; and terms that interact each state variable, including the strategic variables, with the household's own action variables.

The payoff function is the per-period payoff for each household. While the parameters θ are common to all households, the values of the action variables, state variables, and private information shocks vary by household; as a consequence, the per-period payoff is specific to and varies for each household.[3]

We account for the important factors in a household's utility maximization decision by including in the payoff function state variables that affect income from migrating; state variables that affect alternative sources of income; state variables that affect costs of migration; state variables that affect household utility; state variables that affect non-economic considerations such as the marriage market; state variables that affect liquidity and other constraints; and state variables that affect the outside option to not engaging in migration. The per-period payoff function therefore includes terms that are functions of actions, strategic variables, demographic characteristics of the household, natural factors, economic factors, and government policy. We also include shocks to the payoff function that may reflect, for example, shocks to household costs, health, and/or income.

Our specification of the per-period payoff function is agnostic about the actual functional form of the utility function, the actual nature of the constraints, and the actual mechanism by which, for example, local wages affect household utility, and thus is general enough to capture the reduced-form implications of a number of models of general equilibrium behavior of individuals within the household, households in the village, and the village economy. The sources of economic structure in our structural econometric model of the dynamic migration game are dynamic programming and game theory.

There are several sources of uncertainty in our model of a dynamic game. First, future values of the state variables are stochastic. Second, each household i receives private in-

[3]We do not aggregate all households into a single utility function (although we do aggregate all members of a household into the household's utility function), nor is the payoff function for an "average" household only. Instead, the payoff function is the per-period payoff specific to each household, and the per-period payoff to each household depends on the actions played by all households.

formation shocks ε_i which may represent, for example, shocks to household costs, health, and/or income. Third, each household i is uncertain about the migration decisions that other households will make.

At each time t, each household i makes its migration decisions in order to maximize the expected 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. Thus, in each period, households face different tradeoffs between the benefits and costs they can generate by migrating to a given location (US or within Mexico) versus those benefits and costs of migrating to a different location or not migrating at all. The tradeoffs depend on the parameters, the action variables, the state variables, and the private information shocks.

Household i's dynamic optimization problem is given by:

$$\max_{\{a_{it}\}} \quad E\left[\sum_{t=0}^{\infty} \beta^t \pi_i(\mathbf{a}_t, \mathbf{s}_t, \varepsilon_{it}; \theta)|\mathbf{s}_t\right]. \tag{1}$$

The equilibrium concept we use for our incomplete information dynamic migration game is that of a Markov Perfect Nash Equilibrium. A Markov state-space strategy for player i is a function $\sigma_i : S \times E_i \to A_i$ that maps combinations of state-shocks into actions such that $\sigma : S \times E_1 \times ... \times E_N \to A$ is the profile of strategies, and where $E_i \subset \mathbb{R}^M$ is the support of G_i. For a realization of the state vector $\mathbf{s}$, the expected payoff of player i from playing strategy σ_i is:

$$V_i(\mathbf{s}; \sigma; \theta) = E_\varepsilon\left[\pi_i(\sigma(\mathbf{s}, \varepsilon), \mathbf{s}, \varepsilon_i; \theta) + \beta \int V_i(\mathbf{s}'; \sigma; \theta) dP(\mathbf{s}'|\sigma(\mathbf{s}, \varepsilon), \mathbf{s})|\mathbf{s}\right]. \tag{2}$$

In a Markov Perfect Nash Equilibrium, the expected present discounted value that each household i receives from playing its equilibrium strategy σ_i is at least as high as the expected present discounted value it could receive from playing any other alternative strategy σ_i':

$$V_i(\mathbf{s};\sigma;\theta) \geq V_i(\mathbf{s};\sigma_i',\sigma_{-i};\theta). \tag{3}$$

4 Econometric Model

Finding a single equilibrium is computationally costly even for problems with a simple structure. In more complex problems – as in the case of our dynamic migration game, where many agents and decisions are involved – the computational burden is even more important, particularly if there may be multiple equilibria. 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 two-stage 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. The crucial mathematical assumption to be able to estimate the parameters in the payoff function is that the same equilibrium is played in every game (which in our model is a village), even if multiple equilibria exist.

Our econometric estimation takes place in two stages. In the first stage, we estimate the parameters of the policy function. We do so by estimating the empirical relationship between the actions and state variables in the data. Without imposing any structure, this step simply characterizes what households do mechanically as a function of the state vector. The policy functions are therefore reduced-form regressions correlating actions to states. This step also avoids the need for the econometrician to both compute the set of all possible equilibria and specify how household decide on which equilibrium will be played, as the policy functions are estimated from the equilibrium that is actually played in the data (Ryan, 2012). In this stage, we also recover the distribution of the state variables, which describes how these state variables evolve over time.

Following methods in Hotz et al. (1994) and Bajari, Benkard and Levin (2007), we use forward simulation to estimate the value functions. This 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.

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 each household's best response to the actions of its neighbors. Following Bajari, Benkard and Levin (2007), we estimate the parameters by minimizing profitable deviations from the optimal strategy via using a minimum distance estimator.

We present further details of the estimation procedure below.

4.1 Policy functions

The policy functions relate the state variables to the actions played by each household, which in our model are the decision to engage in migration to the US and the decision to engage in migration within Mexico. The actions a_i of each agent i are assumed to be functions of the state variables $\mathbf{s}$ and private information ε_i:

$$a_i = \sigma_i(a_i, \mathbf{s}, \varepsilon_i; \sigma_{-i}). \tag{4}$$

For the policy functions, we regress household i's decision a_{ikt} to engage in migration of type $k \in [USA, Mexico]$ on the fraction $f(a_{-ikt})$ of the households in the same village household i, excluding i, that engage in migration of both types k, and on the state variables s_{it}. Thus, the econometric model is:

$$a_{ikt} = \beta_0 + \sum_k \beta_a f(a_{-ikt}) + s'_{it}\beta_s + \mu_i + \varepsilon_{ikt}, \tag{5}$$

where the vector s_{it} includes state variables at the household, village, municipality, state, and national level as well as border crossing variables; and μ_i is a village fixed effect.

The policy function for household i gives the probability that household i will engage in migration, conditional on the (publicly observable) state variables s_{it}. Since policy functions are based only on information that is observable to all households, household i's policy function also represents the beliefs that household i's neighbors have about the probability that household i will engage in migration.

The state variables in s_{it} that we use for the policy functions include the number of members in the household; the age of the household head; whether the first born is male; the schooling of the household head; the average level of schooling, measured as the number of years of education that have been completed, of household members 15 years old and above; whether the household engaged in migration within Mexico the previous year; whether the household engaged in migration to the US the previous year; the area of land owned by the household that is irrigated for agricultural purposes, interacted with village precipitation; the number of basic schools; the distance to the closest border crossing point; the crime rates at the closest, second closest, and third closest border crossing points; the hourly wage in the primary sector; and employment in the secondary sector.

Since the policy function for each player i depends on the policy functions for all other players, we address the endogeneity of neighbors actions in the structural model by using a fixed point algorithm in the forward simulation, as described below.

4.2 Transition densities

We estimate the distribution of next period's state variables conditional on this period's state variables and actions using flexible transition densities. In particular, we use linear regressions that relate the current level of the state variables to their lags, the lags of other related state variables, and the lags of the action variables.

We model the following transition densities at the household level: the number of males in the household, the number of males in the family,[4] the household size, a dummy indicator for whether the first born of the household was a male, household head schooling, household average schooling, household maximum schooling, household land slope interacted with rain, household land quality interacted with rain, and household irrigated land area interacted with rain. We model these transition densities by regressing these variables on lagged values of state and action variables. Thus, although we do not model schooling and other decisions made by household (other than migration) explicitly, our models allows schooling and other household-level variables to evolve endogenously conditional on state variables and actions via the transition densities.

The age of the head of the household evolves deterministically, so next year's age is today's age plus one.

At the village level, we regress the crime rate at the closest, second closest, and third closest border crossing points on their lags and the lag of the primary sector wage.

At the municipality level, we regress the number of basic schools, the number of indigenous schools, and the number of students in the basic system on the lags of these same variables, and the lags of the employment levels in the three sectors.

At the state level, we regress the employment shares in each sector on the lags of the three shares, and on the lags of average wages.

At the national level, we regress average wages in the primary, secondary, and tertiary sectors on the the lags of these three same variables.

[4] We define a family as the household head, its spouse, and its children.

4.3 Value function

Thee value function for household i is given by:

$$V_i(\mathbf{s};\sigma;\theta) = E\left[\sum_{t=0}^{\infty} \beta^t \pi_i(\sigma(\mathbf{s}_t,\varepsilon_t),\mathbf{s}_t,\varepsilon_{it};\theta)|\mathbf{s}_0 = \mathbf{s}\right]. \tag{6}$$

Bajari, Benkard and Levin (2007) show that the computational burden can be reduced if one assumes linearity in the payoff function. Particularly, they show that if $\pi_i(\mathbf{a},\mathbf{s},\varepsilon_i;\theta) = \Pi(\mathbf{a},\mathbf{s},\varepsilon_i)\cdot\theta$, then the value function can be written as:

$$V_i(\mathbf{s};\sigma;\theta) = E\left[\sum_{t=0}^{\infty} \beta^t \Pi_i(\sigma(\mathbf{s}_t,\varepsilon_t),\mathbf{s}_t,\varepsilon_{it})|\mathbf{s}_0 = \mathbf{s}\right]\cdot\theta = \mathbf{W}_i(\mathbf{s};\sigma)\cdot\theta. \tag{7}$$

Since $\mathbf{W}_i(\mathbf{s};\sigma)$ does not depend on θ, the forward simulation can be used to estimate each $\mathbf{W}_i$ once, which enables us to then obtain V_i for any value of θ.

We use forward simulation to calculate the value function, which is the expected present discounted value of the entire stream of per-period payoffs when the actions are chosen optimally, by simulating $S = 100$ different paths of play of $T = 30$ periods length each using $D = 3$ different initial observed vectors of state variables. Our algorithm for the forward simulation for each initial observed vectors of state variables is as follows:

- Step 0: Starting at $t = 0$ with initial state variables.
- Step 1: Evaluate the policy functions using this period's state variables to determine this period's actions. Our methodological innovation is that we address the endogeneity of neighbors' decisions using a fixed point calculation, as described below.
- Step 2: Calculate this period's payoffs as a function of this period's state variables and actions.

- Step 3: Evaluate the transition densities using this period's state variables and action variables to determine next period's state variables.
- Repeat Steps 1-3 using next period's state variables.

We sum the discounted payoffs over the T periods and average over the S simulations to obtain the expected present discounted value of the entire stream of payoffs.

4.4 Fixed point algorithm

Our methodological innovation is that we address the endogeneity of neighbors' decisions using a fixed point calculation, as follows:

- Step 1: Estimate policy functions.
- Step 2: Use the observed fraction of neighbors with migration in the data as the initial guess for the expected fraction of neighbors with migration in the policy function.
- Step 3: Predict the actions for all households using the policy function evaluated at latest guess for the expected fraction of neighbors with migration.
- Step 4: Calculate the fraction of neighbors with migration using the predicted actions, which becomes the new guess.
- Repeat Steps 3 and 4 until the difference between the guess and the predicted fraction of neighbors with migration is below a certain threshold.

4.5 Estimating the structural parameters

We estimate the parameters θ by imposing the restriction that the observed equilibrium is a Markov Perfect Nash Equilibrium. Then, the equilibrium condition $V_i(\mathbf{s}; \sigma_i, \sigma_{-i}; \theta) \geq V_i(\mathbf{s}; \sigma_i', \sigma_{-i}; \theta)$ yields a set of inequalities that are consistent with the assumed behavior. The goal of the estimation procedure is to find the value of θ that makes all the inequalities to hold at the same time. In practice, we will use an estimator that minimizes profitable deviations from the optimal strategy. Bajari, Benkard and Levin (2007) prove the asymptotic properties of this kind of estimator, which turns out to be consistent and asymptotically normal.

In order to estimate θ we compute alternative value functions $\hat{V}_i(\mathbf{s};\sigma';\theta)$ that result from deviations from the policy function. We compute the corresponding actions that agents would have taken and simulate a whole set of S paths of play of length T, with D initial data sets. A deviation is profitable if the value of the discounted stream of payoffs under the alternative strategy is greater than under the optimal policy. We estimate θ by finding the θ that minimizes profitable deviations.

5 Data and Application to Rural Mexico

The economic importance of migration from Mexico to the US is twofold. Since the mid-1980s, migration to the US has represented an employment opportunity for Mexicans during a period of economic instability and increasing inequality in Mexico. In addition, it has represented an important source of income via remittances, especially for rural households (Esquivel and Huerta-Pineda, 2007).[5] Remittances from the US to Mexico amount to 22.8 billion dollars per year, according to estimates from the World Bank (2012). According to recent calculations, an average of 2,115 dollars in remittances is sent by each of the nearly 11 million Mexicans living in the US, which represents up to 2 percent of the Mexican GDP (D'Vera et al., 2013). Some authors estimate that 13 percent of household total income and 16 percent of per capita income in Mexico come from migrant remittances (Taylor et al., 2008).[6]

With a border 3200 kilometers long, the largest migration flow between two countries, and a wage differential for low-skilled workers between the US and Mexico of 5 to 1 (Cornelious

[5] Esquivel and Huerta-Pineda (2007) find that 3 percent of urban households and up to 10 percent of rural households in Mexico receive remittances.

[6] Castelhano et al. (2018) find that migrant remittances are not associated with increases in rural investment in agricultural production in Mexico, however.

and Salehya, 2007), the US-Mexico migration relationship also imposes challenges to policy-makers of both countries. Beginning in 2000, Mexico moved away from its previous so-called 'no policy policy', and tried instead to pursue a more active policy to influence the US to agree to a workers program and to increase the number of visas issued for Mexicans, although its efforts got frustrated after the 9/11 attacks in September 2001. More recently, other domestic policies have included the programs Paisano and Tres Por Uno, which facilitate the temporary return during holidays of Mexicans legally living in the US and which match the contributions of migrant clubs for the construction of facilities with social impact in Mexican communities, respectively. On the US side, several reforms have been attempted to both open a path for legalization while increasing the expenditure to discourage illegal immigration, both of which affect mostly Mexicans. The most recent, the Deferred Action for Childhood Arrivals, gives access to work permits to individuals who entered the country before they were 16 years of age (Rojas Valdes, Lin Lawell and Taylor, 2018).

We use data from the National Survey of Rural Households in Mexico (ENHRUM) in its three rounds (2002, 2007, and 2010[7]). The survey is a nationally representative sample of Mexican rural households across 80 villages and includes information on the 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[8] to 2010, and that includes household composition variables such as household size, household head age, and 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 in 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

[7] 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.

[8] 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.

status, and land area.[9] We construct variables for land slope and land quality for the complete panel using the date at 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 of contemporaneous precipitation at the village level (Jessoe, Manning and Taylor, 2018) so that the resulting interaction variables vary across households and over time. Rain data covers the period 1990 to 2007. The slope and quality of household land interacted with contemporaneous precipitation captures shocks to agricultural home production and therefore to household income that vary by household and year and that may affect migration decisions.

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 for 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)[10] 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.

We use two sets of border crossing variables that measure the costs of migration. On the Mexican side, we use INEGI's data on crime to compute the homicide rate per 10,000 inhabitants at each of the 37 the Mexican border municipalities. On the United States'

[9]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.

[10]The primary sector includes agriculture, livestock, forestry, hunting, and fisheries. The secondary sector 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.

side, we use data from the Border Patrol that include the number of border patrol agents, apprehensions, and deaths of migrants at each of nine border sectors,[11] and match each border sector to its corresponding Mexican municipality.

We interact these border crossing variables (which are time-variant, but the same for all villages at a given point in time) with measures of distance from the villages to the border (which are time-invariant for each village, but vary for each village-border location pair).

We use a map from the International Boundary and Water Commission (2013) to obtain the location of the 26 crossing-points from Mexico to the United States. Using the Google Distance Matrix API, we obtain the shortest driving route from each of the 80 villages in the sample to each of the 26 crossing-points, and match the corresponding municipality at which these crossing-points are located. This procedure allows us to categorize the border municipalities into those less than 1,000 kilometers from the village; and those between 1,000 and 2,000 kilometers from the village.

By interacting the distances to the border crossing points with the border crossing variables, we obtain the mean of each border crossing variable at each of the three closest crossing points, and the mean of each border crossing variable within the municipalities that are in each of the two distance categories defined above. We also compute the mean of each border crossing variable among all the border municipalities.

Figure A.1 in Appendix A presents a map of the villages in our sample (denoted with a filled black circle) and the US-Mexico border crossing points (denoted with a red X).

Table A.1 in Appendix A presents the summary statistics for the variables in our data set. Table A.2 in Appendix A presents the within and between variation for the migration variables. 'Within' variation is the variation in the migration variable across years for a given village. 'Between' variation is the variation in the migration variable across villages for a given year.

[11] A 'border sector' is the term the Border Patrol uses to delineate regions along the border for their administrative purposes.

6 Results

6.1 Policy functions and transition densities

In Table A.3 in Appendix A, we present the results of the policy functions relating states to actions. Column (1) presents the policy function for migration to the US. Column (2) presents the policy function for migration within Mexico. The implications of these results are discussed in detail in Rojas Valdes, Lin Lawell and Taylor (2018). We use the coefficients that are significant at a 10% level in our structural model to predict the actions played given the state variables. To address the endogeneity of neighbors' decisions, we use a fixed point calculation.

The policy functions we estimate represent the empirical relationship between the actions and states observed in the data. Without imposing any structure, these policy functions simply characterize what households do mechanically as a function of the state vector. As the policy functions are reduced-form regressions correlating actions to states, their results therefore show correlations, not causation.

Our estimated policy functions in Table A.3 in Appendix A show a significant negative own-migration strategic interaction: a household's probability of engaging in migration to the US is negatively correlated with the fraction of neighbors who engage in migration to the US, and a household's probability of engaging in migration within Mexico is negatively correlated with the fraction of neighbors who engage in migration within Mexico. Risk sharing considerations, competition effects (Rojas Valdes, Lin Lawell and Taylor, 2018), and a limited number of employers at the destination site who do not discriminate against migrants from elsewhere (Carrington, Detragiache and Vishwanath, 1996) may be possible explanations for the negative own-migration strategic interaction.

Our policy functions show a significant positive other-migration strategic interaction: a household's probability of engaging in migration to the US is positively correlated with the fraction of neighbors who engage in migration within Mexico, and a household's probability of engaging in migration within Mexico is positively correlated with the fraction of neighbors who engage in migration to the US. One possible explanation for the positive other-migration strategic interaction it that it results from the negative own-migration strategic interaction: if a household is less likely to engage in migration to a destination to which its neighbors are engaging in migration, then it may engage in migration elsewhere instead.

Our policy functions also show that there is persistence in the decision to engage in migration to the US or within Mexico: there is a significant positive correlation between lagged migration to the US and the probability of migration to the US, and similarly a significant positive correlation between lagged migration within Mexico and the probability of migration within Mexico.

In Tables A.4-A.6 in Appendix A, we present the results of the transition densities for the variables at the household, municipality, state, and national levels. These transition densities describe the behavior of state variables over time. We regress the level of each variable on the lag of other relevant state variables. We use the coefficients that are significant at a 10% level to predict the value of next period's state variables, which affect the actions taken of each household in next period as well as the payoff functions.

6.2 Structural parameters

We present the parameter estimates of our structural model in Table 1. The parameters we estimate are the coefficients in the per-period payoff function $\pi_i(\mathbf{a}, \mathbf{s}, \varepsilon_i; \theta)$.

According to our results, the coefficient in the per-period payoff on household head schooling is significant and positive, which indicates that the higher the household head schooling, the higher the per-period payoff to the household.

The coefficient on household land quality interacted with rain is significant and negative. Since higher values of our index for household land quality denote a lower land quality, the significant negative coefficient on the interaction indicates that the higher quality the household land and the more rain, the higher the per-period payoff to the household.

The significant negative coefficient on household land quality interacted with rain interacted with migration to the US indicates that the higher quality the household land and the more rain, the higher the per-period payoff to having a household member migrate to the US. This result suggests that home agricultural production and migration to the US are complements. The likely mechanism is as follows. Higher incomes from home agricultural production relax household credit constraints and enable the household to send a member to migrate to the US. Migration to the US, in turn, generates additional income for the household via remittances, which enables the household to further improve their home agricultural production.

The significant positive coefficient on household land quality interacted with rain interacted with migration within Mexico indicates that the higher quality the household land and the more rain, the lower the per-period payoff on net to having a household member migrate within Mexico. This result suggests that home agricultural production and migration within Mexico are substitutes. Unlike migration to the US, which is costly but also generates income for the household via remittances, migration within Mexico is a substitute rather than a complement to home agricultural production, possibly at least in part because it is less costly and also generates little if any income for the household via remittances.

The significant positive coefficient on hourly wage indicates that the higher the hourly wage, the higher the per-period payoff to the household.

The significant positive coefficient on hourly wage interacted with migration to the US indicates that the higher the hourly wage, the higher the per-period payoff to having a household member migrate to the US.

In contrast, the significant negative coefficient on hourly wage interacted with migration within Mexico, which is smaller in magnitude than the significant positive coefficient on hourly wage, indicates that the hourly wage has less of a positive effect on net on the per-period payoff when a household engages in migration within Mexico.

The significant positive coefficients on the variables interacting crime rate with migration to the US indicates that the higher the crime rate in Mexico, the higher the per-period payoff to having a household member migrate to the US. In contrast, the effects of crime rates at the border on the payoff to having a household member migrate within Mexico are mixed.

6.3 Comparing structural model with observed data

As seen in Table A.7 in Appendix A, which compares welfare calculated using observed data with the welfare predicted by our structural econometric model, our structural econometric model does a fairly good job of predicting welfare calculated based on observed data.

Similarly, when comparing the migration observed in the data in Tables A.8 and A.9 in Appendix A with the analogous migration statistics predicted by our structural econometric model in Tables A.10 and A.11 in Appendix A, our structural econometric model does a fairly good job of predicting the levels and upward trends in migration observed in the data.

7 Counterfactual simulations

We use the estimated parameters to simulate the effects of counterfactual policy scenarios, including those regarding wages, government policy, schooling, crime rates at the border, and precipitation, on migration decisions and welfare. For our counterfactual simulations, we simulate the effects of a counterfactual change that takes place in the year 1997 on migration and welfare over the years 1997 to 2007.

In order to disentangle the effects of strategic interactions and dynamic behavior in our model, we also simulate counterfactual scenarios in which remove strategic interactions, and counterfactual scenarios in which we remove dynamic behavior.

We compare the percentage change in migration and welfare under each counterfactual simulation with those under the base case simulation of no counterfactual change. In particular, for each counterfactual scenario, we compare the average welfare per household-year and the fraction of households with migration under that counterfactual scenario with those under the base case of no change using two-sample t-tests.

There are several channels through which each counterfactual change may affect household welfare. First, the counterfactual change (e.g., in wages) may affect household welfare directly. Second, the counterfactual change may affect migration decisions which affect household welfare. Third, the counterfactual change may affect other decisions of the household which may affect household welfare. Although we focus on explicitly modeling the migration decisions of the households, our model implicitly captures schooling and other decisions made by household by allowing schooling and other household-level variables to evolve endogenously conditional on state variables and actions via the transition densities. Fourth, changes in actions and/or state variables resulting from the counterfactual change may affect future values of the state variables, which may affect future actions and/or welfare. Our estimates of the changes in welfare that arise in each counterfactual simulation capture all channels through which the counterfactual scenario may affect household welfare.

7.1 Wages

Real wages in Mexico plunged after the 1994 crisis and recovered slowly during the period covered by our data set. We simulate changes in the hourly wage in the primary sector. The primary sector includes agriculture, livestock, forestry, hunting, and fisheries. In our structural econometric model, the hourly wage in the primary sector affects both the policy functions and the transition densities.

In 2010, 1 US dollar bought 12.80 Mexican pesos. Thus, the mean hourly wage in the primary sector reported in the summary statistics in Table A.1 in Appendix A of 29 pesos per hour in 2010 pesos is roughly equivalent to 2.3 dollars per hour in 2010 US dollars. Our simulated changes in the primary sector wage ranging from a 50% decrease to a 50% increase therefore represent simulated primary sector wages ranging from a mean of 14.5 pesos (approximately 1.15 US dollars) per hour after a 50% decrease, to a mean of 43.5 pesos (approximately 3.45 US dollars) per hour after a 50% increase. Even after a 50% increase in primary sector wage, the largest increase in primary sector wage that we simulate, mean wages are lower than the 1997 US federal minimum wage of 7.01 dollars in 2010 US dollars.[12]

Figure 1 presents the percentage change from the base case in the fraction of households with migration to the US and within Mexico over the entire simulation period (1997-2007) under each simulated change in primary sector wages in the initial year of the simulation (1997). Error bars indicate the 90% confidence interval from a two-sample t-test comparing the results under the counterfactual simulation with those under the base case of no change. Results show that an increase in primary sector wages leads to a statistically significant increase in migration to the US and within Mexico. Similarly, a decrease in primary sector wages leads to statistically significant decreases in migration to both the US and within Mexico in all but one of the simulated scenarios (that of a 15% decrease). Moreover, the more dramatic the simulated change, the more dramatic the response of the fraction of households with migration. In addition, in all the cases the where changes in migration are statistically significant, the magnitudes of the changes in the fraction of households with migration to the US are much larger than those of the changes in the fraction of households with migration within Mexico.

Figure 2 presents the percentage change from the base case in the average welfare per household-year over the entire simulation period (1997-2007) under each simulated change in primary sector wages in the initial year of the simulation (1997). Error bars indicate the 90% confidence interval from a two-sample t-test. As expected, a decrease in primary sector wages leads to a statistically significant decrease in average welfare per household-year, while an increase in primary sector wages leads to a statistically significant increase in average welfare per household-year.

In addition to the pooled results, we also analyze the results by village. In Figure 3 we show the changes by village in the fraction of households with migration to the US and within Mexico over the entire simulation period (1997-2007) under a 10% decrease and a 10%

[12]The US federal minimum wage in 1997 was 5.15 dollars in 1997 dollars (US Department of Labor, 2017), which is equivalent to 7.01 dollars in 2010 US dollars.

increase in primary sector wages, respectively, in the initial year of the simulation (1997). The red dots denote villages that experience a statistically significant decrease in the fraction of households with migration; the green dots denote villages that experience a statistically significant increase in the fraction of households with migration; and the black dots denote villages with no statistically significant change. We find that there is some heterogeneity at the village level in the changes in the fraction of households with migration to the US and within Mexico.

We examine how this heterogeneity relates to observable village characteristics by analyzing the determinants of significant changes at the village level in the fraction of households with migration. To do so, we regress the village-level changes in the fraction of households with migration over the entire simulation period (1997-2007) that are significant at a 10% level under a simulated 10% increase and a simulated 10% decrease in primary sector wages in the initial year of the simulation (1997), respectively, on the initial village, municipality, state, and national characteristics from the initial year of the simulation (1997). Table 2 presents the results.

As seen in Table 2, under a 10% increase in primary sector wages, significant changes in migration to the US are positively correlated with the initial fraction of households with migration within Mexico. This suggests that when wages increase, greater increases in migration to the US are more likely to occur in villages that were already mobile, as measured by the initial fraction of households with migration within Mexico.

Also as seen in Table 2, significant changes in migration within Mexico are positively correlated with the number of males in the household, and negatively correlated with the household size, which suggests that when wages increase, greater increases in migration within Mexico are more likely to occur where there is a larger share of males in the household who can take advantage of those increases in wages. Significant changes in migration within Mexico are also positively correlated with the distance to the US border and the household head age.

Under a 10% decrease in wages in the primary sector, Table 2 shows that significant changes in migration to the US are negatively correlated with the household head schooling, which suggests that when the wage decreases, larger decreases in migration to the US are more likely to occur in villages where the household head is more educated, perhaps because a more educated household head increases the return for other household members to stay at home, therefore reducing migration to the US, especially when the household is more credit-constrained. In contrast, significant changes in migration to the US are positively correlated with the household average schooling, which suggests that when the wage decreases, larger increases in migration to the US are more likely to occur in villages where the household average schooling is higher, perhaps because more educated households have higher returns to migration to the US, and thus are more likely to engage in migration to the US when credit-constrained.

In Figure 4, we present the changes in average welfare per household-year at the village level under simulated changes of a 10% decrease and a 10% increase in primary sector wages, respectively. Consistent with the aggregate results, most of the villages experience a decrease in welfare under a 10% decrease in primary sector wages, while all of the villages except for one experience a statistically significant increase in welfare under a 10% increase in primary sector wages.

We examine how the village-level welfare results relate to observable village characteristics by analyzing the determinants of significant changes at the village level in average welfare per household-year. To do so, we regress the village-level changes in the average welfare per household-year over the entire simulation period (1997-2007) that are significant at a 10% level under a simulated 10% increase and a simulated 10% decrease in primary sector wages in the initial year of the simulation (1997), respectively, on the initial village, municipality, state, and national characteristics from the initial year of the simulation (1997). As seen in Table 3, statistically significant changes in welfare under a 10% increase in wages in the primary sector are positively correlated with the initial fraction of households with migration within Mexico and the household head age, while statistically significant changes in welfare under a 10% decrease in welfare are positively correlated with the number of males in the household and the household head age, and negatively correlated with the initial fraction of households with migration to the US and the initial fraction of households with migration within Mexico.

Thus, our simulations regarding wages paid in the primary sector show that migration to US and within Mexico increase with primary sector wage in the pooled results, but there is some heterogeneity across villages. Average welfare per household-year is increasing in the primary sector wage for almost all villages.

7.2 Migration policy

Given the significance of migration policy, especially from the US perspective, an important question is: what is the effect of migration policies on migration and welfare? We simulate two types of policies: a floor on schooling for migration to the US, and a cap on the number of households with migration to the US.

7.2.1 Minimum schooling requirement for migration to the US

The first migration policy we simulate is a minimum schooling requirement that specifies a minimum threshold household average schooling needed in order for a household to be allowed to engage in migration to US. We set the threshold to range from 50% (labeled "-50%") up to 150% (labeled "50%") of the average household schooling observed in the data.

As seen in Figure 5, a minimum schooling requirement for migration to the US would have direct negative effects on migration to the US. The greater the requirement for minimum schooling for migration to the US, the more dramatic the drop in migration to the US, with all the simulated changes being statistically significant. Moreover, a minimum schooling requirement for migration to the US would lead to changes in migration within Mexico as well: a minimum schooling requirement for migration to the US from a 25% of the average schooling up to a 150% of the average schooling leads to a statistically significant decrease in the fraction of households with migration within Mexico. Figure 6 shows that this policy leads to a statistically significant decrease in average welfare per household-year in every simulated minimum threshold of schooling required for migration.

In Figure B.1 in Appendix B, we show that the policy would have a negative effect on the fraction of households with migration to the US and within Mexico almost in every village, but that some villages would not experience a significant change and, for the case of Mexico, some villages may even experience an increase in the fraction of households with migration.

In Table B.1 in Appendix B we show that, under a simulated threshold of 110% of the average schooling for migration, significant changes in the fraction of households with migration to the US are positively correlated with the household head schooling at the village level, and negatively correlated with the household size and the initial fraction of households with migration to the US, whereas significant changes in migration within Mexico are positively correlated with household land quality. Similarly, under a simulated threshold of 90% of the average schooling, the shares of employment in the primary and secondary sectors are associated with significant decreases in migration both to the US and within Mexico, and the initial fraction of households with migration to the US is correlated with significant decreases migration to the US.

In Figure B.2 in Appendix B we show that most of the villages experience a statistically significant decrease in welfare under the simulated minimum thresholds of schooling for migration. As shown in Table B.2 in Appendix B, significant changes in welfare under a threshold of 110% and 90% of average schooling are positively correlated with the household head schooling and the initial fraction of households with migration to the US; in addition, significant changes in welfare under a simulated threshold of 90% of average schooling are also negatively correlated with the shares of employment in the primary and secondary sectors.

7.2.2 Cap on total migration to the US

The second migration policy we simulate is a cap on total migration to the US. For this counterfactual policy, we set a cap that denies migration to US to a certain percentage, ranging from 50% to 90%, of the total number of households who would have engaged in migration to the US under the base case simulation. That is, of the households who engage in migration to the US under the base case, we restrict a randomly chosen 50% and 90% of these households from migrating to the US in 1997, the first year of the simulation.

In Figure 7 we show that the simulated caps have statistically significant negative effects on migration not only to the US but also within Mexico. Moreover, the size of the reduction in the fraction of households with migration to the US is greater than the cap. For example, a cap that denies US migration to 50% of the households that would have engaged in migration to the US in the base case leads to a decrease in the fraction of households with migration to the US of 70% for the period of our simulations, due to the spillover effects of the migration decisions. In Figure 8 we show that all our simulated caps on migration lead to a statistically significant decrease in welfare.

In Figure B.3 in Appendix B, we present the effects of a cap of 90% of base case US migration on migration. Consistent with the aggregate finding, all villages experience a statistically significant decrease in migration to the US, while there is some heterogeneity in the signs of the changes in migration within Mexico at the village level. Table B.3 in Appendix B shows that under a simulated cap denying migration to 90% of the households that would have engaged in migration to the US in the base case, significant changes in the fraction of households with migration to the US are positively correlated with household head schooling and the initial fraction of households with migration within Mexico, and negatively correlated with the household size and the initial fraction of households with migration to the US. Under this simulation, significant changes in migration within Mexico are negatively correlated with the initial fraction of households with migration within Mexico.

Figure B.4 in Appendix B shows that all the villages experience a statistically significant decrease in welfare under the simulated cap of migration. And as seen in Table B.4 in Appendix B, significant changes in welfare are positively correlated with the household head schooling, and negatively correlated with the initial fraction of households with migration to the US and the quality of the household land.

Strategic interactions explain why policies that decrease migration to the US also decrease migration within Mexico. Owing to the significant positive other-migration strategic interaction in the policy functions in Table A.3 in Appendix A, decreases in migration to US by neighbors are associated with a decrease in a household's probability of migrating within Mexico.

Dynamic behavior explains why a cap on total migration to the US causes migration to the US to decrease by more than what is required by the policy. Owing to the significant positive effect of lagged migration to the US on the probability of migration to the US in the policy functions in Table A.3 in Appendix A, there is persistence in the decision to engage in migration to the US. Thus, policies that restrict migration to the US are amplified over time.

7.3 Schooling

Policies to improve the levels of schooling assume that a higher level of human capital will improve earning opportunities. We simulate the effect of changes in each the three schooling variables in our model in turn: the schooling of the household head, the average schooling of the household, and the maximum schooling of the household.

7.3.1 Household head schooling

Household head schooling affects both the policy functions and the transition densities. As seen in Figure 9, counterfactual increases in household head schooling have a negative effect on the fraction of households with migration to the US and within Mexico, but the effect is only significant for the very dramatic changes of an increase of 50% for the case of migration to the US, and for the increases of 25% and 50% in household head schooling for the case of migration within Mexico. Almost symmetrically, a very dramatic decrease of 50% in the household head schooling leads to a statistically significant increase in migration to the US, whereas every simulated decrease in household head schooling leads to a statistically significant increase in migration within Mexico. Moreover, there appears to be a monotonic relationship between the simulated changes and the fraction of households with migration to both the US and within Mexico: the lower the household head schooling, the higher the migration to the US and within Mexico, with the changes in migration within Mexico being larger in magnitude. Figure 10 shows that all the simulated increases in household head schooling lead to statistically significant increases in welfare, whereas most of the simulated decreases in household head schooling lead to statistically significant decreases in welfare.

Figure B.5 in Appendix B shows the changes in the fraction of households with migration by village under a 10% increase or decrease in the household head schooling. We see that the results are heterogeneous by village. Table B.5 in Appendix B shows that significant changes in the fraction of households with migration within Mexico under a 10% increase in household head schooling are positively correlated with the distance to the nearest border crossing point and the household head age. Significant changes in migration to the US are positively correlated with the fraction of households with migration within Mexico under a 10% increase in household head schooling, and negatively correlated with the number of household members under a 10% decrease in household head schooling.

As seen in Figure B.6 in Appendix B, there is heterogeneity at the village level in the changes in average welfare per household-year. As seen in Table B.6 in Appendix B, statistically significant changes in welfare are positively correlated with the initial fraction of households with migration within Mexico under a 10% decrease in household head schooling.

7.3.2 Average household schooling

Average household schooling affects both the policy functions and the transition densities. According to the results of our counterfactual simulations of changes in average household schooling, we find in Figure 11 that there are statistically significant effects on migration to the US under very dramatic increases or decreases in average schooling. For migration within Mexico, increases of 15%, 25%, and 50% in average schooling have a statistically significant and positive effect on migration within Mexico; and decreases of 15%, 25%, and 50% have a statistically significant and negative effect on migration within Mexico. As seen in Figure 12, every simulated increase in household average schooling leads to a statistically significant decreases in average welfare per household-year, and every simulated decrease in household average schooling leads to a statistically significant increase in average welfare per household-year.

As seen in Figure B.8 in Appendix B, the effects of changes in average household schooling vary by village. As seen in Table B.7 in Appendix B, significant changes in migration to the US are positively correlated with the fraction of households with migration within Mexico under a 10% increase in the household average schooling, and with employment in the secondary sector under a 10% decrease in the household average schooling. Significant changes in migration within Mexico is negatively correlated with household size and positively correlated with the fraction of households with migration to the US under a 10% increase in the household average schooling.

As seen in Figure B.7 in Appendix B, the changes in welfare by village. Significant changes in average welfare per household year under a 10% increase in household average schoolingare positively correlated with the employment share in the primary and secondary sectors, and with the initial fraction of households with migration within Mexico, as seen in Table B.8 in Appendix B.

7.3.3 Maximum household schooling

Maximum household schooling affects the transition densities. For our counterfactual simulations of changes in maximum household schooling, and similar to our findings in the simulations of changes in the household average schooling, we find in Figure B.9 in Appendix B that dramatic increases in the maximum schooling leads to statistically significant increases in migration within Mexico, while dramatic decreases in the maximum schooling leads to statistically significant decreases in the fraction of households with migration within Mexico. As seen in Figure B.10 in Appendix B, every simulated decrease in household maximum schooling leads to a statistically significant increase in welfare, while only dramatic simulated increases in maximum schooling lead to statistically significant decreases in welfare.

In Figure B.11 in Appendix B, we show that the changes in the fraction of households with migration by village under a simulated 10% increase and decrease in maximum schooling vary by village. As shown in Table B.9 in Appendix B, significant changes in migration to the US are negatively correlated with employment in the primary sector under a 10% increase in maximum household schooling, and positively correlated with the initial fraction of households with migration within Mexico under a 10% decrease in maximum household schooling. Significant changes in migration within Mexico are negatively correlated with household head schooling and the initial fraction of households with migration within Mexico and positively correlated with household average schooling under a 10% increase in maximum household schooling; positively correlated with employment in the secondary sector under a 10% decrease in maximum household schooling; and positively correlated with employment in the primary sector under both a 10% increase and a 10% decrease in maximum household schooling.

Similar to the aggregate results, we find that most of the villages experience an increase in welfare under a simulated decrease in maximum schooling of 10%, and that there is some heterogeneity under a simulated increase of 10% in maximum schooling, as seen in

Figure B.12 in Appendix B. Statistically significant changes in welfare at the village level are positively correlated with household land quality, as seen in Table B.10 in Appendix B.

7.3.4 Mechanisms

To summarize the results of our counterfactual simulations of schooling, we find that as household head schooling increases, migration to US and within Mexico decrease, while average welfare per household-year increases. In contrast, as household average schooling or household maximum schooling increases, migration to US and within Mexico increase, while average welfare per household-year decreases.

One possible explanation is that households with higher levels of household average schooling or household maximum schooling have better returns to education outside the village that they are willing to take advantage of by sending a member to migrate. In contrast, a more educated household head increases the return for other household members to stay at home, therefore reducing migration both to the US and within Mexico.

The effects of schooling on migration decisions arise through the policy functions in Table A.3 in Appendix A. From the policy functions, migration to US and within Mexico decrease with household head schooling, but increase with household average schooling or household maximum schooling.

As seen in our parameter estimates in Table 1, schooling affects per-period payoffs (and therefore welfare) regardless of the migration decision. Thus, the welfare results arise from the direct effect of schooling on household per-payoffs. Average welfare per household-year increases with household head schooling and decreases with household average schooling or household maximum schooling, regardless of the migration decision.

7.4 Crime rates at the border

Crime rates in Mexico experienced a dramatic increase after 2006. An important question that therefore arises is: what is the effect of crime rates at the border on migration decisions?

We simulate changes in the crime rate at the three closest border crossing points from the household villages. Changes in crime rate affect both the policy functions and the transition densities in our structural econometric model.

Figure 13 reports no statistically significant change in migration to the US and within Mexico under any of the simulated scenarios of changes in crime rate at the border in the pooled results. Similarly, as seen in Figure 14, we find that, except under a dramatic increase of 50% in crime rate at the border, there are no statistically significant changes in the average welfare per household-year in the pooled results.

As seen in Figure 15, there is some heterogeneity in the changes in the fraction of households with migration to the US and within Mexico at the village level. As seen in Table 4, under a 10% increase in crime rates at the border, significant changes in migration to the US are positively correlated with the initial fraction of households with migration within Mexico, whereas significant changes in the fraction of households with migration within Mexico are negatively correlated with the employment share in the secondary sector and the initial fraction of the households with migration within Mexico, and positively correlated with household land quality. Under a simulated 10% decrease in crime rates at the border, significant changes in migration to the US are negatively correlated with the number of males in the household, whereas significant changes in migration within Mexico are negatively correlated with the employment share in the secondary sector and positively correlated with the initial fraction of households with migration to the US.

While in the aggregate results there are no statistically significant changes in welfare, there is some heterogeneity at the village level in the changes on average welfare per household-year, as can be seen in Figure 16, and the determinants of which are presented in Table 5. Under a simulated 10% increase in crime rates at the border, households with better land quality experience increases in migration within Mexico as well as increases in average welfare per household-year.

7.5 Precipitation

Changes in climatic conditions are important determinants of productivity in agriculture and may have implications for migration. We simulate changes in precipitation, which affects households differently depending on the soil quality on their land. In our structural econometric model, precipitation has a significant effect on transition densities.

As seen in Figure 17, we find that a 10% decrease in precipitation leads to a statistically significant increase in migration to the US. We find in Figure 18 that this decrease of 10% in precipitation leads to a statistically significant increase in average welfare per household-year.

As seen in Figure B.13 in Appendix B, there is heterogeneity by village in the effects of a 10% increase and a 10% decrease in precipitation on the fraction of households with migration to the US and within Mexico. As shown in Table B.11 in Appendix B, significant changes in migration to the US are positively correlated with household average schooling under a 10% increase in precipitation. Significant changes in migration within Mexico are positively correlated with the number of males in the household and the initial fraction of households with migration to the US, but negatively correlated with employment in the secondary sector.

As seen in Figure B.14 in Appendix B, there is heterogeneity by village in the effects of a 10% increase and a 10% decrease in precipitation on average welfare per household-year. As shown in Table B.12 in Appendix B, significant changes in average welfare per household-year under a 10% decrease in precipitation are positively correlated with the distance to the closest border crossing point, employment in the primary and secondary sectors, and household head age.

Our finding that decreases in precipitation may increase migration to the US is consistent with previous studies that show that other adverse weather conditions, including extreme heat (Jessoe, Manning and Taylor, 2018) and hurricanes (Mahajan and Yang, 2017), increase migration within Mexico (from rural to urban areas) and to the US.

7.6 Removing strategic interactions

In our structural econometric model, strategic interactions can arise through several channels. First, strategic interactions can arise in the policy functions if neighbors' actions affect a household's strategy. Second, strategic interactions can arise in the transition densities if the actions of households in the village affect future values of the the state variables faced by a household. Third, strategic interactions can affect the per-period payoff of a household.

In order to disentangle the effects of strategic interactions in our model, we simulate counterfactual scenarios in which we remove strategic interactions. For these counterfactual scenarios, we set the coefficients on the fraction of neighbors with migration to the US and within Mexico to be 0 in the policy functions; we set the coefficients on the lagged fraction of households with migration to the US and within Mexico to be 0 in the transition densities; and we set the coefficients on all terms involving the fraction of neighbors with migration to be 0 in the per-period payoff function. All other coefficients and parameter values remain the same.

The results from our counterfactual scenario eliminating strategic interactions are presented in Table 6. We find that the fraction of household with migrants to both the US and within Mexico would be considerably higher if there were no strategic interactions. When we look at the heterogeneity of these changes at the village level in Figure B.15 in Appendix B, we observe that these increases in migration would occur in most of the villages in our sample.

Also in Table 6 we show that in the absence of strategic interactions, the average welfare per household-year would be lower than in the base case scenario. As seen in Figure B.16 in Appendix B, average welfare per household-year would decrease in all villages in our sample. Thus, strategic interactions are welfare-increasing.

The results from our counterfactual simulations of migration policy above show that a cap on migration to the US decreases welfare and also decreases migration to both the US and within Mexico. To better understand the role of strategic interactions when there is a cap on migration to the US, we simulate the same caps on migration from a 50% up to a 90% of the migration in the base case, but without allowing for strategic interactions.

In Figure 19 we present the results of the cap of migration with no strategic interactions. Migration to the US still decreases considerably and by more than what the cap was intended to reduce over our simulation period. But now, migration within Mexico increases, in contrast to the situation where strategic interactions took place. Figure B.20 in Appendix B shows that migration to the US decreases in all the villages in our sample, while there are some villages with no change in migration within Mexico. Strategic interactions therefore explain why policies that decrease migration to the US also decrease migration within Mexico.

In Figure B.19 we show that the decrease in welfare resulting from a migration cap is even greater in the absence of strategic interactions. As seen in Figure B.21 in Appendix B, average welfare per household-year would decrease in all villages in our sample. The absence of strategic interactions leads to a more inefficient scenario, with more migration within Mexico, and with a larger loss in welfare resulting from the cap on migration to the US.

7.7 Removing dynamic behavior

In order to disentangle the effects of dynamic behavior in our model, we simulate counterfactual scenarios in which we remove dynamic behavior. For these counterfactual scenarios, we set the discount factor β to 0, and we set the coefficients on lagged migration to US and within Mexico to 0 in both the US migration and Mexico migration policy functions. All other coefficients and parameter values remain the same.

The results from our counterfactual scenarios eliminating dynamic behavior are presented in Table 7. When households do not consider the future when making their decisions, both migration to the US and within Mexico decrease, and average welfare per household-year decreases as well. This aggregate result is also reflected in the pattern at the village level, as observed in Figures B.17 and B.18 in Appendix B. As seen in Figure B.18 in Appendix

B, average welfare per household-year would decrease in all villages in our sample. Thus, household welfare is higher when households behave dynamically and consider the future when making decisions in the present.

The results from our counterfactual simulations of migration policy above show that a cap on migration to the US decreases welfare and also decreases migration to both the US and within Mexico. To better understand the role of dynamic behavior when there is a cap on migration to the US, we simulate the same caps on migration from a 50% up to a 90% of the migration in the base case, but without allowing for dynamic behavior.

In Figure 20, we show the effects of a cap on migration to the US on migration in the absence of dynamic behavior. Migration to the US decreases even more under a cap on migration in the absence of dynamic behavior, while migration within Mexico decreases considerably as well. The decrease in welfare resulting from a migration cap is more than 2 orders of magnitude greater in the absence of dynamic behavior, as shown in Figure B.22. As seen in Figure B.24 in Appendix B, average welfare per household-year would decrease in all villages in our sample. Thus, in the absence of dynamic behavior, the decrease in migration to the US and within Mexico and the reduction in welfare as a result of a migration cap would be even more severe.

8 Conclusion

Dynamic behavior and strategic interactions are important features of migration decisions. Analyses that ignore the possibility of strategic interactions or dynamic behavior lead to misleading results. We build on the previous literature on the determinants of migration by estimating a structural econometric model that incorporates dynamic behavior and strategic interactions, and that enables us to calculate welfare and to analyze the effects of counterfactual scenarios on decisions and welfare.

We use the estimated parameters to simulate the effects of counterfactual policy scenarios, including those regarding wages, government policy, schooling, crime rates at the border, and precipitation, on migration decisions and welfare. In order to disentangle the effects of strategic interactions and dynamic behavior in our model, we also simulate counterfactual scenarios in which remove strategic interactions, and counterfactual scenarios in which we remove dynamic behavior.

Our counterfactual simulations regarding wages paid in the primary sector show that migration to US and within Mexico increase with primary sector wage in the pooled results, but there is some heterogeneity across villages. Average welfare per household-year is increasing in the primary sector wage for almost all villages. Increases in wages in Mexico may increase migration within Mexico if households send a member to migrate within Mexico to take advantage of the higher wage. Increases in wages and income also enable poor and credit-constrained households to better afford investment in schooling, increasing their future expected wage and making future migration more affordable to poor and credit-constrained households.

We find that increases in the wage in Mexico not only increase migration within Mexico, but also increase migration to the US, likely because higher wages make migration to the US becomes more affordable to poor and credit-constrained households. These results are comparable to those of other studies that find that financial constraints are an important determinant of migration and migration selectivity. For example, Angelucci (2015) finds that Oportunidades, the flagship conditional cash transfer program of Mexico, increases migration from Mexico to the US, which similarly provides evidence that poor households in Mexico face binding financial constraints.

Furthermore, our results show that changes in wages have heterogeneous effects by village: when the local wage increases, there is more migration within Mexico in villages with smaller households, with more males, and older household heads; while there is more migration to the US in villages that already have migrants within Mexico. On the other hand, when wages decrease, there is more migration to the US from villages with poorly educated household heads but with a higher average household schooling, consistent with evidence that changes in income relax credit constraints on poor and low educated households but not on the poorest and least educated.

Our result that increases in wages in Mexico will increase migration to the US contradicts a common belief that improving the income of poor households would reduce migration, and therefore that, in order to keep Mexicans in Mexico, one simply needs to improve economic opportunities for Mexicans in their home country. Thus, since it is usually assumed that labor moves to the United States mainly because of a lack of opportunities in Mexico (in other words, implying some substitution across activities), our results finding evidence to the contrary have important implications for the discussion and design of policy.

In terms of counterfactual government migration policy, we find that a minimum threshold household average schooling needed for migration to US decreases migration not only to the US but also within Mexico, and also decreases average welfare per household-year. A cap on total migration to the US decreases migration not only to the US but also within Mexico as well, causes migration to the US to decrease by more than what is required by the policy, and decreases average welfare per household-year.

The current policy discussion on border enforcement at the US border targets Mexican illegal migration as a priority. Our results suggest that such a policy aimed at reducing migration to the US would also reduce migration within Mexico.

In the previous literature, Hanson, Liu and McIntosh (2017) examine how the scale and composition of low-skilled immigration in the United States have evolved over time, and find that, because major source countries for U.S. immigration are now seeing and will continue to see weak growth of the labor supply relative to the United States, future immigration rates of young, low-skilled workers appear unlikely to rebound, whether or not U.S. immigration policies tighten further. Our results show that migration policies that cap total migration from Mexico to the US decrease migration not only to the US but also within Mexico as well, and cause migration to the US to decrease by more than what is required by the policy.

Also in the previous literature, Clemens, Lewis and Postel (2017) evaluate an immigration barrier that was intended to improve domestic terms of employment by shrinking the workforce – a policy change that excluded almost half a million Mexican bracero seasonal agricultural workers from the United States – and fail to reject the hypothesis that exclusion did not affect U.S. agricultural wages or employment. Similarly, Mayda et al. (2017) find that the reduction that took place in 2004 in the annual quota on new H-1B visas allowing skilled foreign-born individuals to work in the United States did not increase the hiring of U.S. workers. In their review of the literature on historical and contemporary immigration to the United States, Abramitzky and Boustan (2017) likewise find that although immigrants appear to reduce the wages of some natives, the evidence does not support the view that, on net, immigrants have negative effects on the US economy. Migration may instead have beneficial effects on the host economy of driving of productive knowledge diffusion and reducing inequality (Bahar and Rapoport, forthcoming). Thus, not only do barriers to migration from Mexico to the U.S. have no positive effect on U.S. agricultural wages or employment (Clemens, Lewis and Postel, 2017), but our results show that such barriers to migration decrease the average welfare of households in rural Mexico.

Our result that a cap total migration from Mexico to the US decreases migration not only to the US but also within Mexico as well, and causes migration to the US to decrease by more than what is required by the policy, arises in part from dynamic behavior and strategic interactions. Strategic interactions explain why policies that decrease migration to the US also decrease migration within Mexico. Owing to the significant positive other-migration strategic interaction in the policy functions, decreases in migration to US by neighbors are associated with a decrease in a household's probability of migrating within Mexico.

Dynamic behavior explains why a cap on total migration to the US causes migration to the US to decrease by more than what is required by the policy. Owing to the significant positive effect of lagged migration to the US on the probability of migration to the US in the policy functions, there is persistence in the decision to engage in migration to the US.

Thus, policies that restrict migration to the US are amplified over time.

Dynamic behavior may also explain why policies that decrease migration to the US also decrease migration within Mexico. Migration within Mexico may be a form of transitory migration whereby households may decide to engage in migration to a given location as a means to eventually engage in migration to another location (Artuc and Ozden, forthcoming). In particular, migration within Mexico may have an option value of facilitating subsequent migration to the US. Thus, policies that decrease migration to the US may also decrease the option value a household may receive from engaging in migration within Mexico, and may therefore decrease migration within Mexico as well.

Shutting down the channel of migration to the US therefore radically modifies the nature of the problem households in rural Mexico face, and therefore the decisions they make and the welfare they are able to achieve. We could think of some possible stories for this to happen, but having in mind an agricultural household with credit constraints being relaxed by migration could be a good starting point. By increasing household income via remittances, migration enables agricultural home production to be run more efficiently and productively than it can be run when there are restrictions to mobility. In addition, with the income generated by migration, households might be able to hire labor to substitute for household labor allocated in the US or other states within Mexico. But when a policy restricts migration to the US, credit constraints bind again and households can no longer afford to hire labor, so household labor allocated somewhere else is called back. Thus, policies that restrict migration to US decrease migration both to the US and within Mexico, and reduce household welfare.

For schooling, we find that migration to US and within Mexico decrease with household head schooling, while average welfare per household-year increases with household head schooling. In contrast, as household average schooling or household maximum schooling increases, migration to US and within Mexico increase, while average welfare per household-year decreases. One possible explanation is that households with higher levels of household average schooling or household maximum schooling have better returns to education outside the village that they are willing to take advantage of by sending a member to migrate. In contrast, a more educated household head increases the return for other household members to stay at home, therefore reducing migration to both to the US and within Mexico.

Dynamic behavior and strategic interactions are important features of migration decisions. Counterfactual simulations that remove the possibility of strategic interactions show that strategic interactions are welfare-increasing, and their absence would result in inefficient rates of migration. Household welfare increases when households consider what other households are doing when making their own migration decisions.

For example, our results show that removing strategic interactions increases migration to the US. At first glance, this result might appear to be counterintuitive from the point of view of migration externalities. A reduction in the number of neighbors migrating reduces the amount of information and externalities available for other households. However, since these externalities operate in a dynamic setting, households respond to this absence of information by providing more migration than what is optimal. This can be interpreted in the context of a model of network formation. In the absence of strategic interactions and the possibility of benefiting from the networks of their neighbors, households would each contribute more to own network since they expect less migration from their neighbors today and in the future.

Counterfactual simulations that remove the possibility of dynamic behavior show that household welfare increases when households behave dynamically and consider the future when making decisions in the present. In the absence of dynamic behavior, the decrease in migration to the US and within Mexico and the reduction in welfare as a result of a migration cap would be even more severe.

Our results point to several potential future avenues of research. First, our model distinguishes between migration within Mexico and to the US, and we include wages and employment of different sectors in Mexico as factors that may affect household decisions and payoffs. In future work we hope to also distinguish between different jobs/locations within Mexico or within the US.

Second, consistent with early models of household decision-making (e.g., Becker, 1981) and the new economics of labor migration, we model decision-making at the household level. However, intra-household dynamics and interactions may affect decisions about migration as well. For example, Lessem (forthcoming) finds in her dynamic programming model that when individuals account for the location of their spouse when making migration decisions, increases in Mexican wages reduce migration rates and durations, and increases in border enforcement reduce migration rates and increase durations of stay in the US. In ongoing work, we are analyzing intra-household decision-making to better understand how decisions are made regarding migration, labor, and schooling within a household.

Our structural econometric model of the dynamic migration game enables a better understanding of the factors that affect migration decisions, and can be used to design policies that better improve the welfare of households in rural Mexico and other parts of the developing world.

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Table 1: Parameter estimates

	Estimate	Standard error
Coefficients in the per-period payoff function on:		
Migration to US	-0.000380	0.07848
Migration within Mexico	-0.000580	0.09041
Fraction of neighbors with migration to US	0.000510	0.06887
Fraction of neighbors with migration to US, squared	-0.000300	0.10875
Fraction of neighbors with migration within Mexico	0.000880	0.06611
Fraction of neighbors with migration within Mexico, squared	-0.000620	0.10882
Number of household members	-0.001190	0.00068 *
Number of household members, squared	0.028990	0.00010 ***
Household head age	-0.448320	0.00000 ***
Household head age, squared	-0.023520	0.00000 ***
First born was a male (dummy)	0.000000	0.21732
Household head schooling (years)	0.002880	0.00035 ***
Household head schooling (years), squared	0.014020	0.00005 ***
Household average schooling (years)	-0.014330	0.00066 ***
Household average schooling (years), squared	0.040190	0.00011 ***
Household land quality interacted with rain (area)	-0.014520	0.00025 ***
Household land quality interacted with rain (area), squared	0.000050	0.00001 ***
Number of basic schools	-0.030090	0.00007 ***
Number of basic schools, squared	-0.000110	0.00000 ***
Hourly wage in primary sector (pesos)	0.035280	0.00194 ***
Hourly wage in primary sector (pesos), squared	0.000400	0.00002 ***
Migration to US interacted with:		
Fraction of neighbors with migration to US	-0.000290	0.12603
Fraction of neighbors with migration within Mexico	-0.000470	0.06262
Number of household members	0.001840	0.00482
Household head age	-0.000630	0.00380
First born was a male (dummy)	-0.000010	0.10227
Household head schooling (years)	-0.001160	0.00530
Household average schooling (years)	0.000370	0.00496
Household land quality interacted with rain (area)	-0.009950	0.00016 ***
Number of basic schools	0.062860	0.00022 ***
Hourly wage in primary sector (pesos)	0.004070	0.00066 ***
Distance to closest border crossing point	0.013130	0.00066 ***
Crime rate at closest border crossing point	0.039170	0.00299 ***
Crime rate at second closest border crossing point	0.009600	0.00029 ***
Crime rate at third closest border crossing point	0.013340	0.00134 ***
Migration within Mexico interacted with:		
Fraction of neighbors with migration to US	-0.000430	0.06094
Fraction of neighbors with migration within Mexico	-0.000440	0.12824
Number of household members	0.002850	0.00493
Household head age	-0.001240	0.00359
First born was a male (dummy)	-0.000010	0.10861
Household head schooling (years)	-0.001330	0.00625
Household average schooling (years)	-0.000040	0.00500
Household land quality interacted with rain (area)	0.023690	0.00018 ***
Number of basic schools	0.122170	0.00026 ***
Hourly wage in primary sector (pesos)	-0.015870	0.00080 ***
Distance to closest border crossing point	-0.008240	0.00068 ***
Crime rate at closest border crossing point	0.050480	0.00272 ***
Crime rate at second closest border crossing point	-0.005120	0.00033 ***
Crime rate at third closest border crossing point	0.033550	0.00125 ***

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants. Wages are in 2010 Mexican pesos.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01

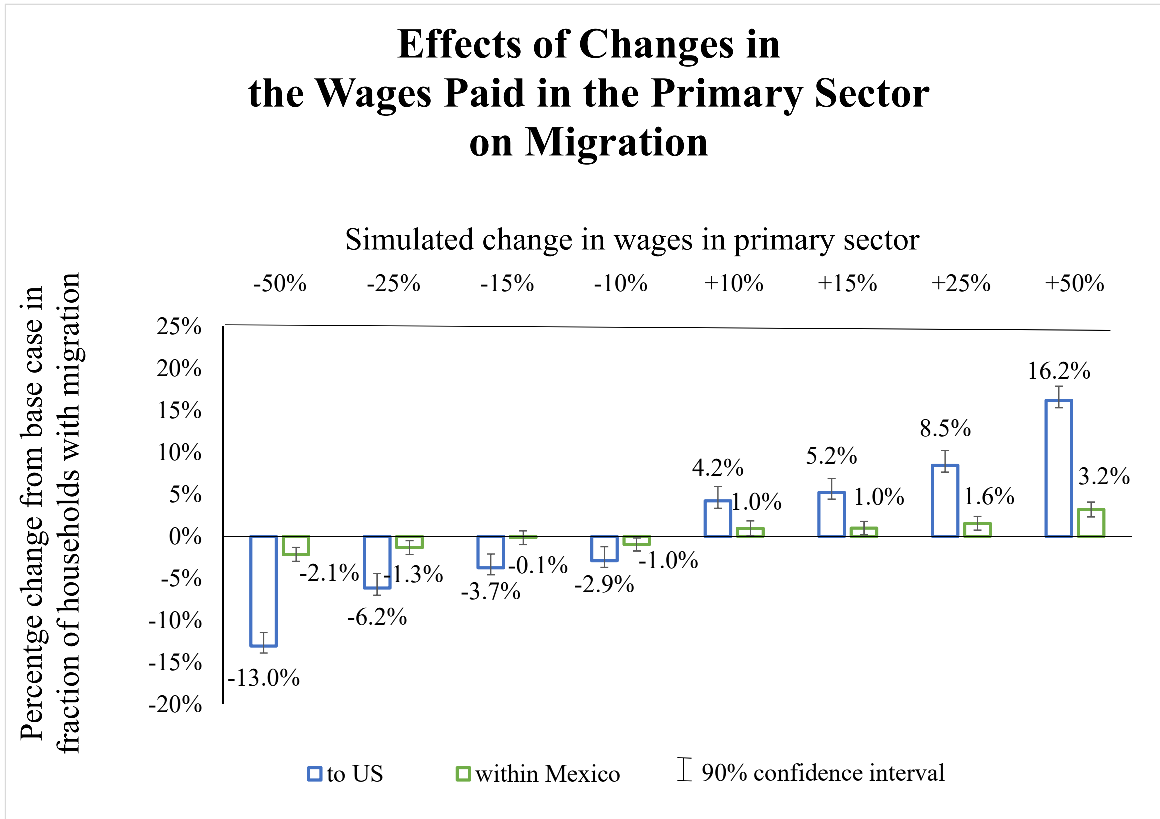


Figure 1: Results of two-sample t-test of the effects of changes in wages in the primary sector on the fraction of households with migration

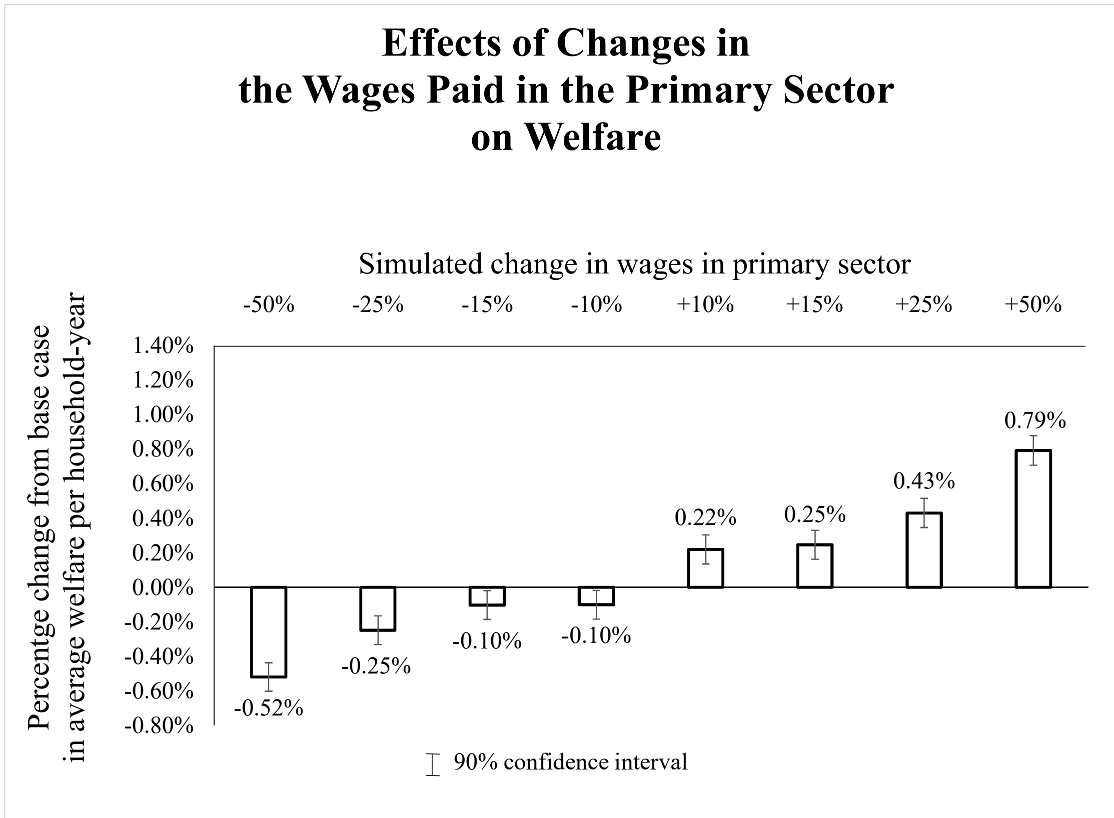


Figure 2: Results of two-sample t-test of the effects of changes in wages in the primary sector on average welfare per household-year

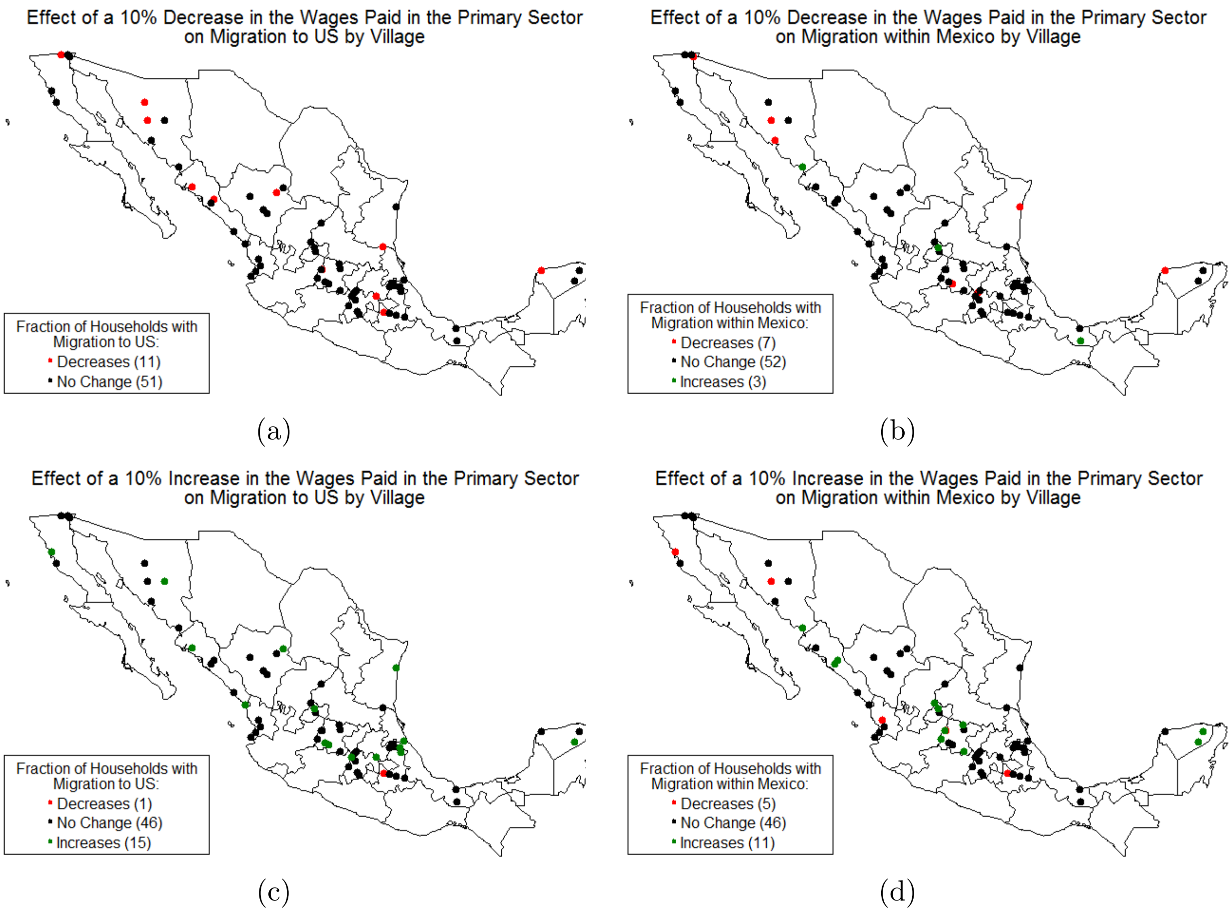


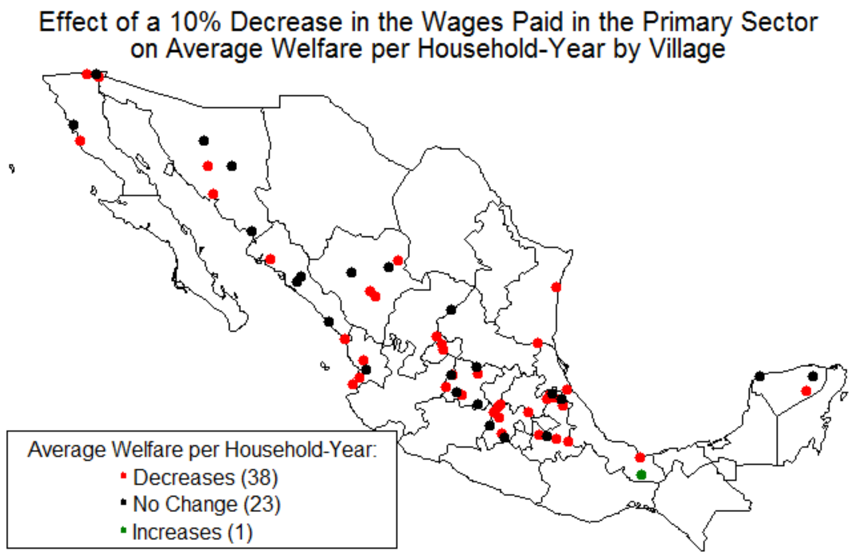
Figure 3: Signs of changes in migration by village that are significant at a 10% level under a 10% change in the wages paid in the primary sector.

Effects of Changes in the Wages Paid in the Primary Sector

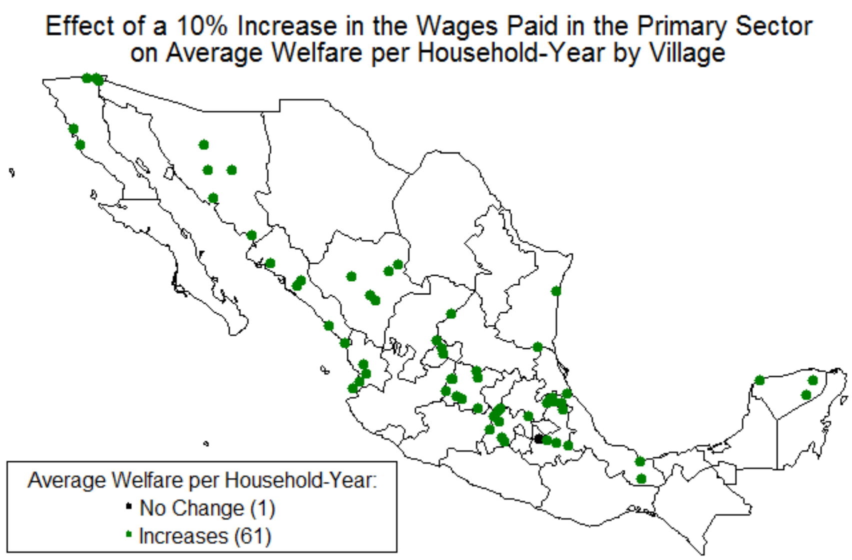
Table 2: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Simulated change in wages in primary sector:	10% Increase		10% Decrease	
Distance to closest border crossing point (1000 km)	-0.0012	0.0102***	0.0020	0.0016
	(0.0055)	(0.0037)	(0.0037)	(0.0046)
Crime rate at closest border crossing point	-0.0002	-0.0002	0.0003	-0.0001
	(0.0005)	(0.0003)	(0.0003)	(0.0004)
Employment in primary sector	0.0001	0.0000	-0.0000	0.0003
	(0.0004)	(0.0002)	(0.0002)	(0.0003)
Employment in secondary sector	0.0004	-0.0000	-0.0001	-0.0005
	(0.0006)	(0.0004)	(0.0004)	(0.0005)
Number of males in household	0.0012	0.0092*	-0.0010	0.0091
	(0.0080)	(0.0053)	(0.0053)	(0.0066)
Household head age	0.0004	0.0007*	-0.0004	0.0003
	(0.0006)	(0.0004)	(0.0004)	(0.0005)
Household head schooling	0.0033	-0.0018	-0.0049**	0.0003
	(0.0036)	(0.0024)	(0.0024)	(0.0030)
Number of household members	-0.0048	-0.0074**	-0.0016	-0.0033
	(0.0053)	(0.0035)	(0.0035)	(0.0044)
Fraction of households with migration to US	0.0180	0.0102	0.0032	-0.0002
	(0.0151)	(0.0101)	(0.0101)	(0.0125)
Fraction of households with migration within Mexico	0.0448*	-0.0031	0.0184	-0.0225
	(0.0230)	(0.0153)	(0.0154)	(0.0191)
Household average schooling	-0.0017	-0.0006	0.0045*	-0.0026
	(0.0039)	(0.0026)	(0.0026)	(0.0032)
Household land quality (1=good, 4=very bad)	0.0005	0.0038	-0.0013	-0.0043
	(0.0056)	(0.0038)	(0.0038)	(0.0047)
Constant	-0.0105	-0.0173	0.0154	0.0218
	(0.0470)	(0.0313)	(0.0314)	(0.0390)
p-value (Pr>F)	0.8550	0.1480	0.4930	0.2520
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



(b)

Figure 4: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a 10% change in the wages paid in the primary sector.

Effects of Changes in the Wages Paid in the Primary Sector

Table 3: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:

Simulated change in wages in primary sector:	10% Increase	10% Decrease
Distance to closest border crossing point (1000 km)	0.0003	0.0004
	(0.0003)	(0.0003)
Crime rate at closest border crossing point	-0.0184	0.0059
	(0.0250)	(0.0276)
Employment in primary sector	0.0048	0.0282
	(0.0176)	(0.0194)
Employment in secondary sector	0.0084	0.0191
	(0.0291)	(0.0321)
Number of males in household	0.3362	0.7454*
	(0.3906)	(0.4310)
Household head age	0.0472*	0.0892***
	(0.0278)	(0.0307)
Household head schooling	-0.1787	-0.2499
	(0.1760)	(0.1942)
Number of household members	-0.3348	-0.3094
	(0.2575)	(0.2841)
Fraction of households with migration to US	0.4864	-1.5430*
	(0.7390)	(0.8154)
Fraction of households with migration within Mexico	2.1125*	-2.1275*
	(1.1273)	(1.2439)
Household average schooling	0.0739	0.1690
	(0.1885)	(0.2080)
Household land quality (1=good, 4=very bad)	-0.1487	0.4680
	(0.2758)	(0.3044)
Constant	1.9611	-7.5317***
	(2.2989)	(2.5366)
p-value (Pr>F)	0.0350	0.0126
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants. Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

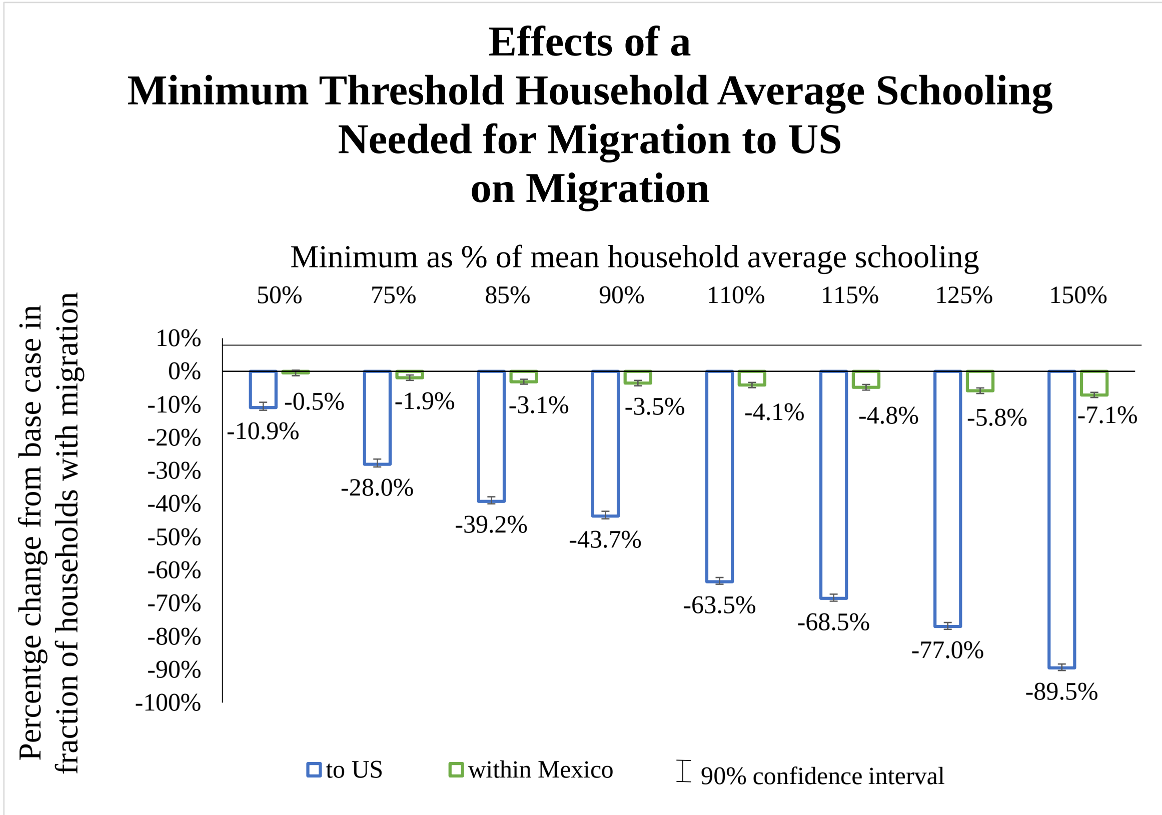


Figure 5: Results of two-sample t-test of the effects of a minimum threshold household average schooling needed for migration to US on the fraction of households with migration

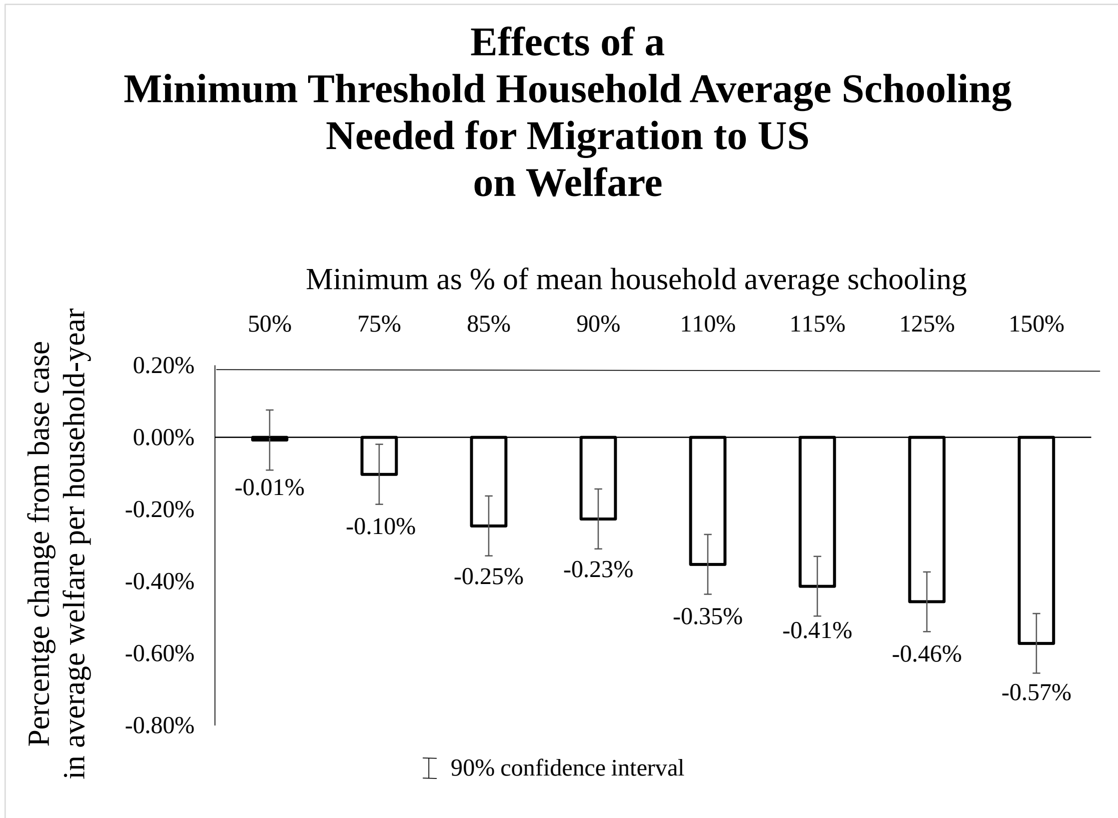


Figure 6: Results of two-sample t-test of the effects of a minimum threshold household average schooling needed for migration to US on average welfare per household-year

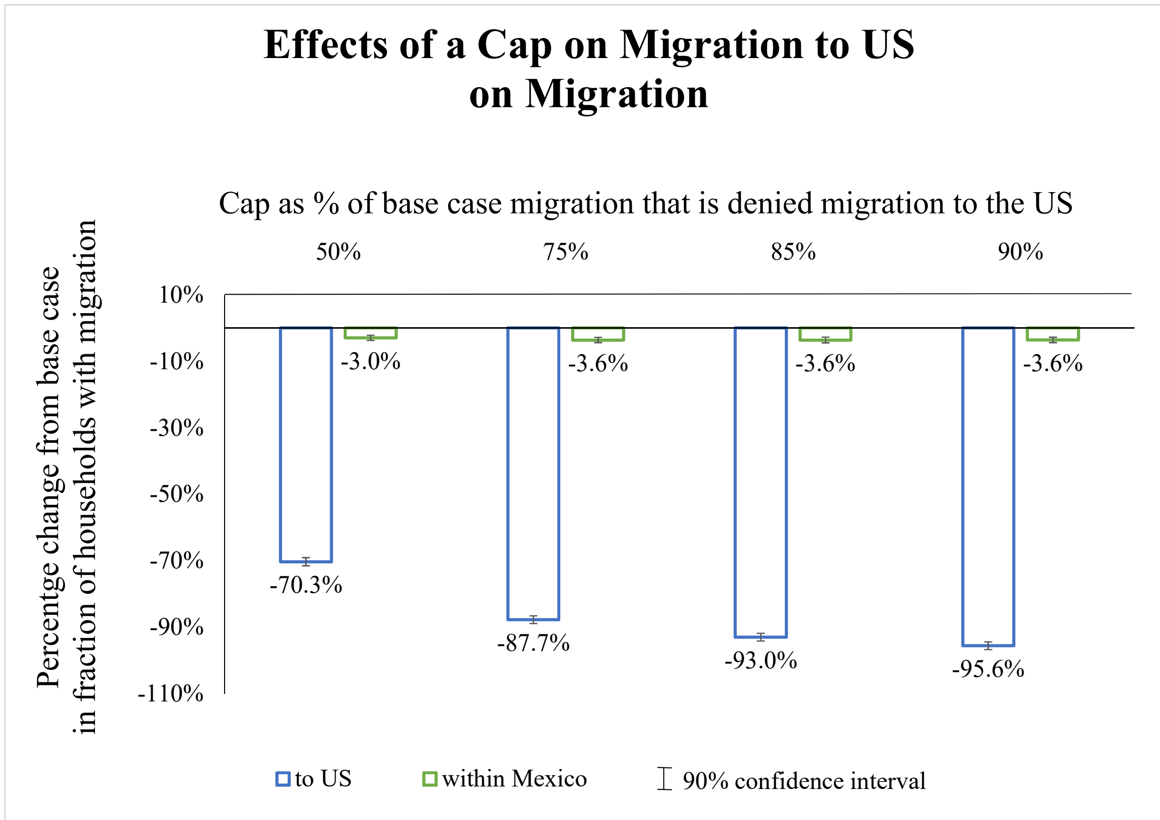


Figure 7: Results of two-sample t-test of the effects of a cap on migration to US on the fraction of households with migration

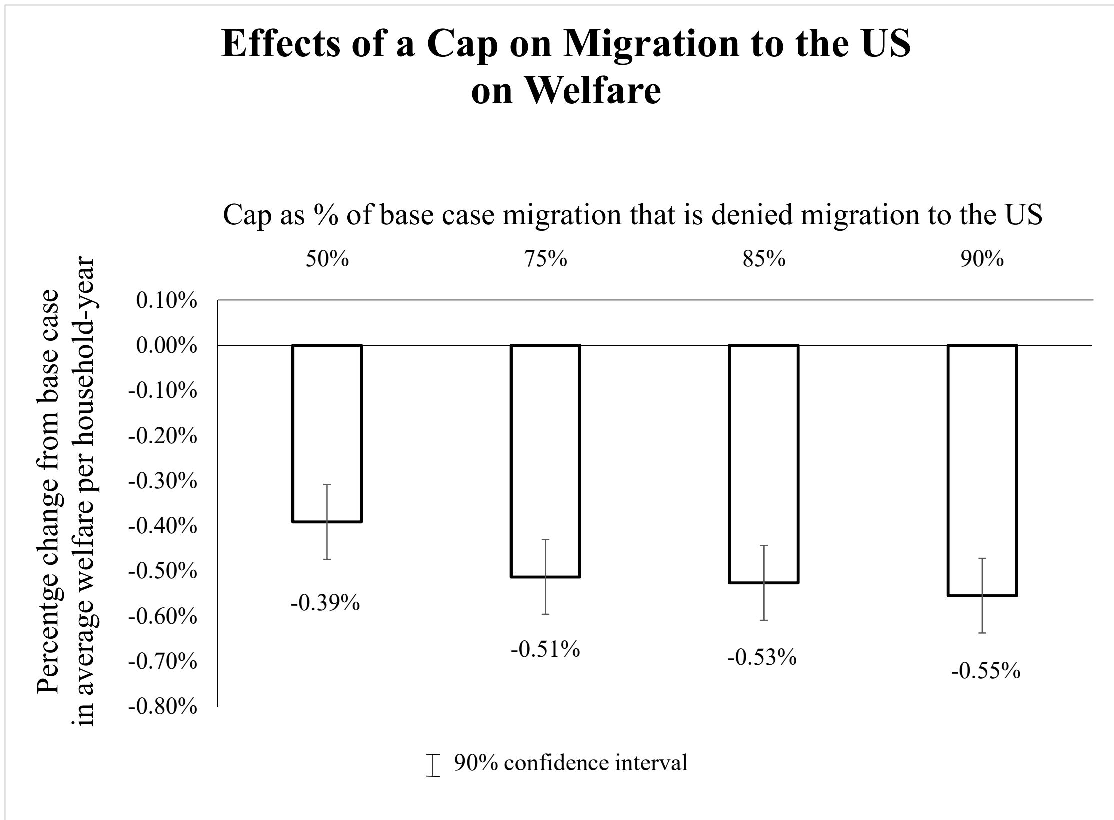


Figure 8: Results of two-sample t-test of the effects of a cap on migration to US on average welfare per household-year

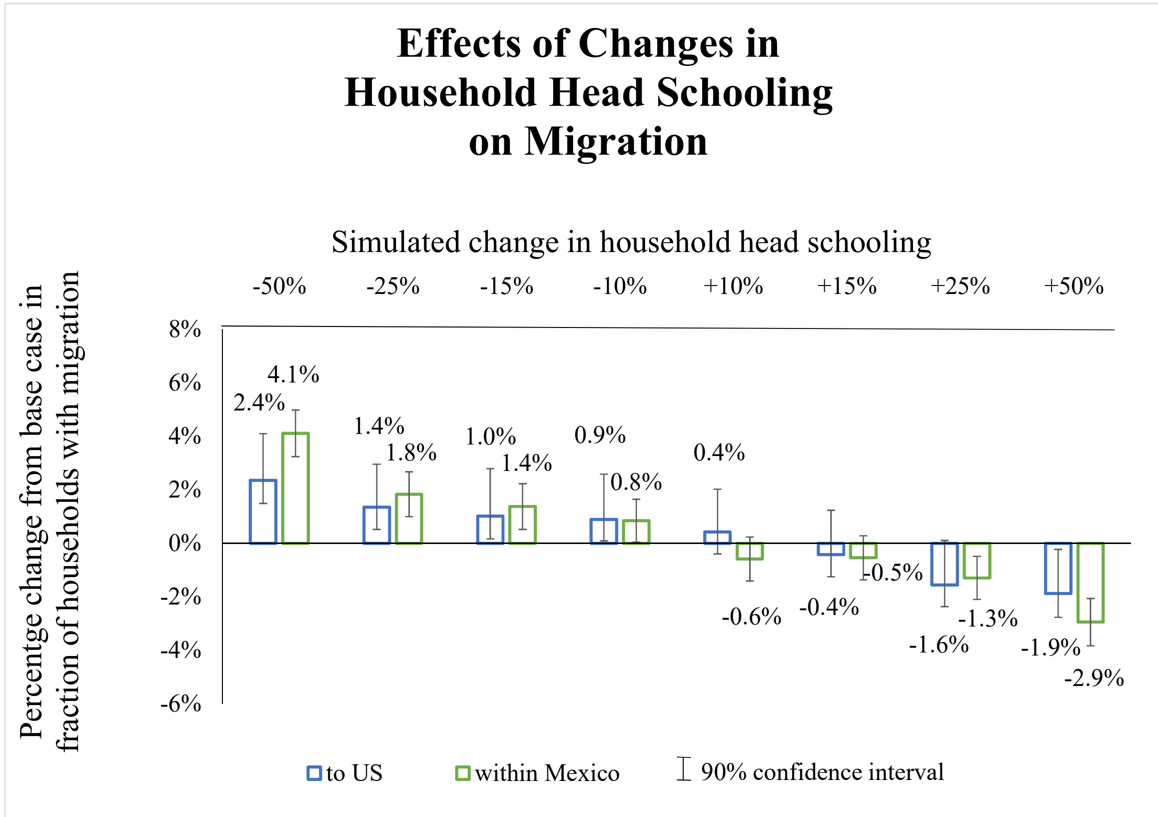


Figure 9: Results of two-sample t-test of the effects of changes in household head schooling on the fraction of households with migration

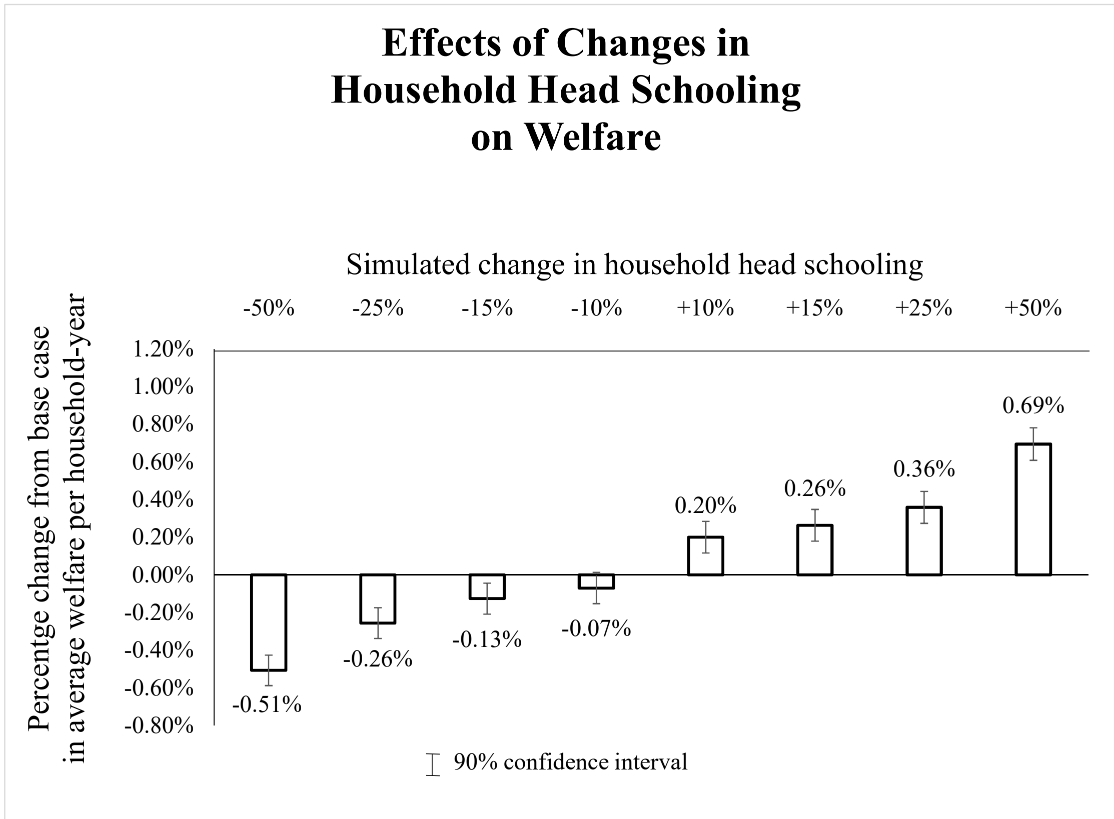


Figure 10: Results of two-sample t-test of the effects of changes in household head schooling on average welfare per household-year

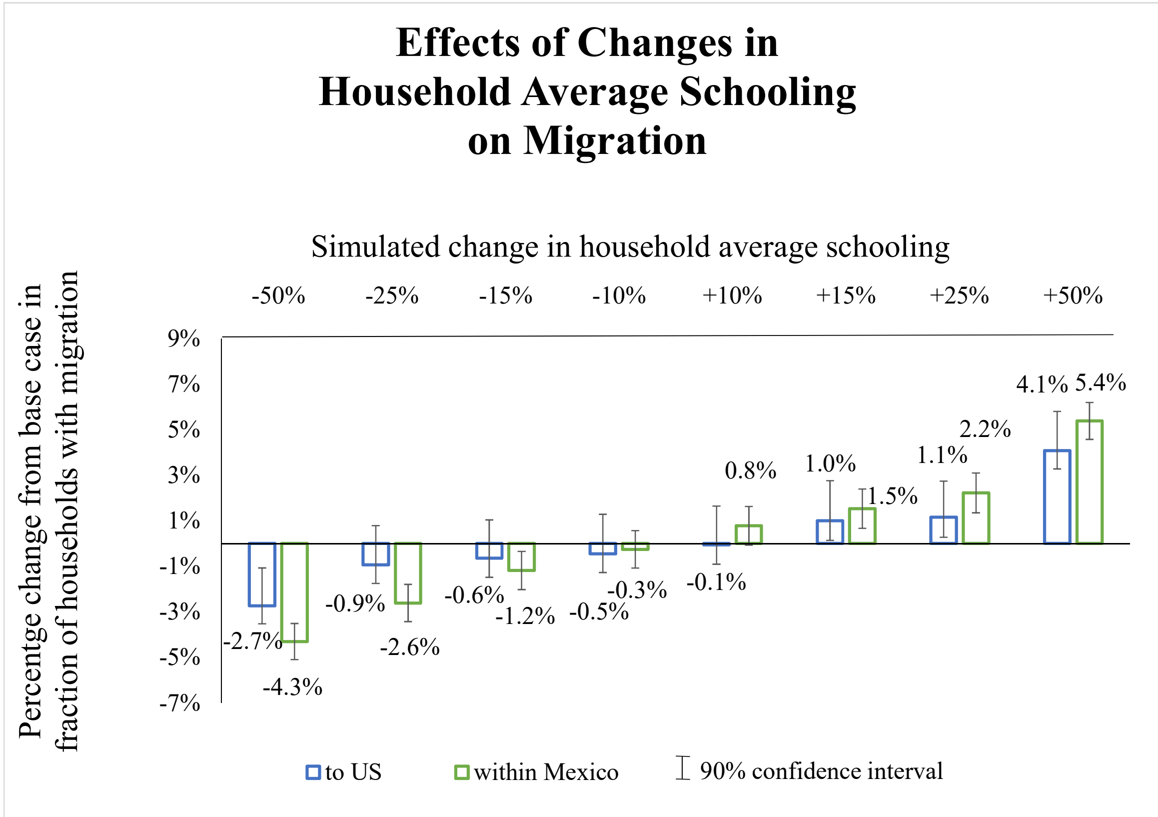


Figure 11: Results of two-sample t-test of the effects of changes in household average schooling on the fraction of households with migration

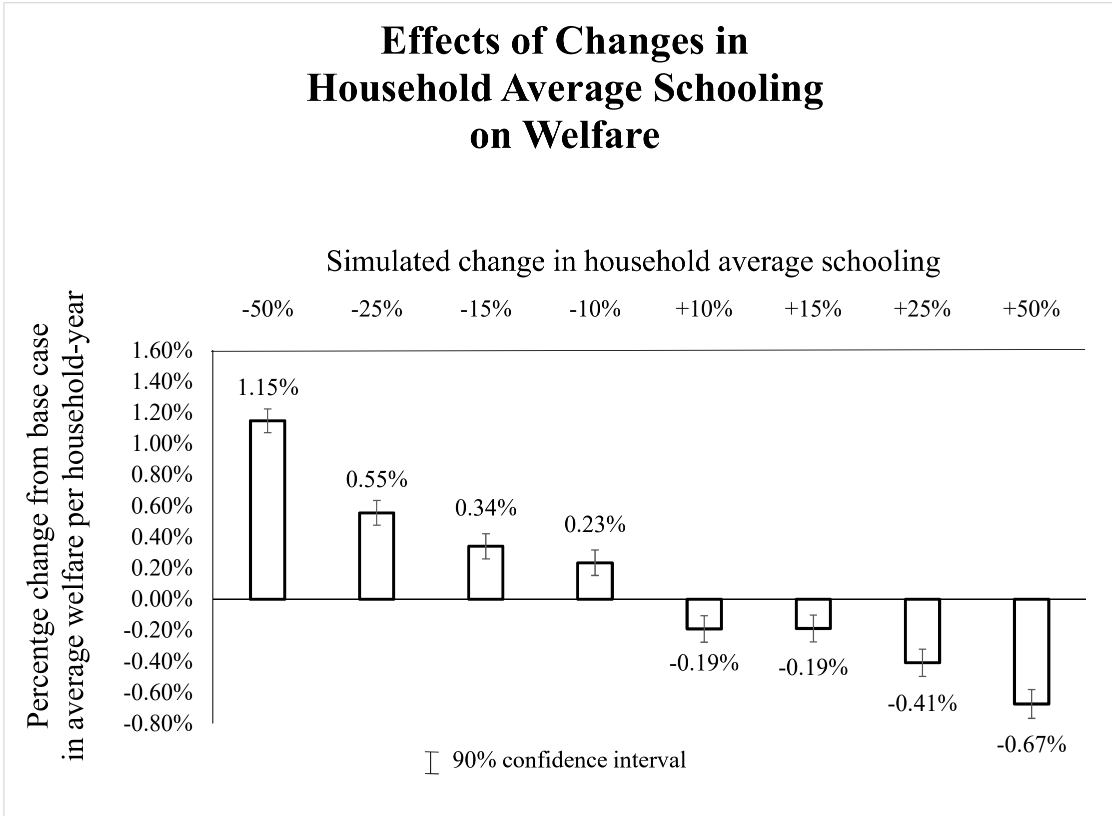


Figure 12: Results of two-sample t-test of the effects of changes in household average schooling on average welfare per household-year

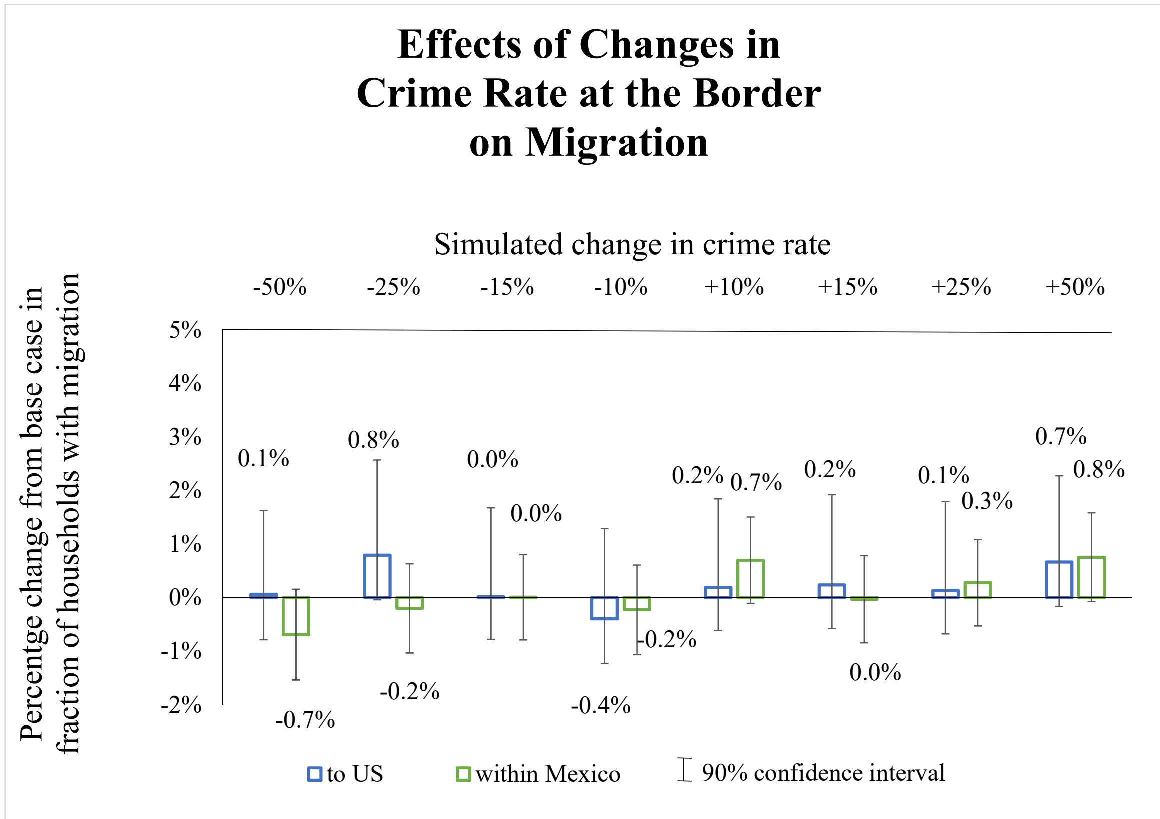


Figure 13: Results of two-sample t-test of the effects of changes in crime rate at the border on the fraction of households with migration

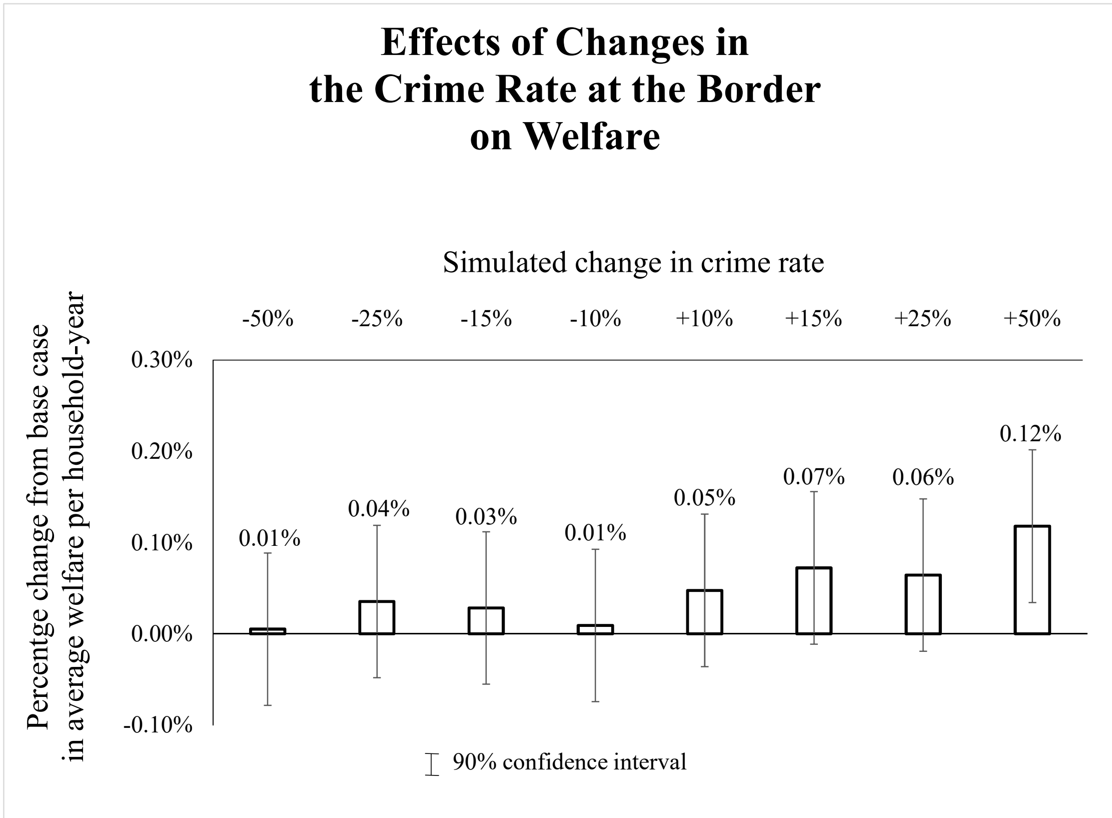


Figure 14: Results of two-sample t-test of the effects of changes in crime rate at the border on average welfare per household-year

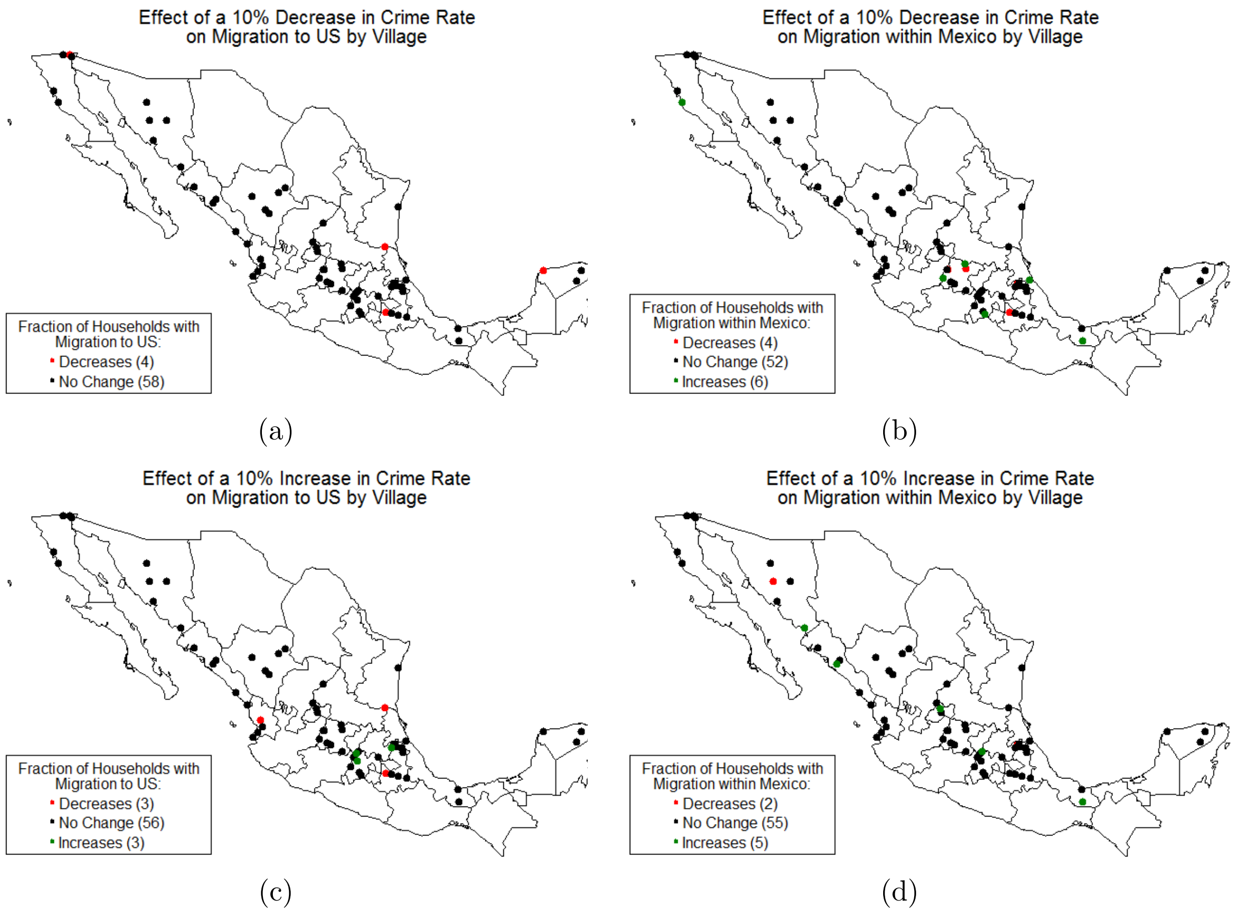
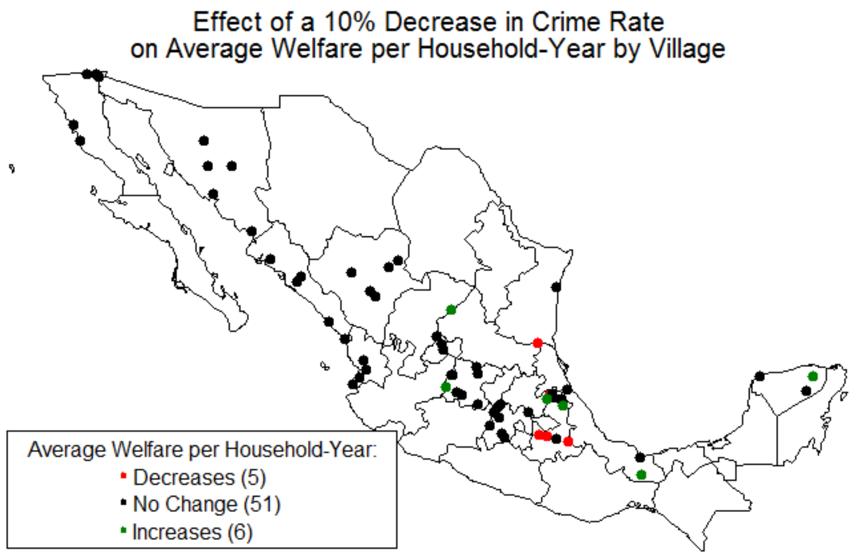


Figure 15: Signs of changes in migration by village that are significant at a 10% level under a 10% change in crime rate at the border.

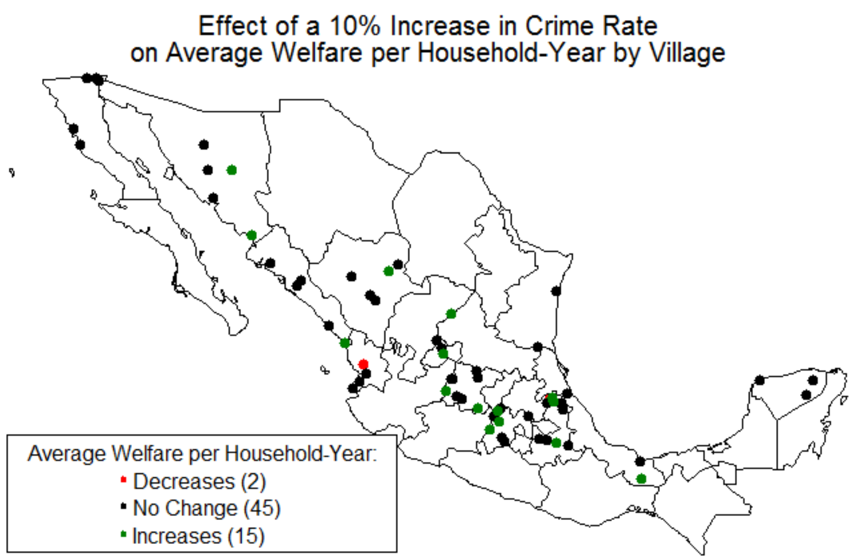
Table 4: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Simulated change in crime rate:	10% Increase		10% Decrease	
Distance to closest border crossing point (1000 km)	0.0005	0.0025	-0.0001	0.0008
	(0.0038)	(0.0052)	(0.0021)	(0.0046)
Crime rate at closest border crossing point	0.0001	0.0000	-0.0001	0.0000
	(0.0004)	(0.0005)	(0.0002)	(0.0004)
Employment in primary sector	-0.0001	-0.0003	0.0000	-0.0004
	(0.0002)	(0.0003)	(0.0001)	(0.0003)
Employment in secondary sector	0.0004	-0.0012**	-0.0000	-0.0010*
	(0.0004)	(0.0006)	(0.0002)	(0.0005)
Number of males in household	-0.0049	0.0110	-0.0058*	0.0111
	(0.0055)	(0.0076)	(0.0030)	(0.0067)
Household head age	0.0003	-0.0003	0.0002	-0.0003
	(0.0004)	(0.0005)	(0.0002)	(0.0005)
Household head schooling	0.0004	0.0010	-0.0017	0.0027
	(0.0025)	(0.0034)	(0.0014)	(0.0030)
Number of household members	0.0010	-0.0027	0.0015	-0.0053
	(0.0036)	(0.0050)	(0.0020)	(0.0044)
Fraction of households with migration to US	-0.0050	0.0009	-0.0020	0.0219*
	(0.0104)	(0.0143)	(0.0057)	(0.0126)
Fraction of households with migration within Mexico	0.0286*	-0.0412*	0.0068	-0.0048
	(0.0158)	(0.0219)	(0.0087)	(0.0193)
Household average schooling	-0.0004	-0.0029	0.0018	-0.0033
	(0.0026)	(0.0037)	(0.0015)	(0.0032)
Household land quality (1=good, 4=very bad)	0.0025	-0.0119**	0.0012	-0.0063
	(0.0039)	(0.0054)	(0.0021)	(0.0047)
Constant	-0.0264	0.0952**	-0.0100	0.0747*
	(0.0322)	(0.0446)	(0.0178)	(0.0393)
p-value (Pr>F)	0.4400	0.1210	0.4930	0.3900
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



(b)

Figure 16: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a 10% change in crime rate at the border.

Table 5: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:

Simulated change in crime rate:	10% Increase	10% Decrease
Distance to closest border crossing point (1000 km)	-0.0001	0.0002
	(0.0004)	(0.0002)
Crime rate at closest border crossing point	-0.0063	-0.0050
	(0.0329)	(0.0230)
Employment in primary sector	-0.0024	-0.0039
	(0.0232)	(0.0162)
Employment in secondary sector	-0.0291	-0.0142
	(0.0382)	(0.0267)
Number of males in household	0.5125	-0.0046
	(0.5132)	(0.3583)
Household head age	-0.0012	0.0073
	(0.0366)	(0.0255)
Household head schooling	0.0787	0.0447
	(0.2313)	(0.1615)
Number of household members	-0.1508	0.0368
	(0.3383)	(0.2362)
Fraction of households with migration to US	0.0172	-0.1842
	(0.9711)	(0.6780)
Fraction of households with migration within Mexico	-1.3377	-1.0705
	(1.4813)	(1.0342)
Household average schooling	-0.2942	-0.0912
	(0.2477)	(0.1729)
Household land quality (1=good, 4=very bad)	-0.7625**	-0.0564
	(0.3625)	(0.2531)
Constant	5.1434*	0.6506
	(3.0208)	(2.1090)
p-value (Pr>F)	0.2450	0.9940
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

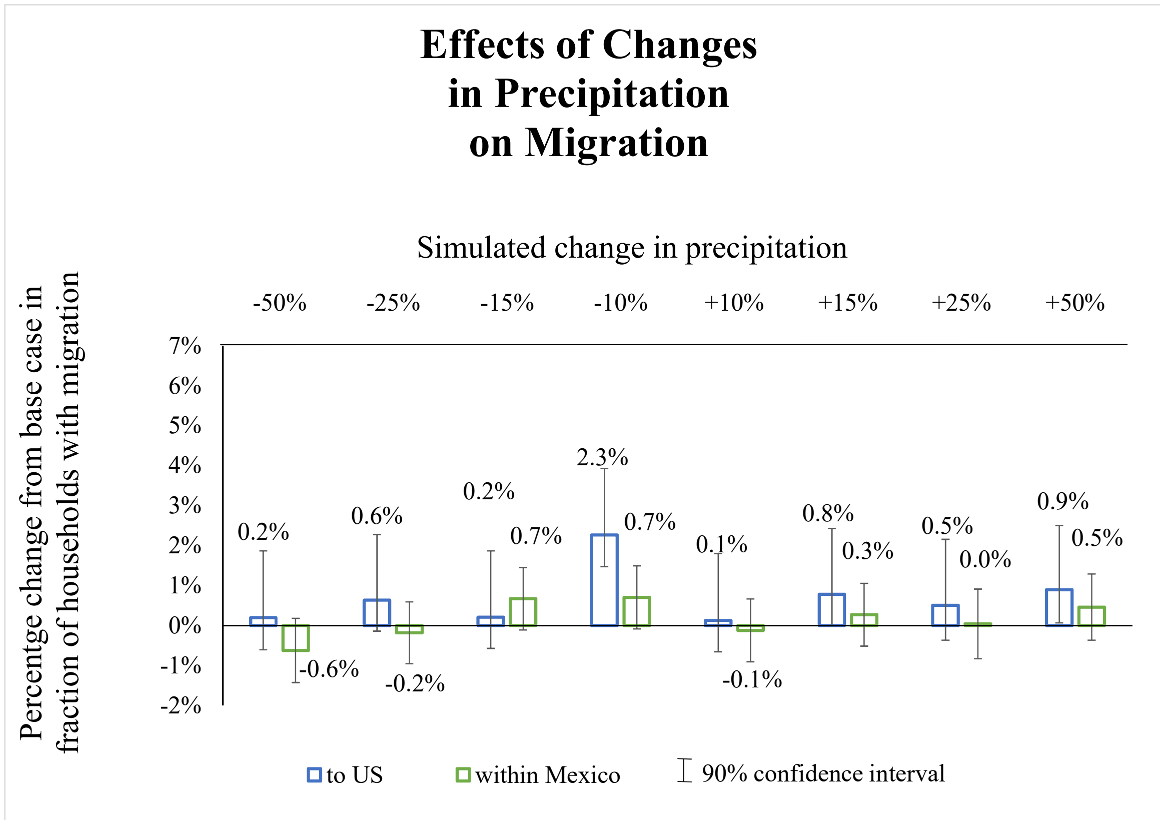


Figure 17: Results of two-sample t-test of the effects of changes in precipitation on the fraction of households with migration

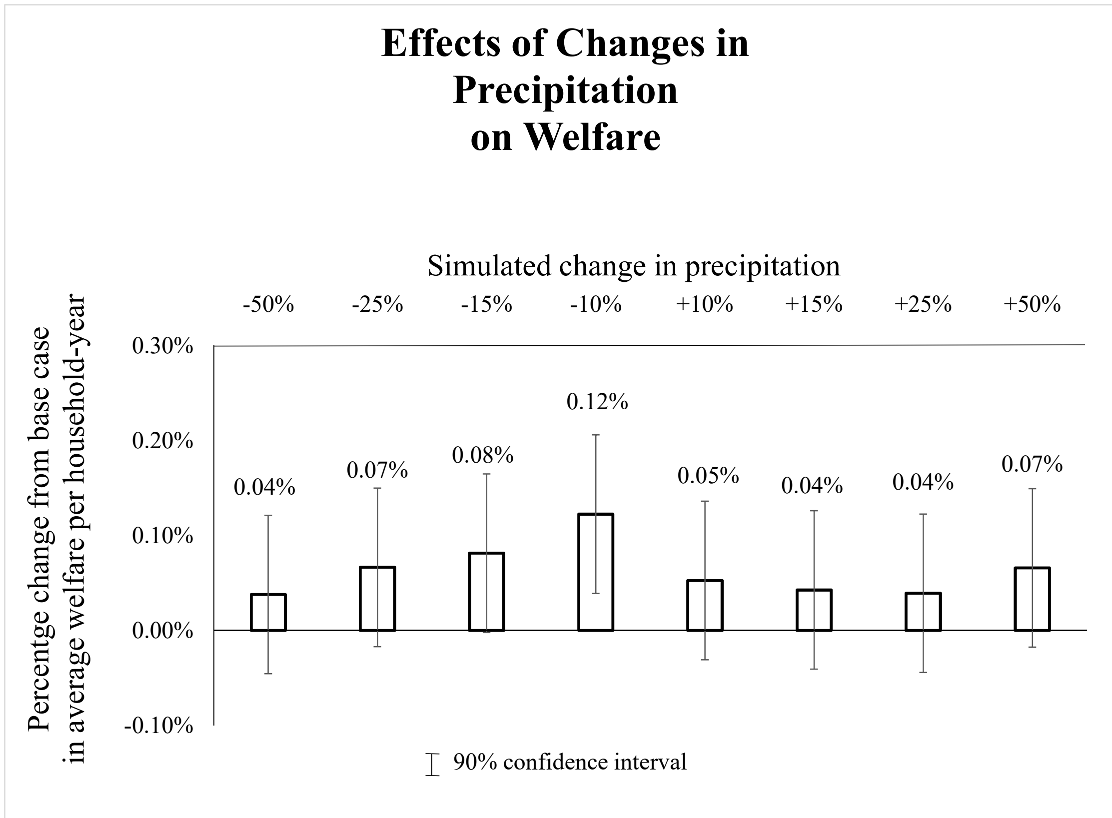


Figure 18: Results of two-sample t-test of the effects of changes in precipitation on average welfare per household-year

Effects of No Strategic Interactions

Table 6: Results of two-sample t-test of the effects of no strategic interactions

	Percentage change from base case
Fraction of households with migration to the US	16.6000 ***
Fraction of households with migration within Mexico	23.1464***
Average welfare per household-year	-1.2378***

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

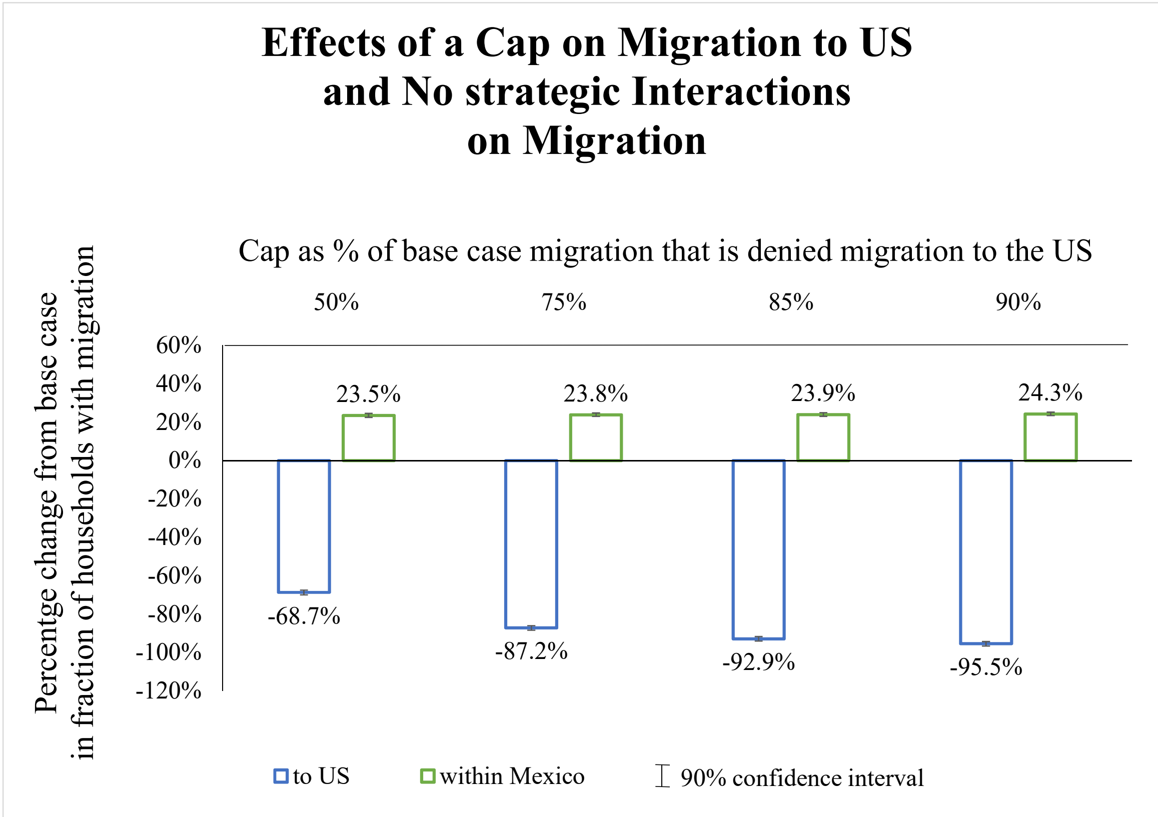


Figure 19: Results of two-sample t-test of the effects of a cap on migration to US with no strategic interactions on the fraction of households with migration

Effects of No Dynamic Behavior

Table 7: Results of two-sample t-test of the effects of no dynamic behavior

	Percentage change from base case
Fraction of households with migration to the US	-63.3507***
Fraction of households with migration within Mexico	-63.1481***
Average welfare per household-year	-65.3700***

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

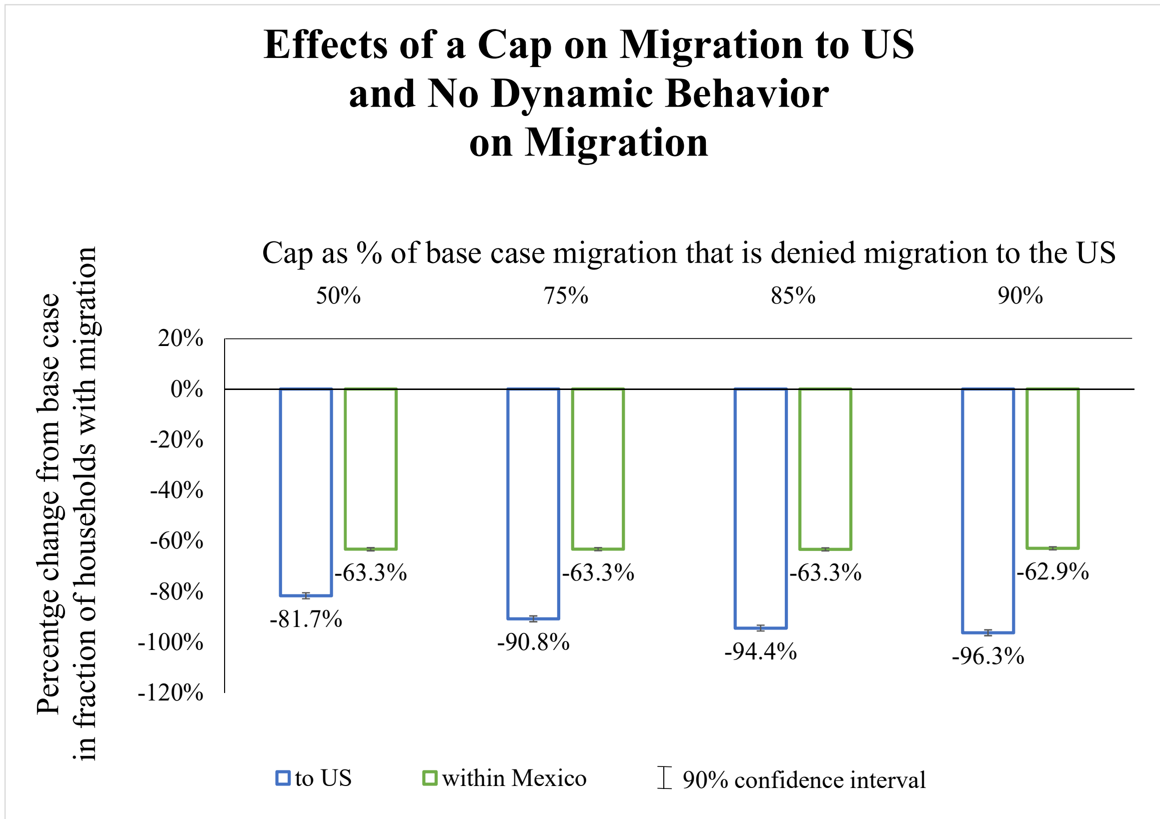


Figure 20: Results of two-sample t-test of the effects of a cap on migration to US with no dynamic behavior on the fraction of households with migration

Appendix A. Supplementary Tables and Figures

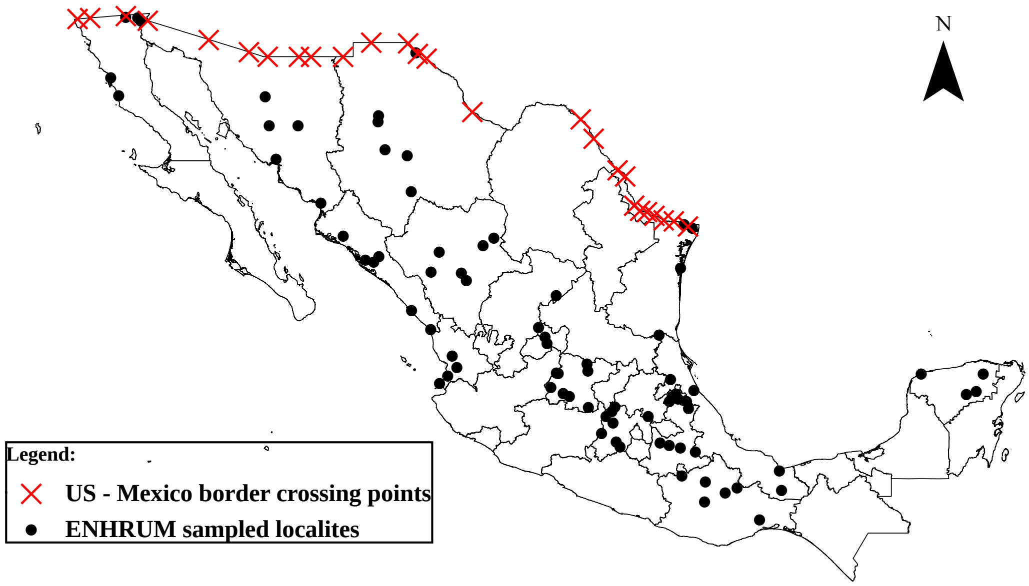


Figure A.1: Location of sampled villages in the ENHRUM survey and the border crossing municipalities

Table A.1: Summary statistics

Variable	Mean	Std.Dev.	Min	Max	# Obs
		Household migration variables			
Household has a migrant to the US (dummy)	0.17	0.38	0	1	25761
Household has a migrant within Mexico (dummy)	0.2	0.4	0	1	25761
		Neighbor migration variables			
Fraction of neighbors with migrants to US	0.17	0.21	0	1	25761
Fraction of neighbors with migrants to Mexico	0.2	0.17	0	0.89	25761
		Household characteristics			
Number of household members	5.94	3.15	1	24	25761
Number of family members	5.48	2.83	1	17	25761
Number of children in household	2.17	1.86	0	12	25761
Number of children in family	1.82	1.85	0	11	25761
Number of males in household	2.93	1.84	0	17	25761
Number of males in family	2.74	1.72	0	12	25761
First born is a male (dummy)	0.5	0.5	0	1	25761
Household head age (years)	45.15	16.26	3	100	25725
Household head schooling (years)	4.75	3.84	0	23	25725
Household average schooling (years)	6.21	2.97	0	20.5	25554
Household maximum schooling (years)	8.99	3.84	0	23	25761
Household head is the most educated (dummy)	0.26	0.44	0	1	30313
Irrigated area (hectares)	0.22	3.38	0	426	21257
Household land slope (1 = flat)	3.42	0.81	1	4	23836
Household land quality (1 = good)	3.33	0.92	1	4	23811

Table A.1: (continued)

Variable	Mean	Std.Dev.	Min	Max	# Obs
Municipality characteristics					
Number of basic schools	284.97	332.44	0	1762	22763
Number of indigenous schools	6.08	12.78	0	72	23313
Number of schools	238.87	301.17	0	1603	13107
Number of classrooms	1399.33	2236.64	0	12707	13322
Number of public libraries	20.09	34.74	0	327	11523
Number of labs	47.84	82.72	0	482	12987
Number of workshops	42.78	69.6	0	424	12987
Number of public libraries	4.92	5.69	0	28	19165
Number of students	42284.31	70057.57	0	372625	22763
Number of vehicles	44556.99	88624.85	0	502836	24220
Number of cars	29396.74	64269.9	0	383512	24220
Number of buses	371.1	841.11	0	5355	24220
Number of trucks	14203.43	23759.15	0	113819	24220
Number of motos	585.72	1685.87	0	18650	24220
State-level variables					
Employment in primary sector (% working population)	20.3	10.37	4.3	52	20635
Employment in secondary sector (% working population)	26.58	6.03	15.1	40.7	20635
Employment in tertiaty sector (% working population)	52.78	7.14	31.6	68.1	20635
National variables					
Hourly wage in primary sector (2010 Mexican pesos)	29.48	5.3	21.91	39.45	30313
Hourly wage in secondary sector (2010 Mexican pesos)	31.77	3.4	24.9	35.98	30313
Hourly wage in tertiary sector (2010 Mexican pesos)	37.81	4.21	30.27	43.54	30313
Average hourly wage (2010 Mexican pesos)	35.97	3.34	29.61	41.44	33873
Border crossing variables					
Distance to the closest border crossing point (km)	847.4	474.1	7.0	2178.3	30352

Table A.1: (continued)

Variable	Mean	Std.Dev.	Min	Max	# Obs
Number of border crossing points					
... < 1000 km	6.3	5.4	0.0	17.0	30352
... 1000-2000 km	12.4	6.0	0.0	26.0	30352
Average crime rate (murders per 10,000 inhabitants)					
... in crossing municipalities < 1000 km	11.5	8.8	1.9	83.7	12166
... in crossing municipalities 1000-2000 km	12.2	7.4	2.9	52.3	16612
... along border municipalities	14.3	2.5	9.9	18.4	17554
... at the closest crossing point	8.7	6.6	0.0	38.2	17554
... at the second closest crossing point	13.8	26.3	0.0	217.4	17554
... at the third closest crossing point	9.6	19.2	0.0	144.2	17554

Table A.2: Within and between variation of migration decisions

		Mean	Std. Dev.	Min	Max	# Obs
Household has a migrant to the US (dummy)						
	Overall	0.1746	0.3796	0.0000	1.0000	25,761
	Within		0.2254	-0.7778	1.1269	
	Between		0.3095	0.0000	1.0000	
Household has a migrant within Mexico (dummy)						
	Overall	0.2000	0.4000	0.0000	1.0000	25,761
	Within		0.2477	-0.7523	1.1524	
	Between		0.3197	0.0000	1.0000	

Notes: Within variation is the variation in the migration variable across years for a given village. Between variation is the variation in the migration variable across villages for a given year.

Table A.3: Policy functions

	Dependent variable is probability of migration to/within	
	US	*Mexico*
	(1)	(2)
Fraction of neighbors with migration to US	-0.1479***	0.0685**
	(0.0322)	(0.0289)
Fraction of neighbors with migration within Mexico	0.0537*	-0.2136***
	(0.0302)	(0.0369)
Number of household members	0.0052***	0.0052***
	(0.0009)	(0.0009)
Household head age (years)	0.0003	0.0007***
	(0.0002)	(0.0002)
First born is male (dummy)	0.0104**	0.0049
	(0.0042)	(0.0043)
Household head schooling (years)	-0.0016*	-0.0030***
	(0.0009)	(0.0009)
Household average schooling (years)	0.0024**	0.0044***
	(0.0011)	(0.0011)
Lag of migration to US	0.8020***	-0.0048
	(0.0108)	(0.0061)
Lag of migration within Mexico	0.0137**	0.8269***
	(0.0058)	(0.0093)
Household land quality interacted with rain (area)	-0.0000	0.0000
	(0.0000)	(0.0000)
Number of basic schools	0.0001***	-0.0001
	(0.0000)	(0.0001)
Distance to closest border crossing point (km)	0.0001**	-0.0002**
	(0.0000)	(0.0001)
Crime rate at closest border crossing point	-0.0001	0.0005*
	(0.0004)	(0.0003)
Crime rate second closest border crossing point	-0.0001***	-0.0000
	(0.0000)	(0.0001)
Crime rate third closest border crossing point	-0.0000	0.0002*
	(0.0001)	(0.0001)
Hourly wage, primary sector	0.0025***	0.0006
	(0.0005)	(0.0005)
Employment in secondary sector	-0.0013	0.0011
	(0.0012)	(0.0012)
Constant	-0.2782***	0.2369**
	(0.0616)	(0.1031)
Village fixed effects	Y	Y
p-value (Pr>F)	0	0
adjusted R-squared	0.743	0.773
# observations	9486	9486

Notes: Standard errors in parentheses. Significance codes: * p<0.10, ** p<0.05, *** p<0.01. Crime rates are in homicides per 10,000 inhabitants. Employment is in % working population.

Table A.4: Transition densities coefficients at the household level

	Dependent variables is:									
	Number of males in household	Number of males in family	Household size	First born is male (dummy)	Household head schooling (years)	Household average schooling (years)	Household maximum schooling (years)	Household's land slope interacted with rain	Household's land quality interacted with rain	Household's irrigated area interacted with rain
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lag of number of males in household	1.0087***	-0.0020	0.0271***	0.0075***	0.0003	-0.0372***	-0.0238**	4.5062	3.1666	-0.8995
	(0.0036)	(0.0032)	(0.0053)	(0.0016)	(0.0033)	(0.0093)	(0.0104)	(19.7362)	(19.7635)	(4.1497)
Lag of number of males in family	-0.0146***	0.9970***	-0.0347***	-0.0039***	-0.0030	0.0334***	0.0219**	-21.0162	-20.2062	0.2350
	(0.0033)	(0.0029)	(0.0049)	(0.0015)	(0.0030)	(0.0086)	(0.0096)	(18.1221)	(18.1472)	(3.8096)
Lag of first born is male (dummy)	0.0143***	0.0140***	0.0119**	0.9790***	-0.0125***	-0.0169*	-0.0076	25.6640	28.5128	-2.2195
	(0.0036)	(0.0032)	(0.0053)	(0.0016)	(0.0032)	(0.0092)	(0.0103)	(19.4757)	(19.5027)	(4.0718)
Lag of household head age (years)	-0.0016***	-0.0016***	-0.0031***	-0.0007***	-0.0006***	-0.0017***	-0.0022***	-0.7295	-0.7458	0.2896*
	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0003)	(0.0004)	(0.7210)	(0.7220)	(0.1510)
Lag of household size (members)	0.0022**	0.0000	1.0021***	-0.0044***	-0.0017*	0.0064**	0.0084***	3.4226	3.9097	0.4858
	(0.0010)	(0.0009)	(0.0015)	(0.0005)	(0.0010)	(0.0028)	(0.0031)	(5.8200)	(5.8281)	(1.2166)
Lag of household head schooling (years)	-0.0004	0.0000	-0.0017	-0.0007**	0.9995***	0.0067***	0.0020	3.5709	3.3941	1.4838*
	(0.0007)	(0.0006)	(0.0010)	(0.0003)	(0.0006)	(0.0018)	(0.0020)	(3.7224)	(3.7275)	(0.7782)
Lag of household average schooling (years)	-0.0012	-0.0015	-0.0007	0.0002	0.0014	0.9434***	-0.0335***	-9.0181	-8.7666	-0.8912
	(0.0013)	(0.0012)	(0.0020)	(0.0006)	(0.0012)	(0.0035)	(0.0039)	(7.3142)	(7.3243)	(1.5289)
Lag of household maximum schooling (years)	-0.0006	-0.0006	-0.0017	0.0003	0.0007	0.0371***	1.0197***	-0.9318	-0.8082	0.3536
	(0.0009)	(0.0008)	(0.0013)	(0.0004)	(0.0008)	(0.0023)	(0.0026)	(4.7920)	(4.7986)	(1.0018)
Lag of fraction of households with migration to US	0.0001	0.0063	0.0030	-0.0047	-0.0030	0.0091	-0.0509*	148.7091***	141.8349***	15.1994
	(0.0090)	(0.0080)	(0.0133)	(0.0040)	(0.0083)	(0.0236)	(0.0264)	(48.2475)	(48.3143)	(10.0782)
Lag of fraction of households with migration within Mexico	-0.0336***	-0.0217**	-0.0454***	-0.0096**	-0.0178	0.0544*	0.0720**	689.5393***	701.5287***	23.7046*
	(0.0110)	(0.0097)	(0.0162)	(0.0048)	(0.0114)	(0.0326)	(0.0364)	(66.0319)	(66.1234)	(13.7949)
Lag of own household migration to US (dummy)	0.0043	0.0053	0.0009	0.0093***	0.0124***	-0.0310**	-0.0003	6.7006	7.0530	-9.4844
	(0.0052)	(0.0046)	(0.0077)	(0.0023)	(0.0046)	(0.0133)	(0.0148)	(28.1827)	(28.2218)	(5.8896)
Lag of own household migration within Mexico (dummy)	0.0102**	0.0086**	0.0161**	0.0082***	0.0095**	-0.0241**	-0.0418***	20.5595	21.1400	-3.2179
	(0.0046)	(0.0041)	(0.0068)	(0.0020)	(0.0040)	(0.0115)	(0.0128)	(24.4302)	(24.4640)	(5.1016)
Lag of number of basic schools					-0.0000	0.0001**	-0.0000			
					(0.0000)	(0.0000)	(0.0000)			
Lag of number of indigenous schools					0.0001*	0.0003*	0.0010***			
					(0.0001)	(0.0002)	(0.0002)			
Lag of household land slope interacted with rain					0.0000	-0.0000	-0.0000	0.8535***	-0.1555***	-0.0036
					(0.0000)	(0.0000)	(0.0000)	(0.0397)	(0.0397)	(0.0085)
Lag of household land quality interacted with rain					-0.0000	0.0000	0.0000	-0.0270	0.9817***	0.0009
					(0.0000)	(0.0000)	(0.0000)	(0.0395)	(0.0396)	(0.0085)
Lag of household's irrigated area interacted with rain					-0.0000	-0.0000	0.0000	0.0046	0.0042	1.0032***
					(0.0000)	(0.0000)	(0.0000)	(0.0139)	(0.0139)	(0.0037)
Constant	0.1221***	0.1225***	0.2423***	0.0653***	0.0538***	0.1398***	0.2563***	319.0271***	314.7990***	-13.8696
	(0.0080)	(0.0071)	(0.0118)	(0.0035)	(0.0079)	(0.0226)	(0.0252)	(43.9870)	(44.0480)	(9.1763)
adjusted R-squared	0.9882	0.9898	0.9908	0.9705	0.9993	0.9889	0.9905	0.7588	0.7628	0.9163
# observations	14554	14554	14554	14554	6497	6497	6497	7168	7168	7117

Notes: Standard errors in parentheses. Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

Table A.5: Transition densities coefficients at the village and municipality level

	Dependent variable is:					
	Crime at closest crossing border point	Crime at second crossing border point	Crime at third crossing border point	Number of basic schools	Number of indigenous schools	Number of students in basic system
	(11)	(12)	(13)	(14)	(15)	(16)
Lag of number of basic schools				0.5484***	0.0003	27.0023***
				(0.0431)	(0.0073)	(3.9734)
Lag of number of indigenous schools				-0.2278	0.4956***	-14.9978
				(0.2207)	(0.0372)	(20.3280)
Lag of number of students in basic system				0.0009*	-0.0001	0.0941**
				(0.0004)	(0.0001)	(0.0413)
Lag of employment in primary sector				1.0530	0.0180	-18.8602
				(1.2750)	(0.2160)	(117.4470)
Lag of employment in secondary sector				1.3148	-0.0555	-51.5847
				(1.2895)	(0.2188)	(118.7885)
Lag of employment in tertiary sector				0.7357	-0.0007	10.5247
				(1.3240)	(0.2243)	(121.9671)
Lag of avg. hourly wage in primary sector (pesos)	-0.5765***	4.2476***	0.4092			
	(0.1314)	(0.8395)	(0.3101)			
Lag of avg. hourly wage in secondary sector (pesos)	-2.0471***	0.3548	0.3891			
	(0.2333)	(1.4910)	(0.5507)			
Lag of avg. hourly wage in tertiary sector (pesos)	1.9010***	-2.6400	-0.9146			
	(0.2633)	(1.6822)	(0.6213)			
Lag of crime at closest border crossing point	0.3543***	0.9985***	0.3662***			
	(0.0285)	(0.1822)	(0.0673)			
Lag of crime at second closest border crossing point	0.0347***	0.2047***	0.0389***			
	(0.0050)	(0.0321)	(0.0118)			
Lag of crime at third closest border crossing point	0.0850***	0.4031***	0.1935***			
	(0.0142)	(0.0909)	(0.0336)			
Constant	17.2215***	-33.4177*	15.3372**	-35.3086	8.6043	19691.8306*
	(3.1505)	(20.1307)	(7.4350)	(126.5089)	(21.4457)	(11653.7577)
adjusted R-squared	0.3736	0.1547	0.1001	0.9814	0.9907	0.7589
# observations	960	960	960	743	735	743

Notes: Standard errors in parentheses. Employment is in % working population. Crime is in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

Table A.6: Transition densities coefficients at the state and national level

	Employment in primary sector	Employment in secondary sector	Employment in tertiary sector	Avg. hourly wage in primary sector (pesos)	Avg. hourly wage in secondary sector (pesos)	Avg. hourly wage in tertiary sector (pesos)
	(17)	(18)	(19)	(20)	(21)	(22)
Lag of employment in primary sector	-0.1632	0.2706	0.6664***			
	(0.2584)	(0.2075)	(0.2382)			
Lag of employment in secondary sector	-0.4812**	0.7253***	0.5811***			
	(0.2405)	(0.1932)	(0.2217)			
Lag of employment in tertiary sector	-0.4501**	0.1884	1.0455***			
	(0.2202)	(0.1769)	(0.2030)			
Lag of avg. hourly wage in primary sector (pesos)	-0.4508***	0.2284**	0.3217**	0.9509*	0.8702**	1.0556**
	(0.1342)	(0.1078)	(0.1237)	(0.5007)	(0.2892)	(0.3295)
Lag of avg. hourly wage in secondary sector (pesos)	-0.1500	0.0685	0.1867	-0.0404	0.9658*	0.4484
	(0.1820)	(0.1462)	(0.1678)	(0.8731)	(0.5043)	(0.5745)
Lag of avg. hourly wage in tertiary sector (pesos)	0.2400	-0.3680*	-0.1159	0.1823	-1.0594	-0.6512
	(0.2726)	(0.2189)	(0.2513)	(1.0005)	(0.5779)	(0.6583)
Constant	57.7381**	1.0251	-36.6682*	-2.7204	15.6277**	17.2455**
	(23.1182)	(18.5670)	(21.3111)	(11.1884)	(6.4624)	(7.3613)
adjusted R-squared	0.9547	0.9204	0.9101	0.7020	0.7410	0.7777
# observations	154	154	154	12	12	12

Notes: Standard errors in parentheses. Employment is in % working population. Wages are in 2010 Mexican pesos.
Significance codes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A.7: Summary of welfare based on actual and simulated data

	Estimate	Standard error
Actual average welfare per household year based on:		
Actual data	-0.017739	0.14013
Simulated data	-0.012241	0.00004***

Notes: Standard errors in parentheses. Significance codes: * p<0.10, ** p<0.05, *** p<0.01

Table A.8: Observed migration

	To US	Within Mexico
Fraction of households with migration	0.1809	0.2113
Fraction of households with migration per village-year		
Mean	0.1787	0.2406
Std. Dev.	0.2327	0.2242

Table A.9: Observed fraction of households with migration by year

	Fraction of households with migration to/within:	
Year	US	Mexico
1997	0.1478	0.1770
1998	0.0942	0.1964
1999	0.1045	0.2091
2000	0.1781	0.2022
2001	0.1661	0.1764
2002	0.1952	0.2321
2003	0.1825	0.2142
2004	0.2030	0.2179
2005	0.2191	0.2285
2006	0.2328	0.2272
2007	0.2634	0.2567

Table A.10: Simulated migration

	Migration to US		Migration within Mexico	
	Mean	Std.Dev.	Mean	Std.Dev.
Fraction of households with migration	0.2965	0.0207	0.2936	0.0102
Fraction of households with migration per village year				
Mean	0.2976	0.0219	0.3310	0.0161
Std. Dev.	0.2329	0.0099	0.2294	0.0121

Table A.11: Simulated migration by year

	Fraction of households with migration to/within:			
	US		Mexico	
Year	Mean	Std.Dev.	Mean	Std.Dev.
1997	0.1974	0.0116	0.2108	0.0132
1998	0.2367	0.0127	0.2448	0.0156
1999	0.2631	0.0164	0.2712	0.0152
2000	0.2845	0.0203	0.2880	0.0163
2001	0.2983	0.0232	0.2985	0.0179
2002	0.3100	0.0255	0.3054	0.0187
2003	0.3196	0.0305	0.3128	0.0162
2004	0.3258	0.0324	0.3166	0.0188
2005	0.3335	0.0353	0.3211	0.0196
2006	0.3405	0.0372	0.3280	0.0198
2007	0.3519	0.0410	0.3327	0.0202

Appendix B. Counterfactual Simulations

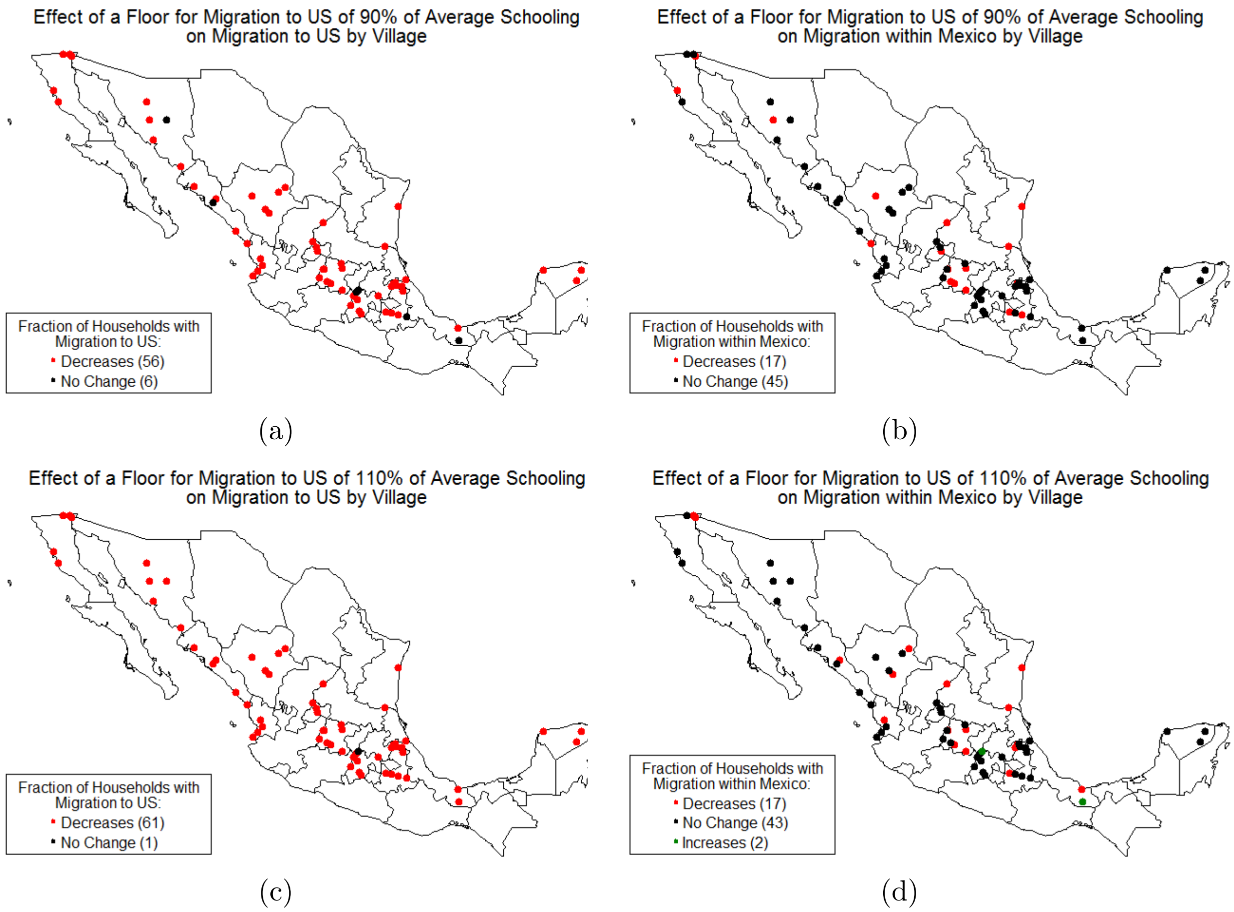


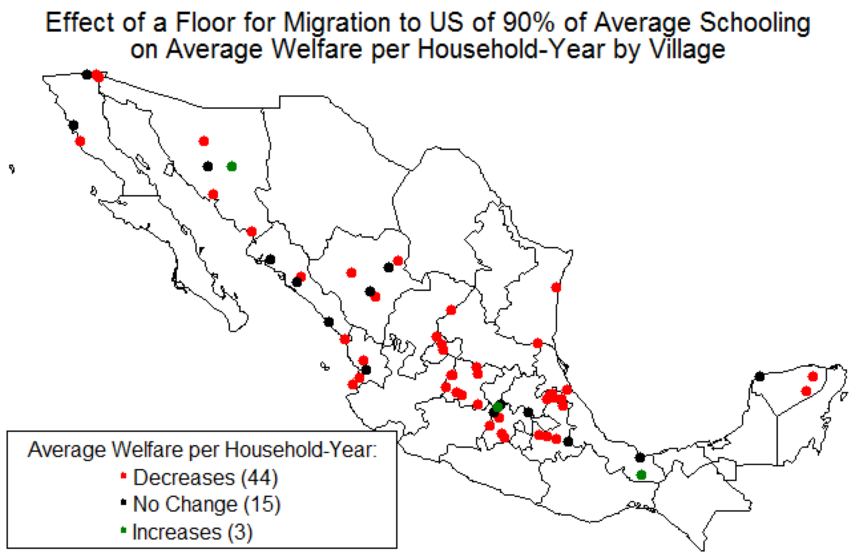
Figure B.1: Signs of changes in migration by village that are significant at a 10% level under a minimum threshold household average schooling needed for migration to US of 10% above and below the average schooling.

Effects of a Minimum Threshold Household Average Schooling Needed for Migration to US

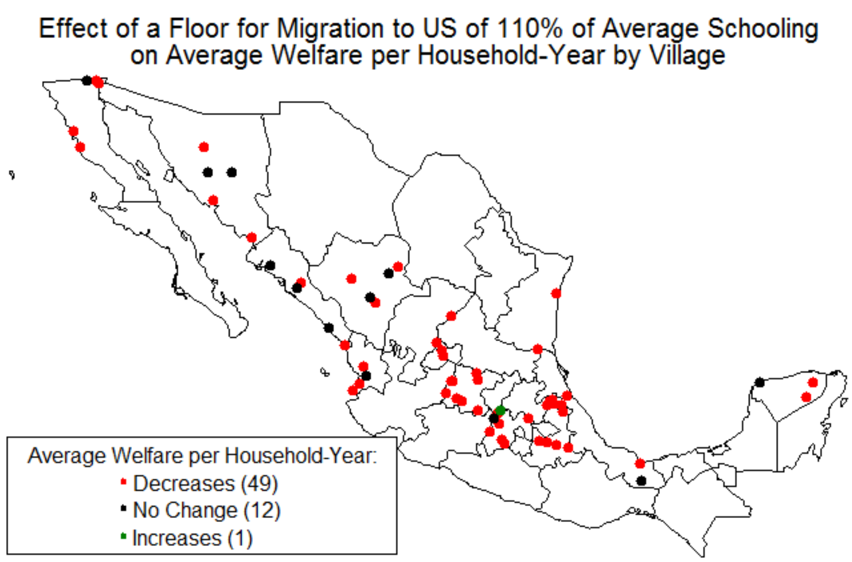
Table B.1: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Minimum as % of mean household avg. schooling :	110%		90%	
Distance to closest border crossing point (1000 km)	0.0060	0.0095	0.0039	0.0059
	(0.0234)	(0.0064)	(0.0270)	(0.0041)
Crime rate at closest border crossing point	-0.0006	0.0001	0.0011	-0.0002
	(0.0022)	(0.0006)	(0.0025)	(0.0004)
Employment in primary sector	-0.0025	-0.0004	-0.0034*	-0.0005*
	(0.0015)	(0.0004)	(0.0018)	(0.0003)
Employment in secondary sector	-0.0033	-0.0007	-0.0058*	-0.0008*
	(0.0025)	(0.0007)	(0.0029)	(0.0004)
Number of males in household	0.0542	0.0061	0.0303	0.0038
	(0.0340)	(0.0093)	(0.0392)	(0.0060)
Household head age	-0.0007	-0.0008	-0.0031	0.0003
	(0.0024)	(0.0007)	(0.0028)	(0.0004)
Household head schooling	0.0292*	-0.0010	0.0219	0.0004
	(0.0153)	(0.0042)	(0.0177)	(0.0027)
Number of household members	-0.0424*	-0.0031	-0.0229	-0.0051
	(0.0224)	(0.0061)	(0.0258)	(0.0040)
Fraction of households with migration to US	-0.4193***	-0.0230	-0.3037***	-0.0022
	(0.0642)	(0.0175)	(0.0741)	(0.0114)
Fraction of households with migration within Mexico	0.0297	-0.0408	-0.0105	0.0038
	(0.0980)	(0.0268)	(0.1131)	(0.0174)
Household average schooling	0.0009	0.0032	0.0023	-0.0002
	(0.0164)	(0.0045)	(0.0189)	(0.0029)
Household land quality (1=good, 4=very bad)	0.0037	-0.0179***	0.0025	-0.0012
	(0.0240)	(0.0065)	(0.0277)	(0.0043)
Constant	-0.0259	0.1014*	0.1685	0.0327
	(0.1998)	(0.0546)	(0.2306)	(0.0355)
p-value (Pr>F)	0.0000	0.1190	0.0000	0.2170
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



(b)

Figure B.2: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a minimum threshold household average schooling needed for migration to US of 10% above and below the average schooling.

Effects of a Minimum Threshold Household Average Schooling Needed for Migration to US

Table B.2: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:		
Minimum as % of mean household avg. schooling :	110%	90%
Distance to closest border crossing point (1000 km)	0.0001	-0.0001
	(0.0009)	(0.0009)
Crime rate at closest border crossing point	-0.0426	0.0199
	(0.0795)	(0.0848)
Employment in primary sector	-0.0733	-0.1102*
	(0.0559)	(0.0597)
Employment in secondary sector	-0.1004	-0.1809*
	(0.0923)	(0.0985)
Number of males in household	1.6459	1.0590
	(1.2400)	(1.3226)
Household head age	-0.0034	-0.0971
	(0.0883)	(0.0942)
Household head schooling	1.1830**	1.0083*
	(0.5588)	(0.5960)
Number of household members	-0.7789	-0.4507
	(0.8174)	(0.8719)
Fraction of households with migration to US	-13.3467***	-8.8057***
	(2.3461)	(2.5024)
Fraction of households with migration within Mexico	-2.0534	-1.3157
	(3.5787)	(3.8171)
Household average schooling	-0.1743	-0.3158
	(0.5984)	(0.6383)
Household land quality (1=good, 4=very bad)	0.1624	0.4884
	(0.8757)	(0.9340)
Constant	-2.1404	4.7190
	(7.2982)	(7.7843)
p-value (Pr>F)	0.0000	0.0000
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants. Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

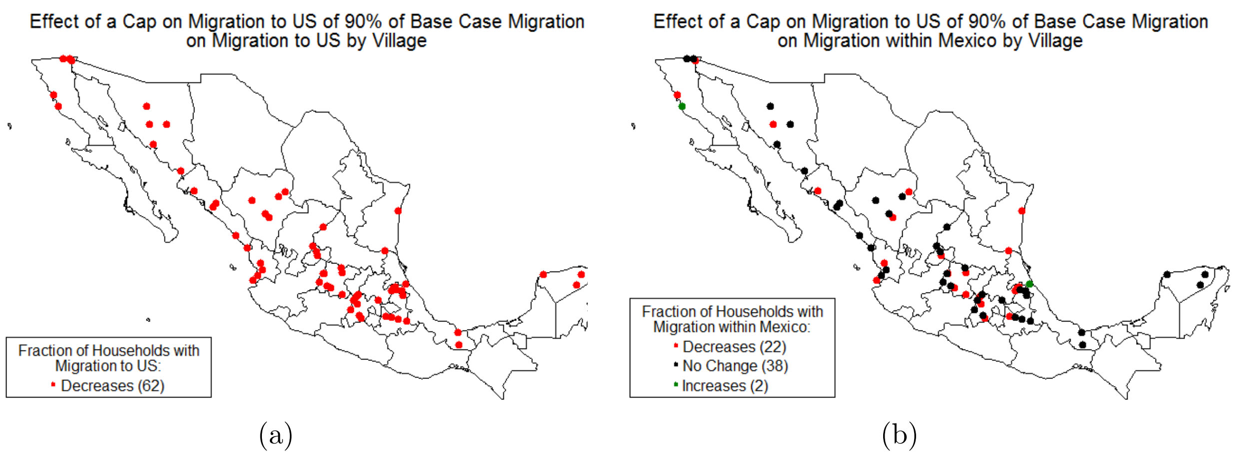
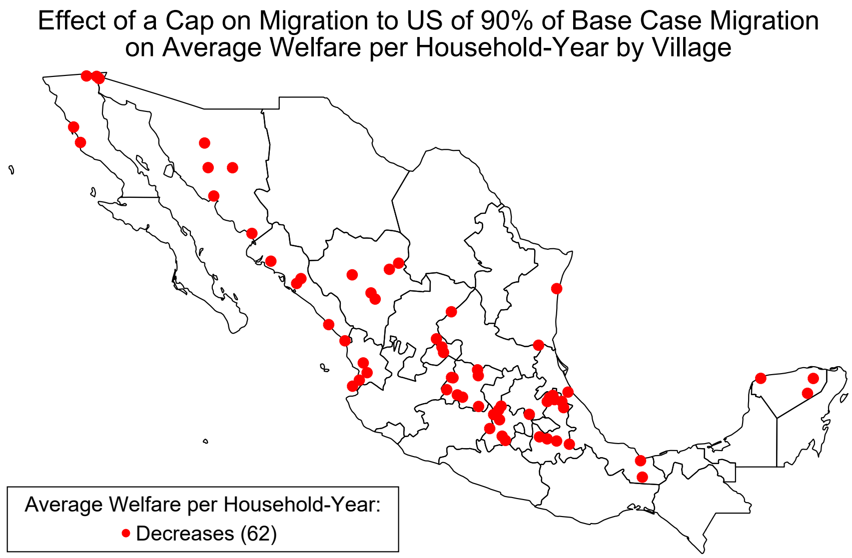


Figure B.3: Signs of changes in migration by village that are significant at a 10% level under a cap on migration to US of 90% of base case migration.

Table B.3: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*
Cap as % of base case migration that is denied migration to US:	90%	
Distance to closest border crossing point (1000 km)	0.0110	0.0055
	(0.0139)	(0.0055)
Crime rate at closest border crossing point	-0.0006	-0.0001
	(0.0013)	(0.0005)
Employment in primary sector	-0.0015	0.0003
	(0.0009)	(0.0004)
Employment in secondary sector	-0.0004	-0.0003
	(0.0015)	(0.0006)
Number of males in household	0.0188	0.0089
	(0.0202)	(0.0080)
Household head age	0.0005	0.0003
	(0.0014)	(0.0006)
Household head schooling	0.0218**	-0.0017
	(0.0091)	(0.0036)
Number of household members	-0.0228*	-0.0059
	(0.0133)	(0.0053)
Fraction of households with migration to US	-0.5293***	-0.0246
	(0.0382)	(0.0151)
Fraction of households with migration within Mexico	0.1350**	-0.0446*
	(0.0583)	(0.0230)
Household average schooling	-0.0159	0.0014
	(0.0098)	(0.0039)
Household land quality (1=good, 4=very bad)	0.0238	-0.0018
	(0.0143)	(0.0056)
Constant	-0.2165*	0.0010
	(0.1189)	(0.0470)
p-value (Pr>F)	0.0000	0.2130
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)

Figure B.4: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a cap on migration to US of 90% of base case migration.

Table B.4: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:	
Cap as % of base case migration that is denied migration to US:	90%
Distance to closest border crossing point (1000 km)	-0.0004
	(0.0007)
Crime rate at closest border crossing point	-0.0891
	(0.0635)
Employment in primary sector	-0.0480
	(0.0447)
Employment in secondary sector	-0.0308
	(0.0738)
Number of males in household	0.3228
	(0.9909)
Household head age	0.0276
	(0.0706)
Household head schooling	0.8344*
	(0.4465)
Number of household members	0.0176
	(0.6532)
Fraction of households with migration to US	-16.5421***
	(1.8749)
Fraction of households with migration within Mexico	0.8716
	(2.8599)
Household average schooling	-0.4593
	(0.4782)
Household land quality (1=good, 4=very bad)	1.5704**
	(0.6998)
Constant	-9.5214
	(5.8322)
p-value (Pr>F)	0.0000
# observations	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants. Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

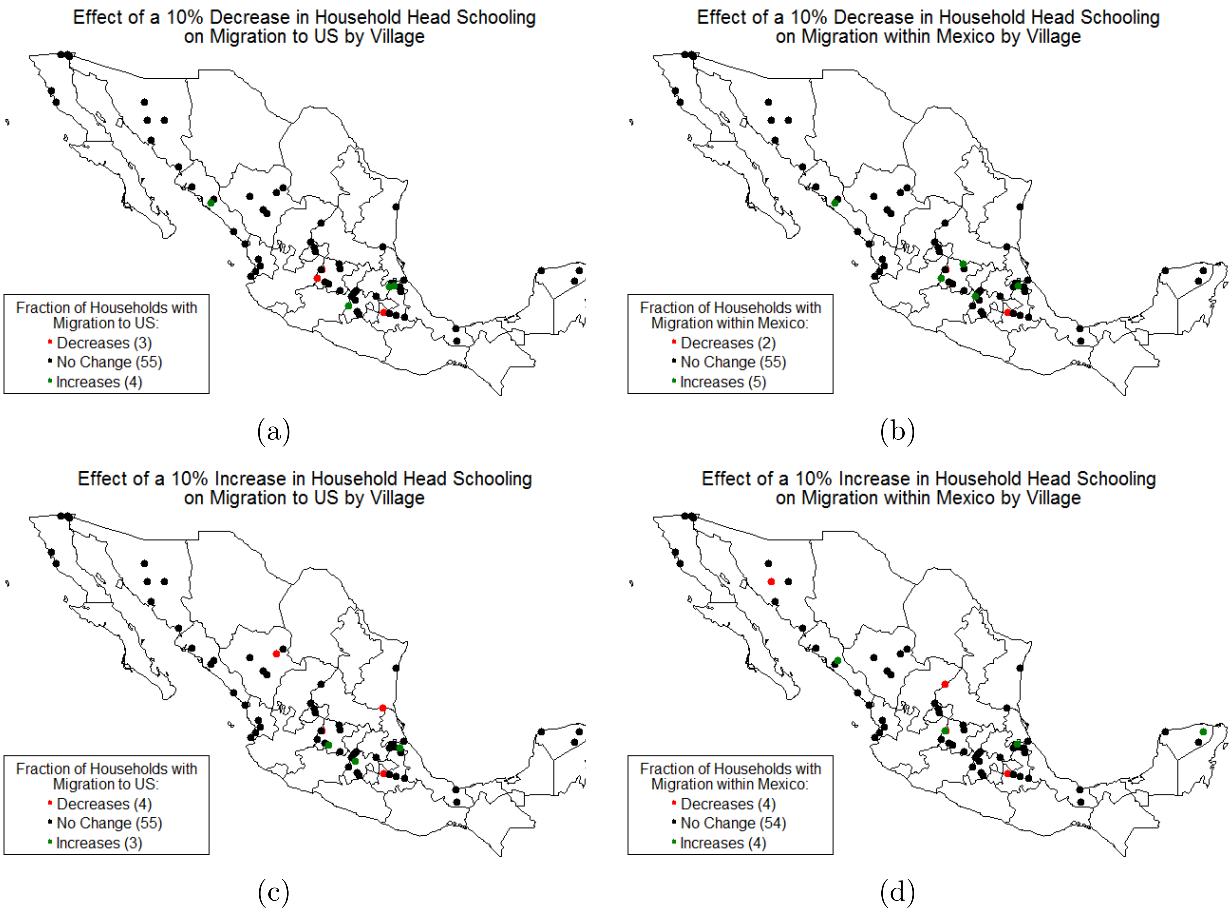


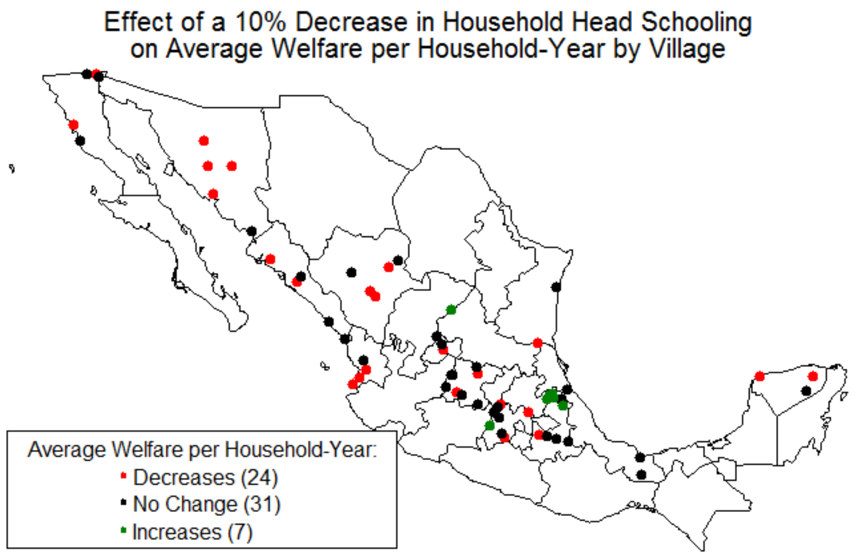
Figure B.5: Signs of changes in migration by village that are significant at a 10% level under a 10% change in household head schooling.

Effects of Changes in Household Head Schooling

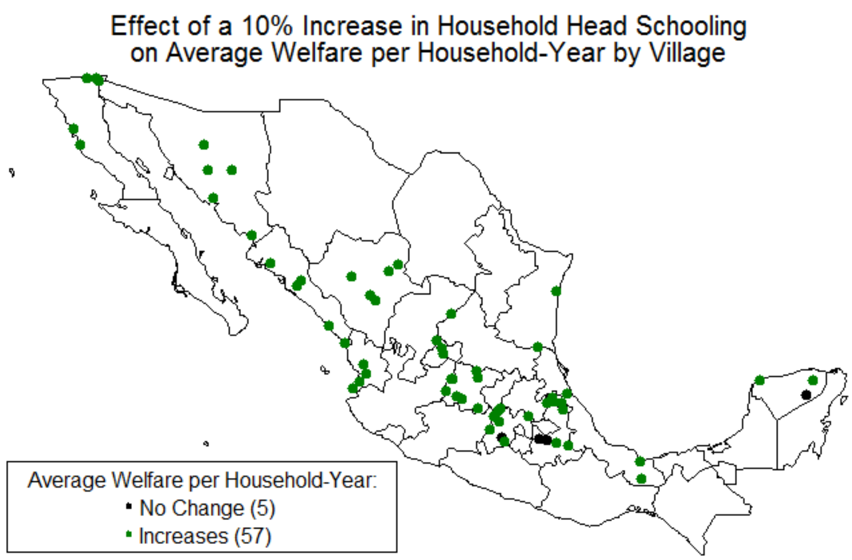
Table B.5: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Simulated change in household head schooling:	10% Increase		10% Decrease	
Distance to closest border crossing point (1000 km)	-0.0007	0.0082**	0.0006	0.0014
	(0.0035)	(0.0035)	(0.0030)	(0.0027)
Crime rate at closest border crossing point	0.0002	-0.0002	-0.0001	-0.0001
	(0.0003)	(0.0003)	(0.0003)	(0.0002)
Employment in primary sector	-0.0004	-0.0002	-0.0000	0.0000
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Employment in secondary sector	-0.0003	-0.0002	-0.0000	0.0002
	(0.0004)	(0.0004)	(0.0003)	(0.0003)
Number of males in household	-0.0057	-0.0025	0.0067	0.0041
	(0.0051)	(0.0051)	(0.0043)	(0.0039)
Household head age	0.0002	0.0008**	0.0002	-0.0000
	(0.0004)	(0.0004)	(0.0003)	(0.0003)
Household head schooling	0.0009	-0.0045*	-0.0030	-0.0012
	(0.0023)	(0.0023)	(0.0020)	(0.0018)
Number of household members	0.0006	-0.0028	-0.0060**	-0.0042
	(0.0034)	(0.0034)	(0.0029)	(0.0026)
Fraction of households with migration to US	0.0158	-0.0030	-0.0072	0.0056
	(0.0097)	(0.0097)	(0.0082)	(0.0074)
Fraction of households with migration within Mexico	0.0398***	-0.0021	0.0149	0.0123
	(0.0148)	(0.0148)	(0.0125)	(0.0112)
Household average schooling	-0.0010	0.0027	0.0022	0.0022
	(0.0025)	(0.0025)	(0.0021)	(0.0019)
Household land quality (1=good, 4=very bad)	0.0031	-0.0003	-0.0012	-0.0019
	(0.0036)	(0.0036)	(0.0031)	(0.0027)
Constant	-0.0031	0.0051	0.0147	0.0064
	(0.0303)	(0.0301)	(0.0256)	(0.0229)
p-value (Pr>F)	0.2510	0.1620	0.2400	0.7200
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



(b)

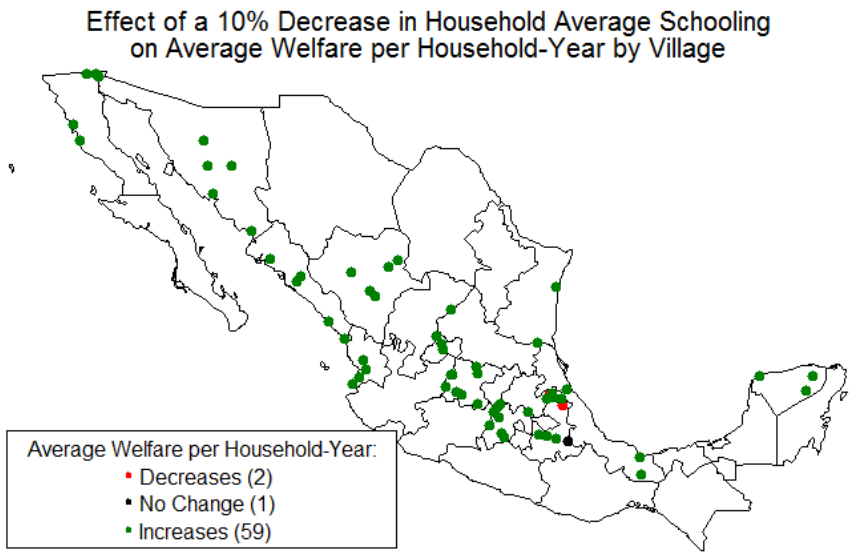
Figure B.6: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a 10% change in household head schooling.

Effects of Changes in Household Head Schooling

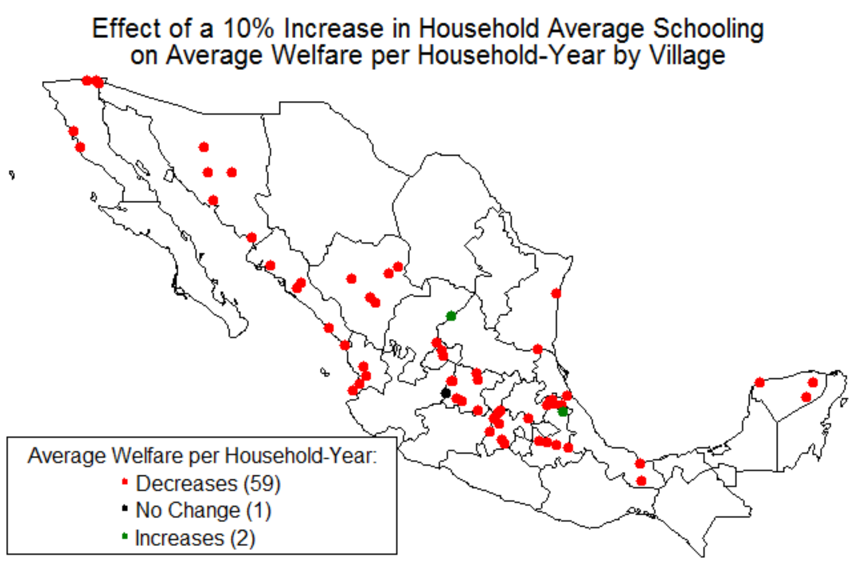
Table B.6: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:		
Simulated change in household head schooling:	10% Increase	10% Decrease
Distance to closest border crossing point (1000 km)	0.0001	-0.0004
	(0.0004)	(0.0003)
Crime rate at closest border crossing point	0.0140	-0.0196
	(0.0353)	(0.0286)
Employment in primary sector	0.0045	0.0202
	(0.0248)	(0.0201)
Employment in secondary sector	-0.0078	0.0288
	(0.0410)	(0.0332)
Number of males in household	0.2115	0.3310
	(0.5501)	(0.4455)
Household head age	0.0177	-0.0073
	(0.0392)	(0.0317)
Household head schooling	0.3173	-0.2266
	(0.2479)	(0.2008)
Number of household members	-0.1582	-0.2908
	(0.3626)	(0.2937)
Fraction of households with migration to US	-0.1332	0.8187
	(1.0408)	(0.8430)
Fraction of households with migration within Mexico	-0.4954	3.5098***
	(1.5875)	(1.2859)
Household average schooling	0.0407	-0.2804
	(0.2655)	(0.2150)
Household land quality (1=good, 4=very bad)	-0.3484	0.2945
	(0.3885)	(0.3146)
Constant	1.3123	0.9217
	(3.2375)	(2.6223)
p-value (Pr>F)	0.1620	0.0000
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants. Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



(b)

Figure B.7: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a 10% change in household average schooling.

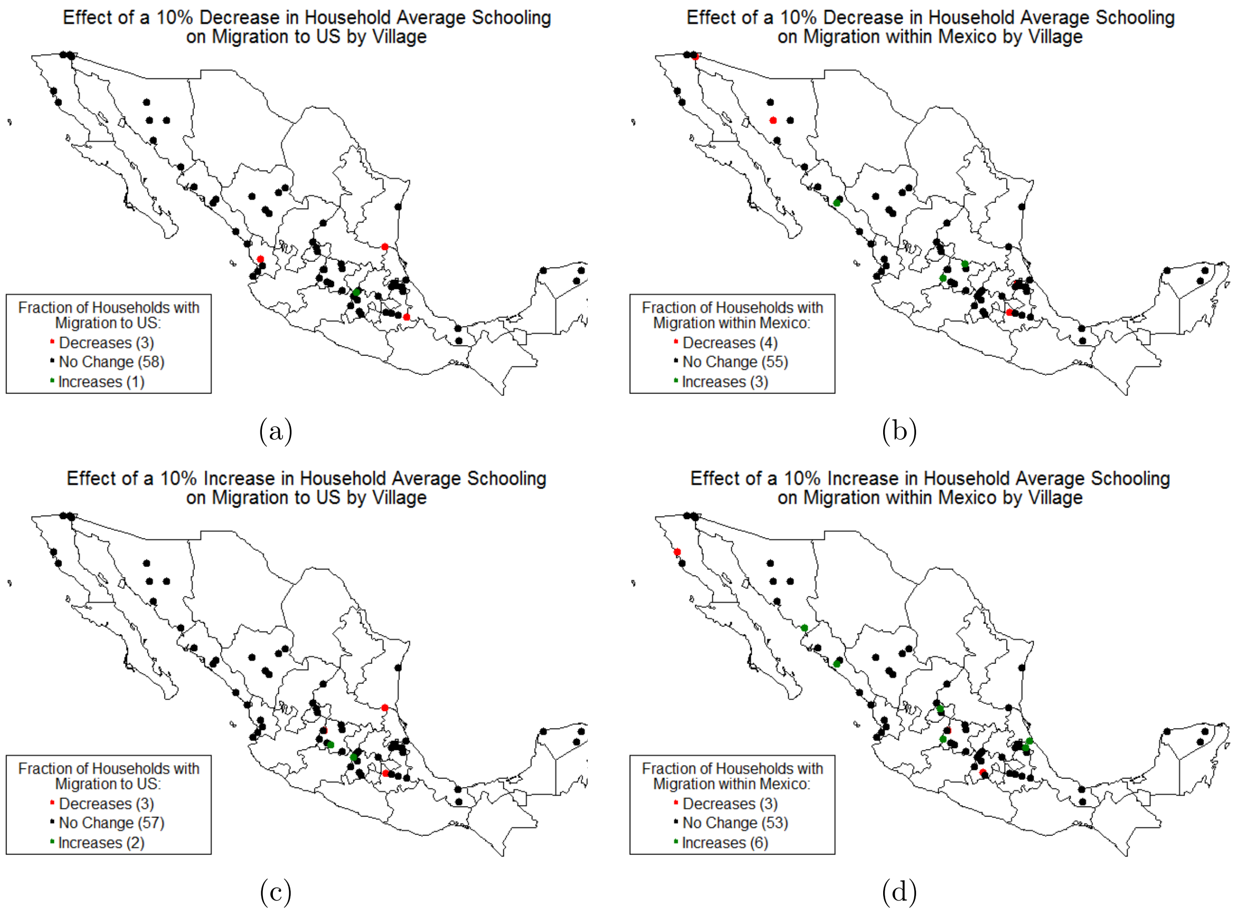


Figure B.8: Signs of changes in migration by village that are significant at a 10% level under a 10% change in household average schooling.

Table B.7: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Simulated change in household average schooling:	10% Increase		10% Decrease	
Distance to closest border crossing point (1000 km)	0.0018	-0.0009	0.0016	0.0027
	(0.0026)	(0.0028)	(0.0036)	(0.0032)
Crime rate at closest border crossing point	-0.0001	-0.0002	0.0001	-0.0000
	(0.0002)	(0.0003)	(0.0003)	(0.0003)
Employment in primary sector	-0.0001	0.0002	0.0001	-0.0001
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Employment in secondary sector	0.0001	-0.0000	0.0008*	-0.0003
	(0.0003)	(0.0003)	(0.0004)	(0.0003)
Number of males in household	0.0010	0.0056	0.0043	-0.0034
	(0.0038)	(0.0041)	(0.0053)	(0.0046)
Household head age	0.0004	0.0001	-0.0000	-0.0000
	(0.0003)	(0.0003)	(0.0004)	(0.0003)
Household head schooling	0.0007	0.0024	0.0000	-0.0016
	(0.0017)	(0.0018)	(0.0024)	(0.0021)
Number of household members	-0.0030	-0.0051*	-0.0022	0.0018
	(0.0025)	(0.0027)	(0.0035)	(0.0030)
Fraction of households with migration to US	0.0100	0.0186**	-0.0069	0.0061
	(0.0073)	(0.0077)	(0.0100)	(0.0087)
Fraction of households with migration within Mexico	0.0226**	0.0186	0.0093	-0.0143
	(0.0111)	(0.0117)	(0.0153)	(0.0133)
Household average schooling	-0.0001	-0.0024	0.0007	0.0020
	(0.0019)	(0.0020)	(0.0026)	(0.0022)
Household land quality (1=good, 4=very bad)	0.0023	0.0020	0.0020	-0.0006
	(0.0027)	(0.0029)	(0.0037)	(0.0032)
Constant	-0.0182	0.0008	-0.0355	0.0087
	(0.0226)	(0.0239)	(0.0311)	(0.0271)
p-value (Pr>F)	0.6060	0.3660	0.7970	0.8240
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

Table B.8: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:		
Simulated change in household average schooling:	10% Increase	10% Decrease
Distance to closest border crossing point (1000 km)	0.0001	0.0000
	(0.0003)	(0.0004)
Crime rate at closest border crossing point	-0.0286	0.0220
	(0.0307)	(0.0356)
Employment in primary sector	0.0596***	-0.0329
	(0.0216)	(0.0250)
Employment in secondary sector	0.0884**	-0.0543
	(0.0356)	(0.0413)
Number of males in household	0.3521	0.3513
	(0.4786)	(0.5552)
Household head age	0.0545	-0.0201
	(0.0341)	(0.0395)
Household head schooling	0.2486	-0.0521
	(0.2157)	(0.2502)
Number of household members	-0.3469	0.0326
	(0.3155)	(0.3660)
Fraction of households with migration to US	0.2671	0.3786
	(0.9056)	(1.0505)
Fraction of households with migration within Mexico	2.7680*	-1.7872
	(1.3814)	(1.6025)
Household average schooling	-0.1846	0.0792
	(0.2310)	(0.2680)
Household land quality (1=good, 4=very bad)	-0.1244	0.0435
	(0.3380)	(0.3921)
Constant	-6.8471**	4.0741
	(2.8172)	(3.2679)
p-value (Pr>F)	0.0839	0.6950
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

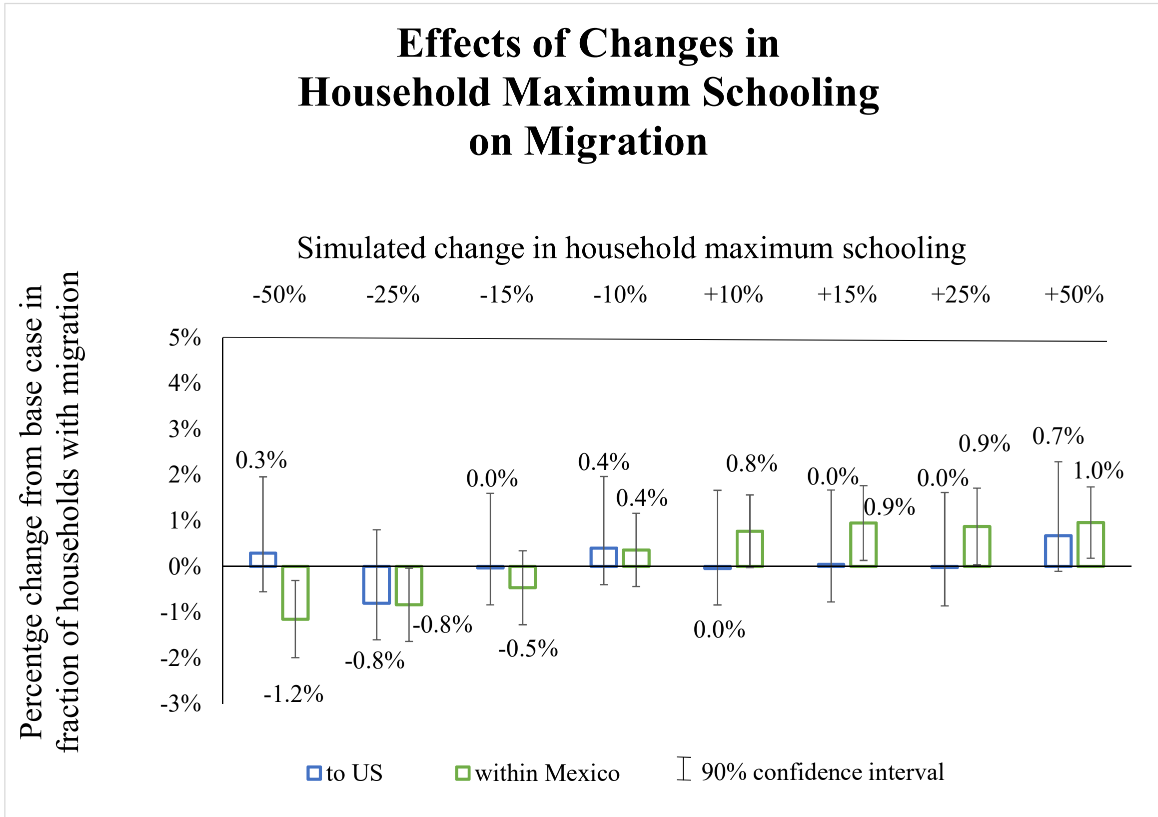


Figure B.9: Results of two-sample t-test of the effects of changes in household maximum schooling on the fraction of households with migration

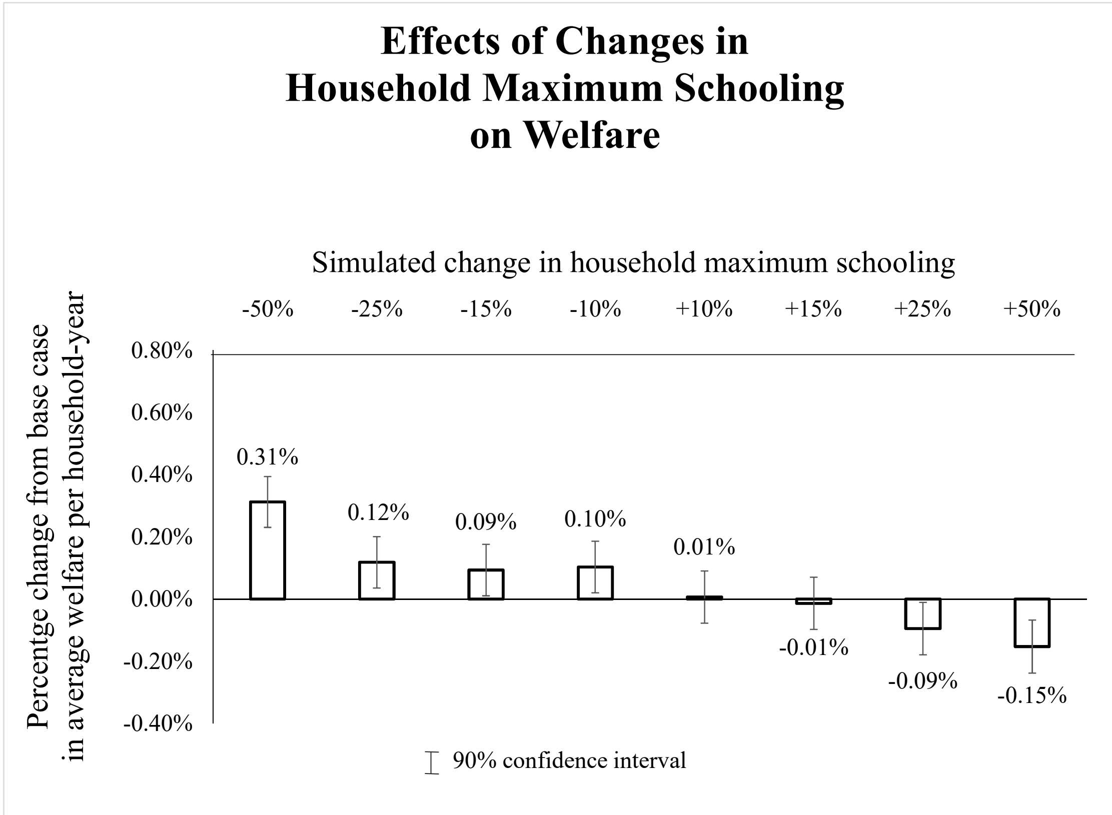
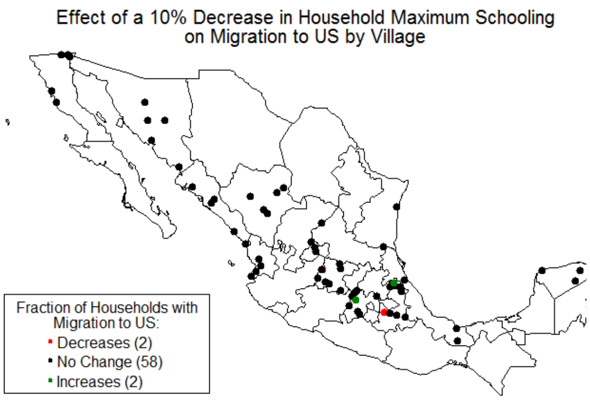
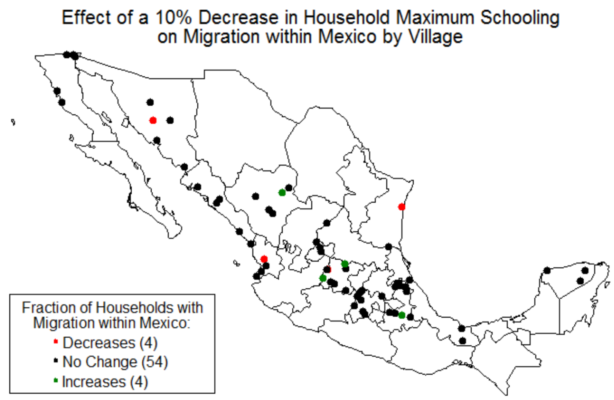


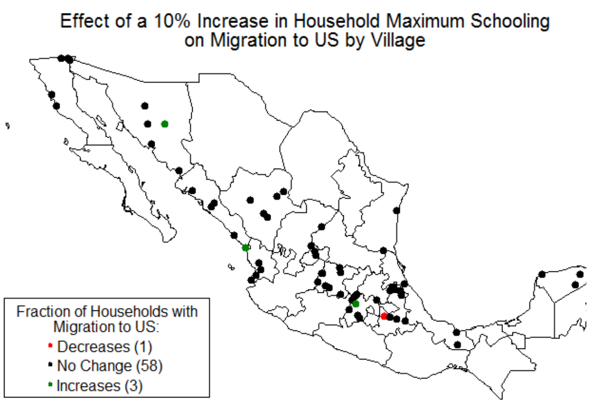
Figure B.10: Results of two-sample t-test of the effects of changes in household maximum schooling on average welfare per household-year



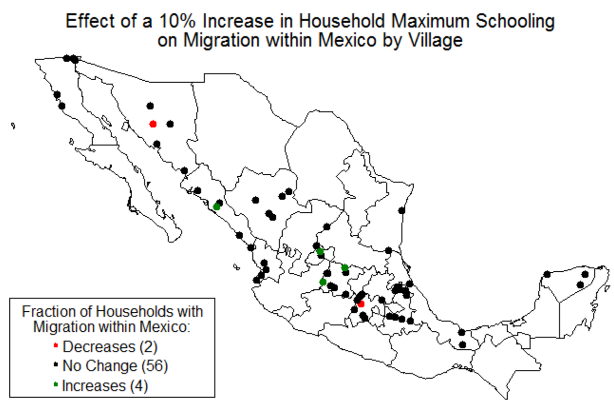
(a)



(b)



(c)



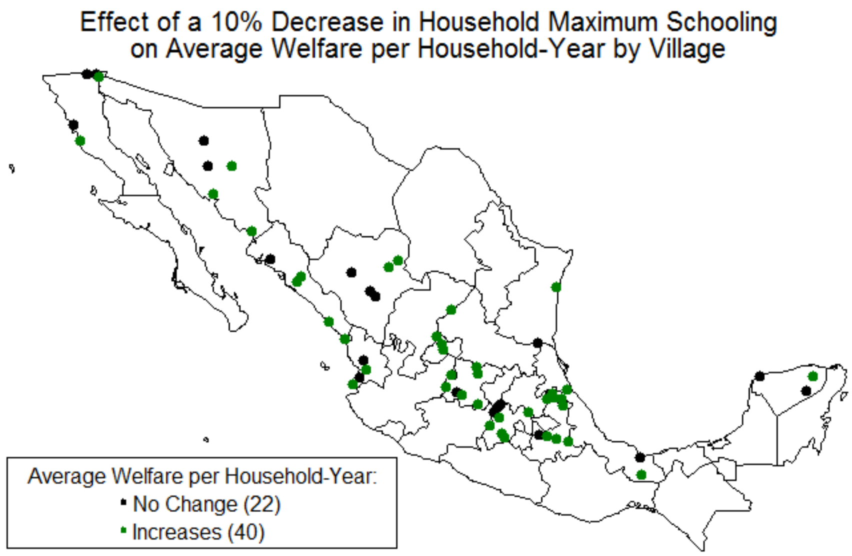
(d)

Figure B.11: Signs of changes in migration by village that are significant at a 10% level under a 10% change in household maximum schooling.

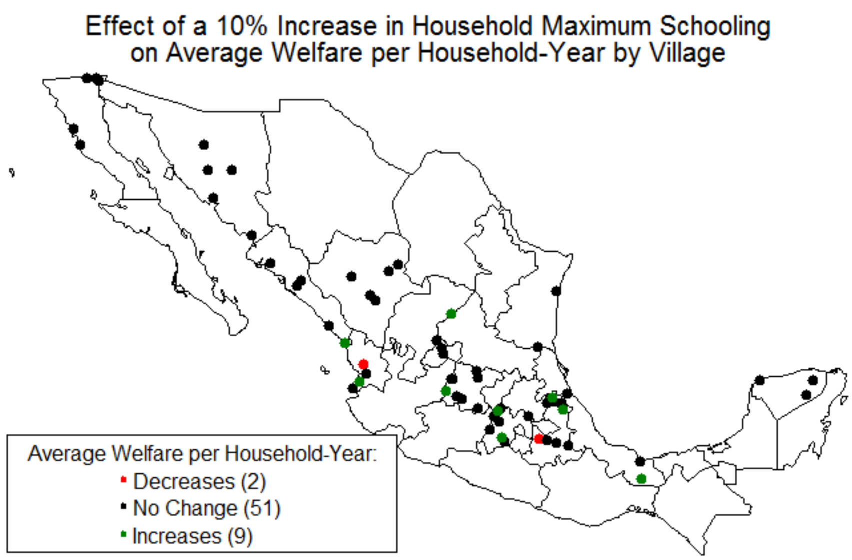
Table B.9: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Simulated change in household max schooling:	10% Increase		10% Decrease	
Distance to closest border crossing point (1000 km)	-0.0029	0.0024	-0.0016	0.0036
	(0.0031)	(0.0027)	(0.0026)	(0.0027)
Crime rate at closest border crossing point	0.0001	-0.0001	-0.0000	-0.0002
	(0.0003)	(0.0003)	(0.0002)	(0.0002)
Employment in primary sector	-0.0005**	0.0004**	-0.0002	0.0003*
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Employment in secondary sector	-0.0005	0.0001	-0.0001	0.0006**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Number of males in household	-0.0069	0.0046	-0.0050	0.0028
	(0.0045)	(0.0039)	(0.0038)	(0.0039)
Household head age	0.0004	-0.0001	0.0004	0.0002
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Household head schooling	0.0011	-0.0033*	0.0004	-0.0000
	(0.0020)	(0.0018)	(0.0017)	(0.0017)
Number of household members	0.0024	-0.0021	0.0000	-0.0027
	(0.0030)	(0.0026)	(0.0025)	(0.0025)
Fraction of households with migration to US	0.0069	0.0009	0.0086	0.0033
	(0.0086)	(0.0074)	(0.0072)	(0.0073)
Fraction of households with migration within Mexico	0.0187	-0.0217*	0.0269**	-0.0051
	(0.0131)	(0.0114)	(0.0110)	(0.0111)
Household average schooling	-0.0012	0.0036*	-0.0010	-0.0003
	(0.0022)	(0.0019)	(0.0018)	(0.0019)
Household land quality (1=good, 4=very bad)	-0.0004	-0.0010	-0.0001	-0.0005
	(0.0032)	(0.0028)	(0.0027)	(0.0027)
Constant	0.0115	-0.0053	0.0067	-0.0171
	(0.0267)	(0.0232)	(0.0225)	(0.0227)
p-value (Pr>F)	0.2710	0.0609	0.1430	0.6210
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



(b)

Figure B.12: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a 10% change in household maximum schooling.

Effects of Changes in Household Maximum Schooling

Table B.10: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:		
Simulated change in household max schooling:	10% Increase	10% Decrease
Distance to closest border crossing point (1000 km)	-0.0000	-0.0002
	(0.0002)	(0.0003)
Crime rate at closest border crossing point	-0.0097	-0.0219
	(0.0207)	(0.0286)
Employment in primary sector	0.0001	0.0317
	(0.0146)	(0.0202)
Employment in secondary sector	-0.0146	-0.0131
	(0.0240)	(0.0333)
Number of males in household	0.0608	0.1577
	(0.3226)	(0.4467)
Household head age	-0.0054	0.0374
	(0.0230)	(0.0318)
Household head schooling	0.0223	-0.1200
	(0.1454)	(0.2013)
Number of household members	-0.0334	0.1065
	(0.2126)	(0.2945)
Fraction of households with migration to US	0.1105	0.0888
	(0.6103)	(0.8452)
Fraction of households with migration within Mexico	-0.6218	-1.4331
	(0.9310)	(1.2893)
Household average schooling	-0.0959	-0.1469
	(0.1557)	(0.2156)
Household land quality (1=good, 4=very bad)	-0.5970**	-0.3226
	(0.2278)	(0.3155)
Constant	3.6366*	1.4631
	(1.8985)	(2.6293)
p-value (Pr>F)	0.3340	0.0109
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

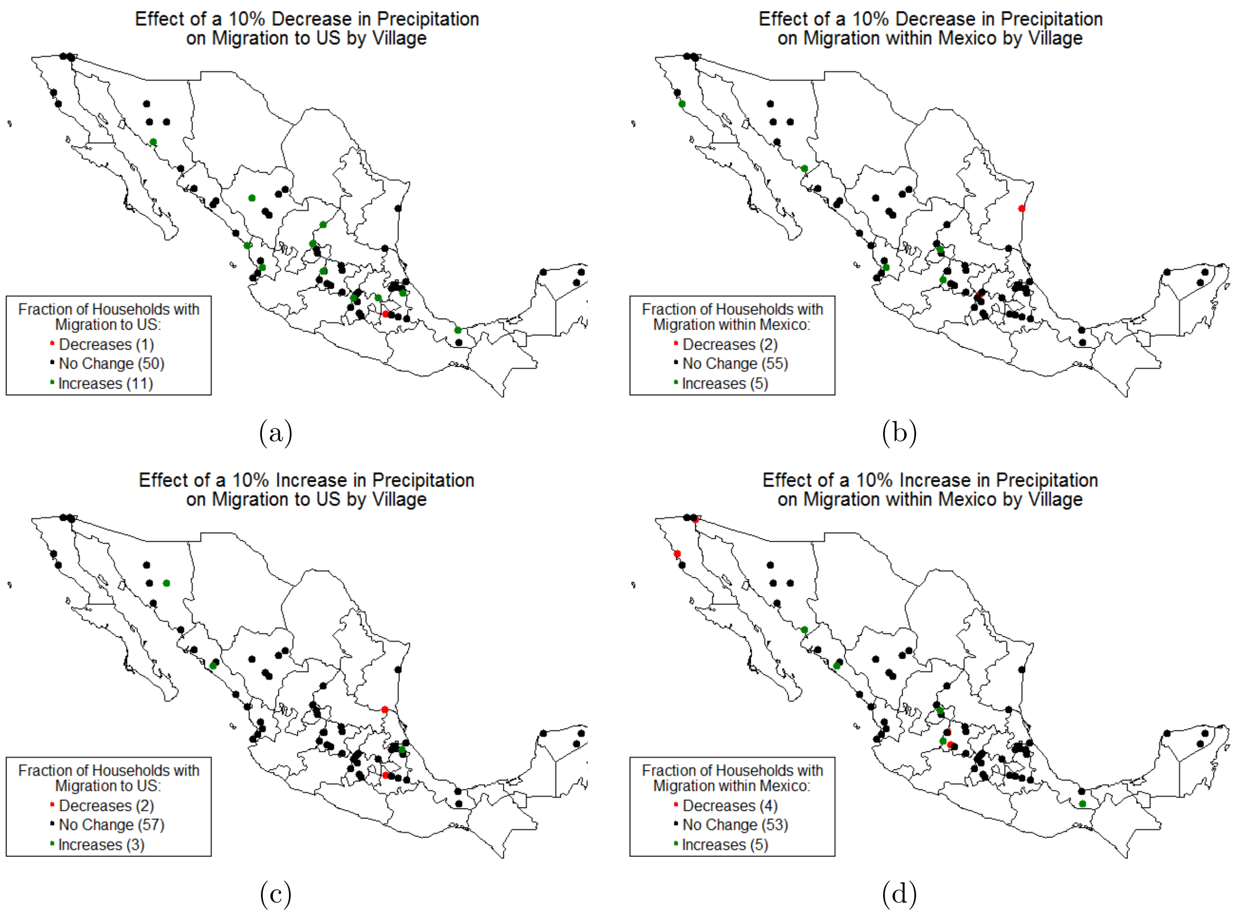
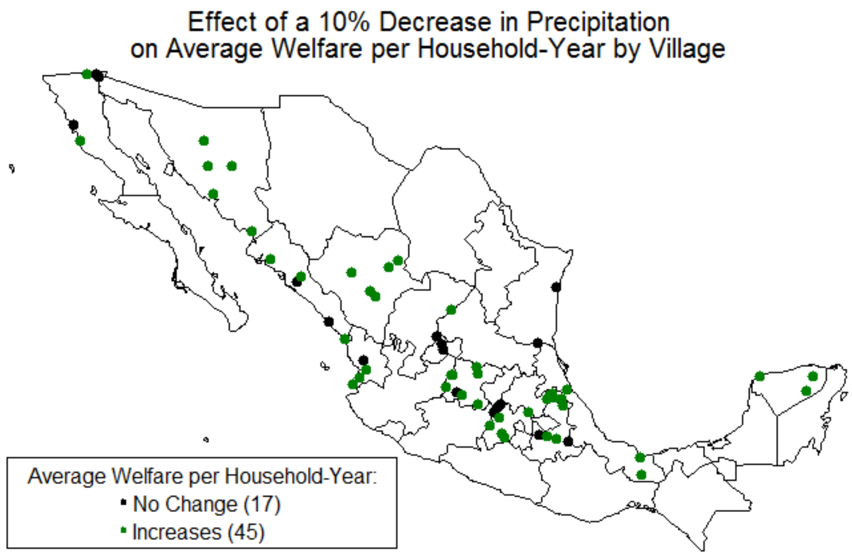


Figure B.13: Signs of changes in migration by village that are significant at a 10% level under a 10% change in precipitation.

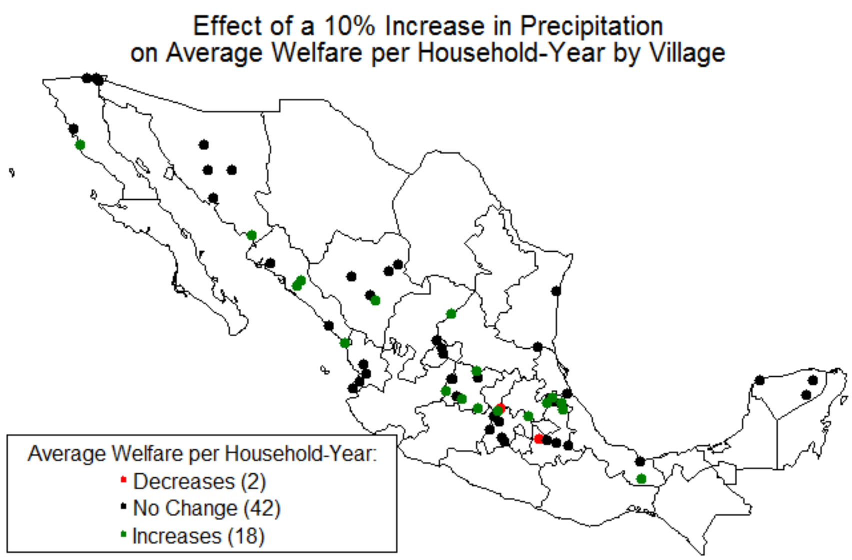
Table B.11: Determinants of significant changes at the village level in the fraction of households with migration

Dependent variable is the value of significant changes in the fraction of households with migration to/within:	*US*	*Mexico*	*US*	*Mexico*
Simulated change in precipitation:	10% Increase		10% Decrease	
Distance to closest border crossing point (1000 km)	-0.0000	0.0022	-0.0013	0.0008
	(0.0024)	(0.0045)	(0.0046)	(0.0034)
Crime rate at closest border crossing point	0.0001	-0.0001	-0.0000	-0.0002
	(0.0002)	(0.0004)	(0.0004)	(0.0003)
Employment in primary sector	0.0001	-0.0000	0.0002	0.0002
	(0.0002)	(0.0003)	(0.0003)	(0.0002)
Employment in secondary sector	-0.0001	-0.0009*	0.0003	-0.0000
	(0.0003)	(0.0005)	(0.0005)	(0.0004)
Number of males in household	-0.0040	0.0111*	0.0059	-0.0008
	(0.0034)	(0.0066)	(0.0066)	(0.0049)
Household head age	0.0003	-0.0001	0.0001	0.0002
	(0.0002)	(0.0005)	(0.0005)	(0.0003)
Household head schooling	-0.0024	0.0023	0.0030	0.0004
	(0.0016)	(0.0030)	(0.0030)	(0.0022)
Number of household members	0.0010	-0.0060	-0.0047	-0.0002
	(0.0023)	(0.0043)	(0.0044)	(0.0032)
Fraction of households with migration to US	-0.0108	0.0217*	0.0058	0.0085
	(0.0065)	(0.0124)	(0.0126)	(0.0093)
Fraction of households with migration within Mexico	0.0008	-0.0078	0.0257	-0.0157
	(0.0099)	(0.0189)	(0.0192)	(0.0142)
Household average schooling	0.0030*	-0.0044	-0.0022	-0.0004
	(0.0017)	(0.0032)	(0.0032)	(0.0024)
Household land quality (1=good, 4=very bad)	0.0014	-0.0068	-0.0013	0.0012
	(0.0024)	(0.0046)	(0.0047)	(0.0035)
Constant	-0.0215	0.0705*	-0.0032	-0.0073
	(0.0203)	(0.0386)	(0.0391)	(0.0289)
p-value (Pr>F)	0.3010	0.1190	0.9300	0.7150
# observations	62	62	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.



(a)



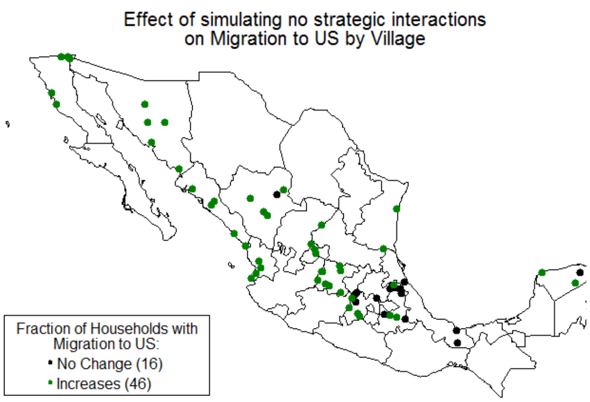
(b)

Figure B.14: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a 10% change in precipitation.

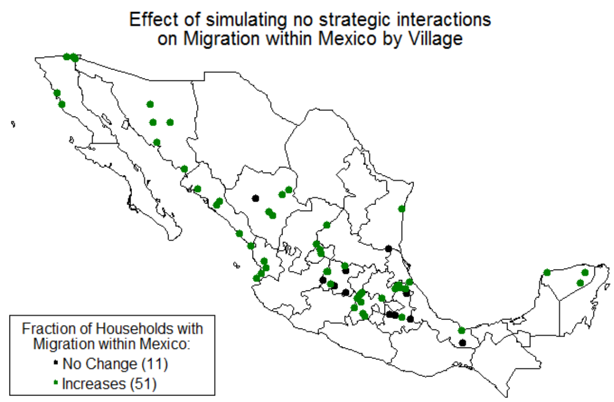
Table B.12: Determinants of significant changes at the village level in the average welfare per household-year

Dependent variable is the value of significant changes in the average welfare per household-year:		
Simulated change in precipitation:	10% Increase	10% Decrease
Distance to closest border crossing point (1000 km)	-0.0001	0.0007*
	(0.0003)	(0.0004)
Crime rate at closest border crossing point	-0.0081	-0.0152
	(0.0271)	(0.0377)
Employment in primary sector	0.0028	0.0504*
	(0.0190)	(0.0265)
Employment in secondary sector	-0.0163	0.0817*
	(0.0314)	(0.0438)
Number of males in household	0.3220	0.0577
	(0.4222)	(0.5879)
Household head age	0.0250	0.0811*
	(0.0301)	(0.0419)
Household head schooling	-0.0462	0.1166
	(0.1902)	(0.2649)
Number of household members	-0.1570	-0.4131
	(0.2783)	(0.3876)
Fraction of households with migration to US	0.9024	1.4540
	(0.7987)	(1.1124)
Fraction of households with migration within Mexico	0.4676	2.2693
	(1.2184)	(1.6968)
Household average schooling	-0.1425	-0.2854
	(0.2037)	(0.2837)
Household land quality (1=good, 4=very bad)	-0.0554	0.1127
	(0.2981)	(0.4152)
Constant	1.0168	-3.2178
	(2.4847)	(3.4604)
p-value (Pr>F)	0.5210	0.1450
# observations	62	62

Notes: Standard errors in parentheses. Crime rates are in homicides per 10,000 inhabitants.
Significance codes: * p<0.10, ** p<0.05, *** p<0.01.

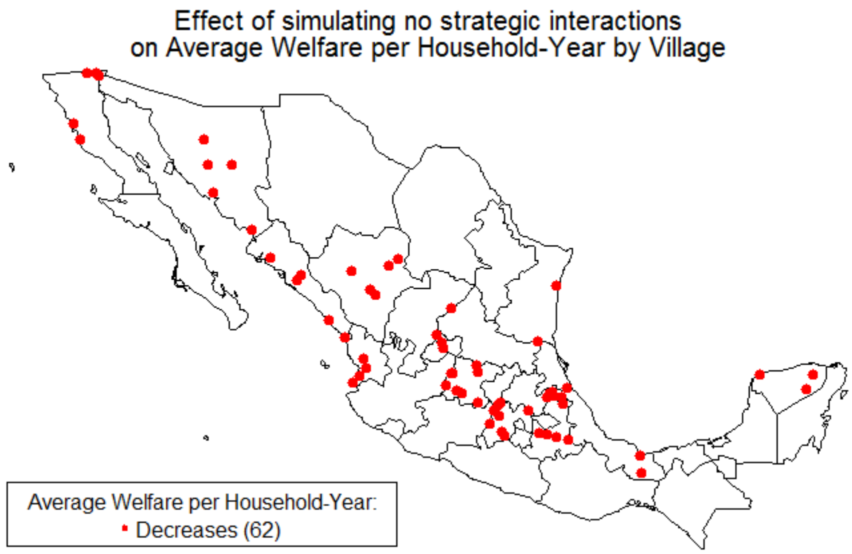


(a)



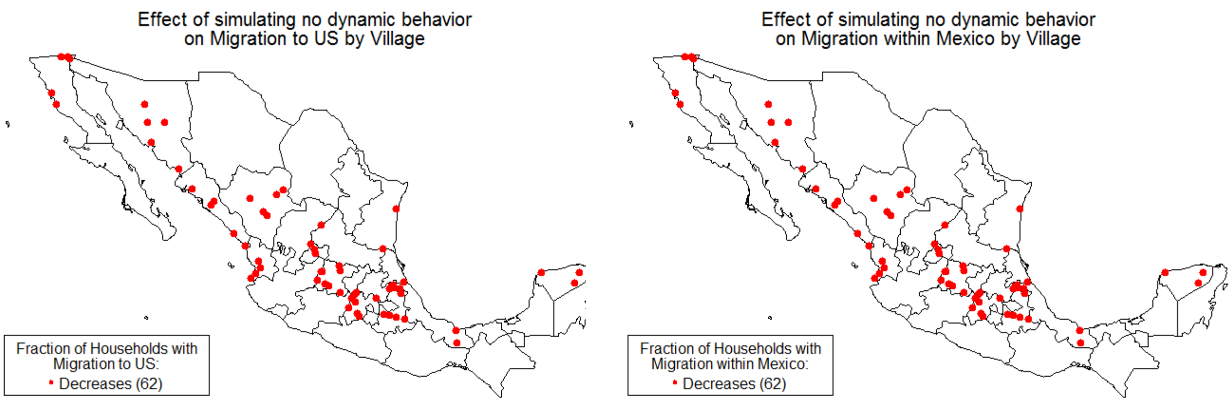
(b)

Figure B.15: Signs of changes in migration by village that are significant at a 10% level when simulating no strategic interactions.



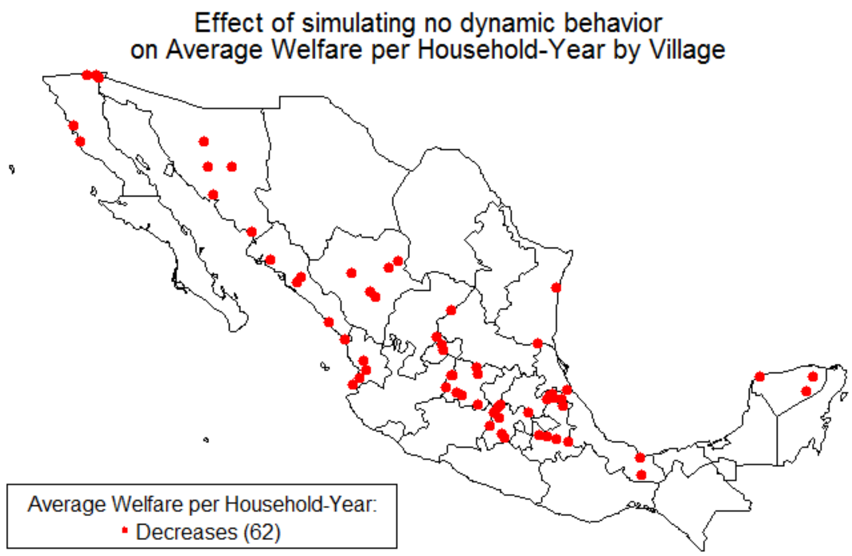
(a)

Figure B.16: Signs of changes in average welfare per household-year by village that are significant at a 10% level when simulating no strategic interactions.



(a) (b)

Figure B.17: Signs of changes in migration by village that are significant at a 10% level when simulating no strategic interactions.



(a)

Figure B.18: Signs of changes in average welfare per household-year by village that are significant at a 10% level when simulating no dynamic behavior.

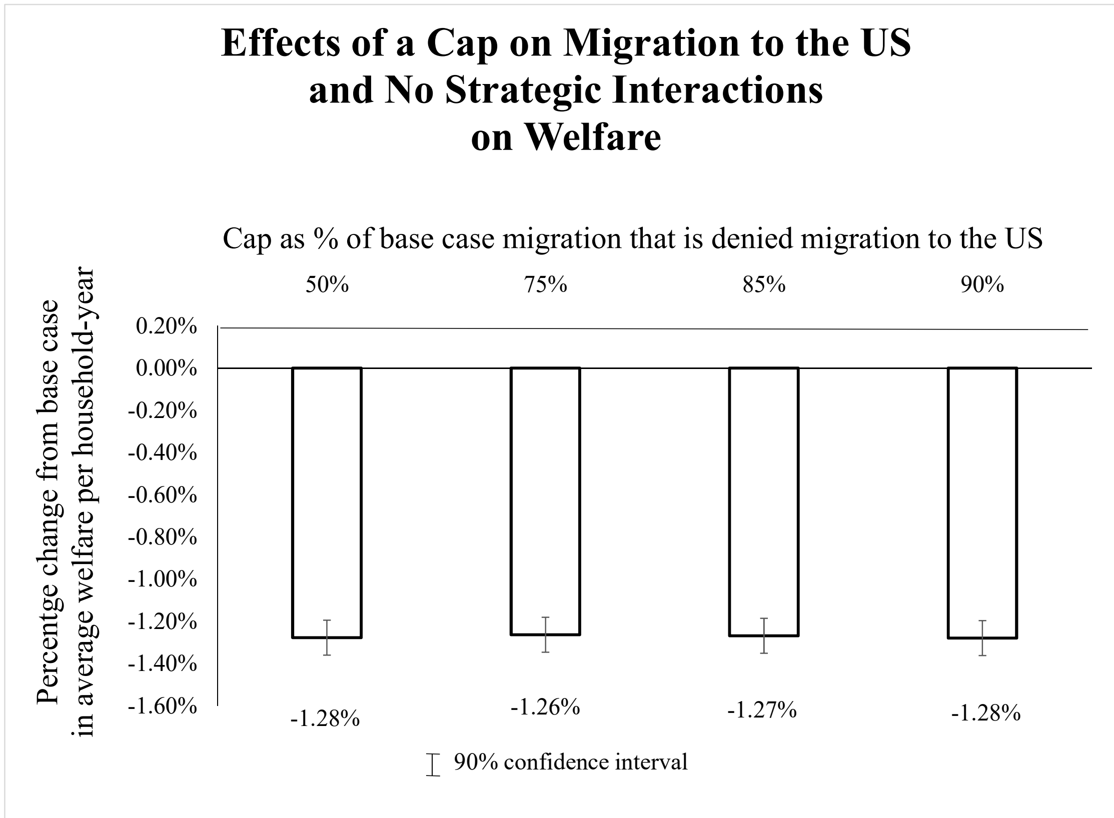
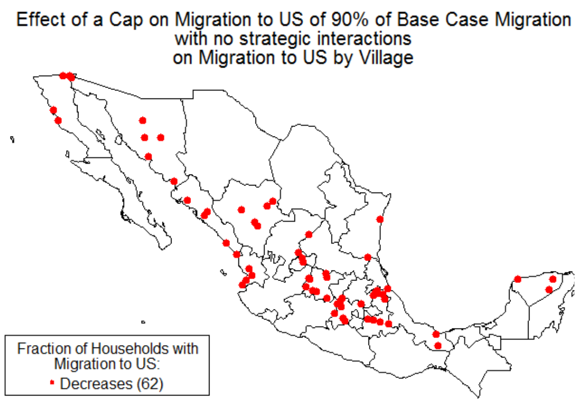
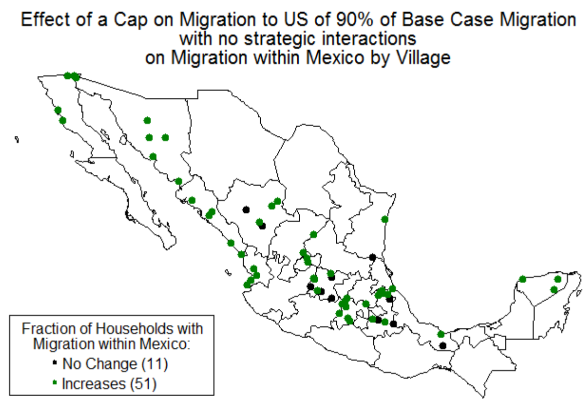


Figure B.19: Results of two-sample t-test of the effects of a cap on migration to US with no strategic interactions on average welfare per household-year

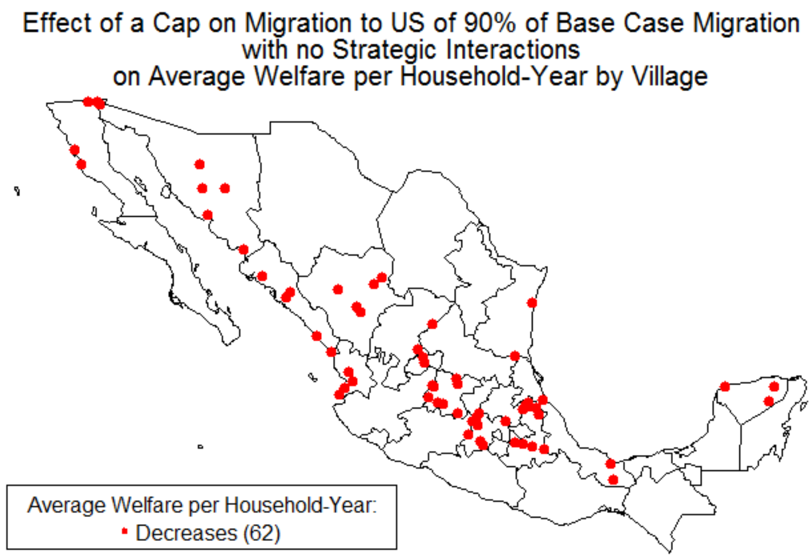


(a)



(b)

Figure B.20: Signs of changes in migration by village that are significant at a 10% level under a cap of 90% of base case migration and no strategic interactions.



(a)

Figure B.21: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a cap of 90% of base case migration and no strategic interactions.

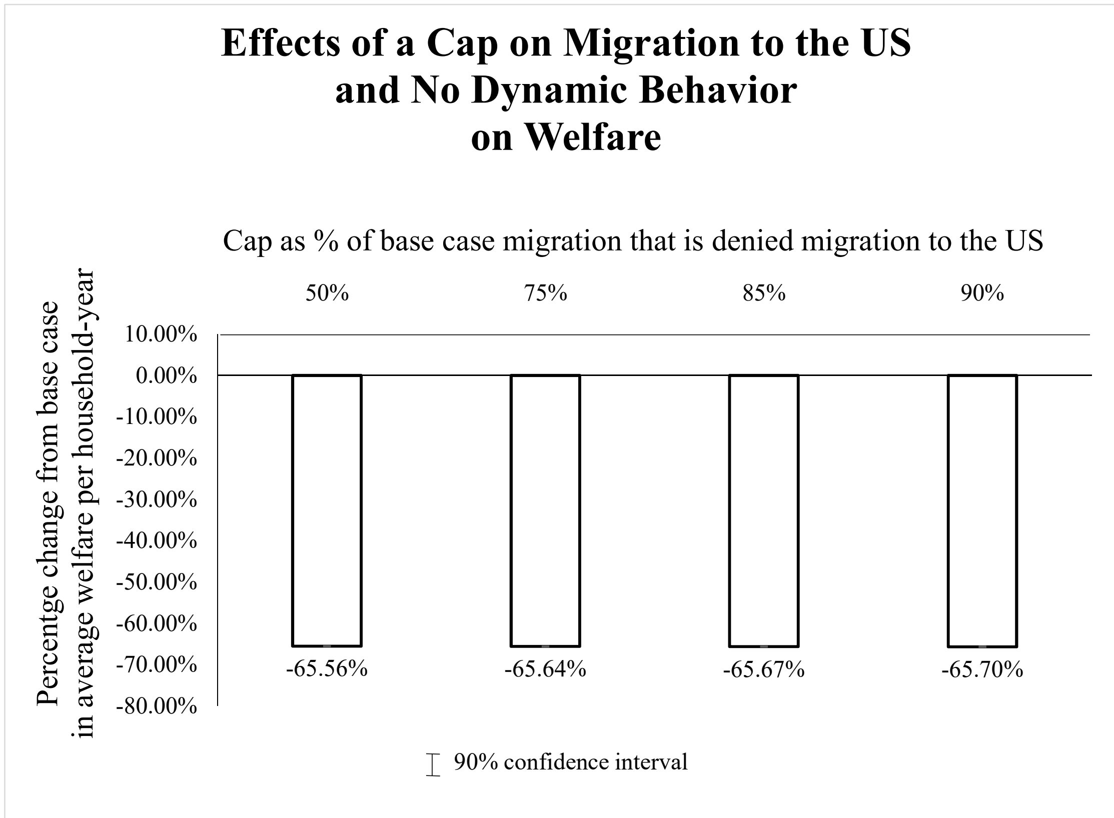
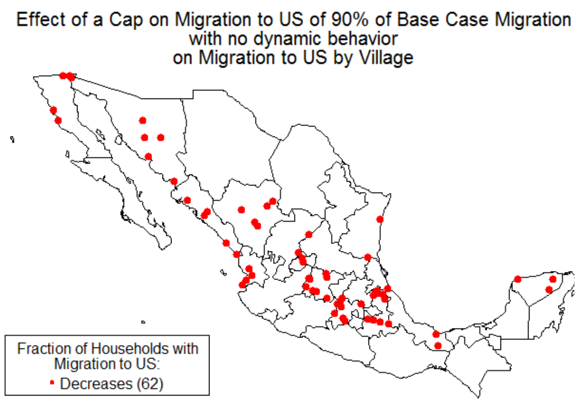
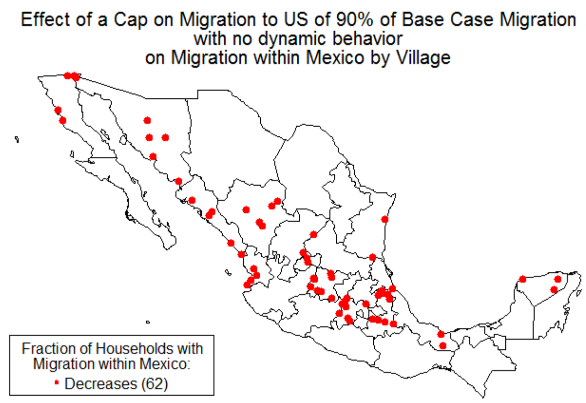


Figure B.22: Results of two-sample t-test of the effects of a cap on migration to US with no dynamic behavior on average welfare per household-year

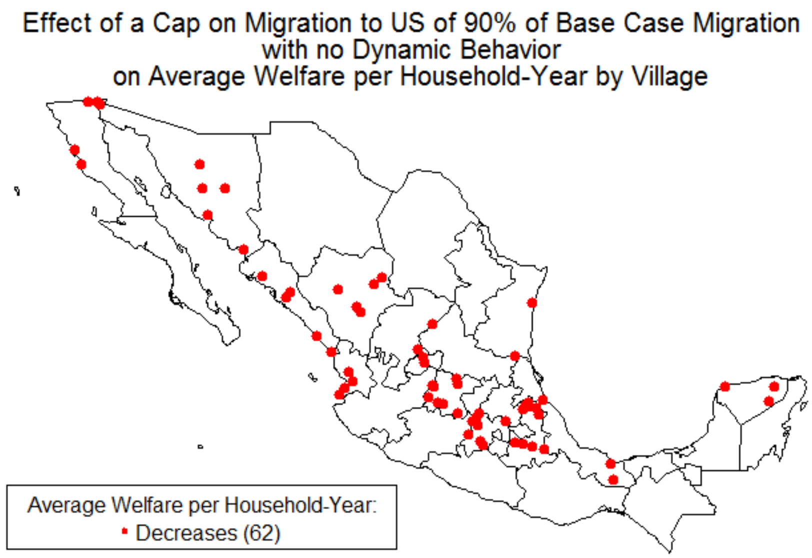


(a)



(b)

Figure B.23: Signs of changes in migration by village that are significant at a 10% level under a cap of 90% of base case migration and no dynamic behavior.



(a)

Figure B.24: Signs of changes in average welfare per household-year by village that are significant at a 10% level under a cap of 90% of base case migration and no dynamic behavior.