MIGRATION, SEX RATIOS AND VIOLENT CRIME: EVIDENCE FROM MEXICO'S MUNICIPALITIES*

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Abstract

A rather unexplored consequence of Mexican net international migration, strongly dominated by the emigration of working age males to the U.S., is the creation of significant community level sex ratio imbalances in Mexico. We use a municipal level data set to explore empirically the effect of male-to-female ratios on homicides rates. OLS estimates suggest that for the average Mexican municipality, a decline in one male per each hundred females results in a decline of about 0.4-0.6 homicides per 100,000 inhabitants. This incapacitation effect persists after controlling for socio-economic characteristics and municipal level fixed effects. In order to establish causality we use the occurrence of natural disasters at the municipal level as an exogenous migration push instrument. IV estimates suggest that OLS estimates may be biased downward and that there is indeed a causal crime reducing effect of migration operating through sex ratios.

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1 Introduction

The United States and Mexico share the tenth longest border in the world and also one of the most dissimilar economically. Mexico's per capita income as a fraction of that of the U.S. has oscillated from being about a third in the early 1900s to about a fourth in 2005.[1] Historically, Mexican migration has responded to incentives triggered by such income differential and has been particularly driven by flows of working age males being pulled by the demand for manual labor in the U.S.

Mexican migration to the U.S. is sufficiently large and biased towards males as to create substantial community level sex imbalances.[2] In fact, in the 15 to 64 age bracket Mexico had a lower male-to-female ratio (surplus of females) than any region in the world in 2000.[3] In the 15 to 40 age category, almost half of Mexico's 2,445 municipalities have a sex ratio below 90 and only five percent of them over 105. As we will show in more detail in section 3, this is primarily driven by migration to the U.S. rather than sex ratios at birth, selective abortion (infant mortality) or differential mortality.

This inadvertent consequence of Mexico's international migration patterns has been rather under-researched. In this paper, we use a municipal level data set to uncover the effect that sex ratios may have on homicide rates both directly and through the impact of Mexican migration to the U.S. Homicide rates are of interest in and of themselves, but they are also highly correlated (0.95) with the sum of all violent crimes, including

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[1] Based on information in Coatsworth (1998) and IMF's International Financial Statistics (2005).
[2] According to Coale (1991) the "natural" sex-ratio in a stationary population would range from 97.9 and 100.3. The common wisdom on the "natural" overall sex-ratio (across all ages) is that it tends to 100 reflecting the higher mortality of females at childbearing ages and male's shorter life span.
[3] According to the United Nations' Demographic Yearbook (2003) the sex ratios in this age category worldwide and for Mexico were 102 and 89, respectively.

kidnapping and assaults, and can thus be taken as a proxy for general violence. Understanding the determinants of violent crime is of interest to economists not only because it may affect the prospects of investment and economic development at the macro level but also because it affects human behavior directly.

Our paper contributes to two strands in the literature. First, by exploring the socioeconomic and demographic correlates of homicide rates it contributes to the empirical literature on crime, particularly in the context of a developing country where this type of studies are more scarce. Second, and perhaps more importantly, the implications of Mexican emigration flows to the U.S. on the *Mexican* side of the border have just recently been explored. Furthermore, most existing studies have tended to focus on migration's effect on the domestic labor supply and the poverty alleviation consequences of increasing monetary remittances from Mexican workers. Very rarely have these studies focused on social or other dimensions of this phenomenon.[4]

The motivation for exploring the link between sex ratios and homicides is given in part by "testosterone-driven" theories of violent behavior that imply that Mexico's emigration of young males to the U.S. provide a significant escape valve to violent crime. In section 4, we show that for the average Mexican municipality in 2000 there existed a positive and significant empirical correlation between sex ratios and homicide rates. This effect is robust to the introduction of various socio-economic controls and state level fixed effects. We find that this effect is no longer statistically different from zero when using the homicide rate per 100,000 *young males* instead of the overall rate. A significant effect when using per *male* rates would suggest the existence of an *interaction*

[4] Hanson (2005) studies the effects of migration on the domestic labor supply and Unger (2005) and Esquivel and Pineda-Huerta (2006) study how increasing remittances from Mexican workers residing in the U.S. have helped to alleviate poverty in Mexico.

component to the sex ratio effect, where the surplus of females could be having a taming effect on male's violent behavior either through marriage or reduced social stress associated with finding a mate. Since this is not the case, we call the result found an *incapacitation* effect; one where a decline in the relative number of males reduces homicides rates simply because males are statistically more likely than females to commit, or be the victims of, homicides. In all, OLS estimates suggest that for the average Mexican municipality, a decline in one male per each hundred females results in a decline of about 0.4 homicides per 100,000 inhabitants.

One potential problem with this result is that of endogeneity. If municipal level sex ratios are largely determined by migration and underlying local economic conditions affect both the extent of migration and homicide rates then OLS estimates may be biased. In section 5, we use a two stage instrumental variable approach in order to find the *causal* effect of sex ratios on homicide rates. In our preferred specification we use the incidence of natural disasters at the municipal level as an exogenous migration *push* instrument. Indeed, results suggest that there is a significant crime reducing effect of sex ratios on homicide rates operating through the migration instrument. The magnitude on the IV estimates suggests that OLS estimates are biased downward.

Finally, in section 6, we use a municipal panel data set (1990-2005) to corroborate our results. The coefficient on sex ratios using municipality specific fixed effects is positive and significant. Again, this effect is no longer there once similar regressions are used on the rate of homicides per *males*. In terms of magnitude, the coefficient of interest is remarkably close to the one obtained in the 2000 cross section, in this case, a decline in one male per each hundred females results in a decline of about 0.6 homicides per

100,000 inhabitants. In a panel version of the IV procedure used in section 5, although the first stage is not as strong as before, the coefficient of interest is large and significant suggesting again a downward bias in the OLS estimates.

Section 7 concludes that based on the evidence from the empirical exercises presented here, indeed, migration to the U.S. constitutes an "escape valve" to homicides and, more generally violent crime, via the impact it has on the demographic composition at the community level in Mexico.

2 The Mechanics of Sex Ratios and Homicides

Over the last two decades, the economics empirical literature on crime has focused on studying the incidence of deterrence and economic factors on crime but relatively little attention has been given to sex ratios.[5] Furthermore, most studies have been carried out almost exclusively in the context of industrialized economies or cross country studies.[6] The role of sex ratios on violent crimes in the context of developing countries has been the subject of studies primarily for India. These studies find a significant positive relationship between the male-to-female ratio at the district level and murder rates, in other words, the excess supply of man is positively correlated with violent crimes.

There are several causal interpretations of this finding. On the one hand Oldenberg (1998) suggests that causation runs from violence to sex ratios; he argues that the incidence of homicides leads to stronger preferences for sons who are deemed to be

[5] For systematic reviews of the empirical literature on crime see, Cameron (1998), Land, McCall and Cohen (1990) and Kposowa, Breault and Harrison (1995). In this context, it is important to note the work by Steven Levitt and coauthors that, by finding exogenous sources of variation determining the level of policing but unrelated to the level of crime, solved a prevalent identification problem in this literature.

[6] Fajnzylber, Lederman and Loayza (1998, 2000, 2002a, 2002b) explore the empirical determinants of homicide and robbery rates within a sample of developed and developing countries. The authors find that social capital reduces the incidence of violent crime (2000) and that crime is positively related to income inequality, tends to be countercyclical and shows a significant amount of inertia (2002a).

better equipped to deal with an already violent environment. On the other hand, Drezé and Khera (2000) seem to prefer the notion that women are biologically less inclined to violent behavior and that the larger presence of women (as captured by the sex ratio) leads to lower homicide rates.

Although the notion of a direct effect of sex imbalances on homicide rates has some intuitive appeal, it has never been formalized. As Drezè and Khera (2000) argue, possible rationales includes male competition for females, social stress associated with shortage of females and the taming effects of marriage or female companionship on males. However, part of the problem in formalizing these ideas is that we do not know how and why a shortage of females would translate into more homicides, many of which are unrelated to sexual matters.

In other social sciences, the empirical crime literature tends to agree with the notion of "testosterone-driven" theories of crime.[7] Recent work by Den Boer and Hudson (2004) links Asia's increasingly high sex ratios (excess supply of men) with the prospects of sectarian and ethnic violence. The authors refer to males with low probability of having their family tree bear fruit given the shortage of females as "bare branches." The argument on how "bare branches" may fuel violence is based on the fact that young unmarried males are more likely to incur in socially disruptive behavior.[8]

Given that Mexican migration to the U.S. is primarily composed of young males, we would expect that the indirect effect of migration flows via changes in the sex ratios

[7] For a systematic review of the literature in sociology see Messner and Sampson (1991).
[8] The type of disruptive behavior that they describe is directly relevant to the incidence of homicides. For instance they argue that: "An unmarried man between 24 and 35 years of age is about three times as likely to murder another male as is a married man the same age" (p.14). Den Boer and Hudson (2002) argue that: "It is when young do not marry that socially disruptive behavior is intensified" (p.13-14) and "Married men are less likely than single men of the same age to kill an unrelated male" (p.14).

would actually reduce crime in Mexico either through the change in the demographic composition (*incapacitation*) or through the reduction in violent behavior resulting from social *interaction* in the presence of excess supply of females. One could also rationalize crime reduction using a simple version of Becker's (1968) canonical model of crime.

In Becker's model, for the fraction of the population incurring in a crime to decline one need either higher returns for legal activities or a combination of lower returns to illegal activities and improved enforcement and higher penalties. Mathematically, the marginal criminal follows the following rule:

[1] $$B - pC > W + w,$$

where B represents the pecuniary and non-pecuniary benefits of criminal activities, p is the probability of being subject to a cost C of punishment, W represents the returns from legal activity and w simply adds heterogeneity to avoid trivial solutions.

Consider first the right hand side of inequality [1]. If migration to the U.S. results in a labor supply shortage then it is reasonable to expect an increase in wages in sending municipalities and thus, according to Becker's model and holding other parameters constant, the proportion of the population incurring in illegal behavior should decline.[9]

Turning to the left side hand side of equation [1], the population involved in criminal activity will increase if B, the benefits of criminal activities, declines or if pC, the expected punishment cost, increases. Since it is not clear how selective migration may affect policing and enforcement efforts we speculate how returns on crime may be

[9] In fact, Hanson (2005) shows that, over the 1990s, average hourly earnings in high migration states in Mexico rose over low migration states by 6-9%. Therefore, high migration states may benefit from two crime reducing effects, one coming from wages and another from the change in demographic composition.

affected by lower sex ratios.[10] Originally, the benefits of criminal activities, B, are meant to capture all the psychic and material benefits of crime. Consider refining the definition of the benefits from crime as:

[2] $$B \equiv (1 - p)\, l - c,$$

where p is as before, l can be interpreted as the psychological or material prize from crime, and c is the cost of perpetrating the crime. Re-writing condition [1] we have that the marginal criminal in this model has a net benefit function:

[3] $$NB = (1 - p)\, l - c - pC - (W + w).$$

Furthermore, suppose there is a moral threshold m such that individual i commit a crime only if $NB \geq m$.

Given this simple extension of the model there are a couple of channels through which a biased sex ratio may operate. If, as suggested by Den Boer and Hudson (2002) violent crime increases with the frequency of interaction amongst males and from the competition derived from the shortage of females, then l may be lower when there is an excess supply of females. Furthermore, the threshold m may be lower where there is more social interaction amongst unmarried males.[11]

3 Sex Ratios and Migration in Mexico

The scatter plots shown in Figure A1 in the appendix motivate our inquiry into the role that migration to the U.S. may play on homicide rates *through* its effect on sex ratios. We

[10] Admittedly, it is possible that there is a systematic relation between law enforcement effort, development and migration. However, we will make the case later that this interrelation in Mexico is weak.

[11] Den Boer and Hudson (2002) suggest that the sole interaction between testosterone driven young males may, by itself, lead to higher probability of conflict: "Men who congregate with men tend to be more sensitive about status and reputation; even if they are not intoxicated with drink or enraged by insult, they instinctively test one another, probing for signs of weakness" (p.15).

use data from CONAPO on migration rates at the state level and a comprehensive migration intensity index at the municipal level.[12] All plots clearly show a negative relationship between sex ratios and Mexican emigration to the U.S., in other words, the relative number of females increases as a state or municipality becomes a more intensive sender of migrants. In the first and second plot we use the rates of migration to the U.S. at the state level and in the third we use CONAPO's migration intensity index at the municipal level. Note that in the first plot, where we use the 15 to 40 age category, the x-axis scale is much more skewed towards a surplus of females than in the second plot where we use the overall sex ratio. This reflect the fact that mortality rates in this age category are slightly higher for males than for females but most importantly because it encompasses males able to perform manual labor which is the demographic group most likely to migrate to the U.S. Indeed, we will show data below that shows that the average Mexican emigrant to the U.S. in the 1990s averaged 30 years of age.

Migration to the U.S. by itself significantly explains over half of the cross municipal variation in sex ratios in Mexico in 2000.[13] However, before claiming that migration is the main driver of sex imbalances it is important to carefully inspect other potential causes of sex imbalances such as selective infant mortality and abnormal differential mortality between males and females as potential causes. Figure 1 serves this purpose. In this figure we particularly focus on the 1990-2005 period as it pertains to the range of the sample used in this paper.

[12] The migration intensity index is CONAPO's summary migration measure capturing: 1) percentage of households receiving remittances from abroad; 2) percentage of households with migrants in the U.S. in the last five years; 3) percentage of households with circular migrants in the last five years, that is, household members going back and forward to the U.S.; and 4) percentage of households with returning members from the U.S. during the last five years. This is the best migration indicator available from a reliable homogeneous source at the municipal level; unfortunately it is available only for 2000.

[13] R^2 of regressing the sex ratio in the 15-40 age category against CONAPO's migration intensity index.

The sex ratio at birth in Mexico can be deemed within the "normal" range established by experts as it has ranged from 107 to 103 during the last forty years.[14] As opposed to some evidence brought about in the Asian context, historical data on child mortality before the age of one provides no evidence of gender-based abortion.[15] This is consistent with the remarkable stability of the top line in Figure 1 for the 0-4 age category, which is also always within "natural" standards.

Clearly, the shift downward in the second and third lines in Figure 1 relative to the first reflect the fact that for all age categories, except for people over 65 years old, mortality rates for males are higher than for females. However, we find no evidence of differential mortality rates based on gender that would justify the fall in overall sex ratios below the range (98-100) deemed as natural starting in the mid 1980s. Mortality rates for male and females remain relatively stable over the last thirty years and are close to international demographic norms.

While it is not possible to infer from Figure 1 alone what the contribution of migration may be to sex ratio imbalances, it is clear that the deficit of males has been increasing over three decades. Overall sex ratios moved from parity (100) in 1970 to 94 in 2000. For the main age group encompassing working age males the sex ratio dropped from 96 in 1970 to 89, lower than any other region in the world covered by the U.N.'s Demographic Yearbook reported in 2000.

Figure 2 suggests that this drastic decline in the sex ratio amongst young adults coincides with a surge in Mexican emigration to the U.S. starting in the 1970s. According to estimates by Mexico's CONAPO, total cumulative Mexican migration to the U.S.

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[14] According to Den Boer and Hudson (2002), the common wisdom regarding "natural" sex ratios at birth is that they range from 105 to 107 males per every 100 females.

[15] Based on INEGI's, *Estadísticas Históricas de la República Mexicana*.

increased 1.5 times from the decade of the 1970s to 3.3 million in the 1990s. Furthermore, CONAPO estimates that the stock of Mexican-born individuals residing in the U.S. increased 60% in the 1990s and amounts to nearly 9% of Mexico's current population.

Mexico's migration to the U.S. is hardly heterogeneous, it has been thoroughly documented to be driven by working age males meeting the demand for manual (unskilled) labor. According to the 2000 census, over 75% of Mexican emigrants to the U.S. were males. Furthermore, data on temporary migrants by the CONAPO's surveys show that throughout the 1990s, out of every 100 Mexican migrants to the U.S. close to 95 were males, they were on average 30 years old and had barely completed, on average, primary school (see Table A1 in the appendix).

The surge in migration throughout the 1990s has resulted in a net decline in the relative number of males at the municipal level in every age category and particularly for young adults. Furthermore, the cross municipal dispersion has also increased along with migration. In our sample of 2,402 municipalities the average sex ratio in the 15 to 40 age group dropped from an already low 94 in 1990 to 90 in 2000 and the cross municipal standard deviation increased from 10.5 in 1990 to 10.8 in 2000.

Given the well documented problem of Mexican illegal immigration to the U.S. how seriously should one take this migration data? The answer is that one should think of CONAPO's migration data as a lower bound estimate. The dramatic surge in the country's workers remittances over the last 25 years suggests that data on migrants could be underestimated.[16] At US$20 billion per year, Mexico is second only to India in the

[16] Such a large increase in remittances is unlikely to be fully explained by a gradual increase of the stock of Mexicans living in the U.S. or nominal wage growth. Furthermore, studies show that recent immigrants are

magnitude of its remittances originating in the U.S., and they now constitute its second largest source of foreign exchange. Furthermore, worker's remittances increased three times during the 1990s alone.

4 Cross Sectional OLS Evidence

The focus on the first set of empirical exercise is on explaining cross municipal variation in homicide rates. This approach is suitable because most of the variables of interest change slowly in time and also because some of the most interesting and informative socioeconomic controls at the municipal level are the result of a study by CONAPO that is only available for the year 2000. The control variables used are in the same spirit as those in Drezè and Khera (2000) for India and are shown in Table 1.

However, our data is superior to that used in Drezè and Khera (2000) in two respects. First, it covers the entire country and the unit of analysis is at the municipal level, the smallest possible political division. Higher levels of aggregation, including district and state-level data sets, are likely to miss out local variations in homicide rates and their social context. Second, our data set allows us to use more control variables and state level fixed effects, which should ease concerns on other biases. In addition, as explained in the next sub-section, we work with two different sources of homicide rates. This allows us to validate our results and eases concerns about measurement error.

4.1 Dependent Variables

A well know problem with crime statistics, even within fairly homogenous sample

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more likely to regularly send remittances than migrants who have been in the U.S. long enough and have probably already brought in the members of their immediate families.

spaces, is that of underreporting and, thus, measurement error. In this study we focus on homicide rates for two reasons. First, it is arguably the type of crime imposing the highest social cost on communities. Second, measurement error on homicides is minimized relative to other crime types given that homicides are likely more salient and, hence, least prone to go unreported.

In Mexico, the main source of municipal level homicide data are judicial statistics based on crimes reported to the local prosecutor's office.[17] However, there is perhaps a more reliable source based on death certificates, which distinguishes all "violent deaths due to aggression inflicted by another human being" and its municipality of occurrence. Both types of statistics are compiled by Mexico's Instituto Nacional de Estadística, Geografía e Informática (INEGI). After matching the judicial data available for the 1998-2004 periods we are able to work with 2,402 out of Mexico's 2,445 municipalities. The data on violent deaths by aggression span over 15 years, from 1990 to 2005, and is consistently available for 2,377 municipalities. Because social and economic factors may not impact crime contemporaneously, we use the average homicide rates and the average rate of violent fatalities for the period of 1998-2002.[18]

4.2 Regresors

In other to capture the effect of sex ratios on homicide rates an effort is made to control for a variety of socioeconomic characteristics and deterrence factors commonly used in

[17] Crimes are prosecuted under either federal or common law depending on type and place of occurrence and are reported as having been sentenced or being in the process of sentencing (alleged). The figures used here use the total sum per municipality.

[18] This is the same approach used in Drezè and Khera (2000). Using the crime rates for 2000 rather than the averages does not affect the results. Also, results are practically unchanged when one uses sentenced or alleged crimes separately instead of the sum of the two.

the empirical crime literature.[19] In contrast with the data used in Drezè and Khera (2000) for India, we do have municipal level information on poverty and include also measures on employment and income.

A couple of indicators in Table 1 deserve further elaboration. CONAPO's municipal "marginalization" index which we refer to as poverty is an average measure capturing household's characteristics in terms of access to education, home characteristics (e.g. running water, sewer, dirt floors, crowding, etc.), unemployment and inequality. As defined in footnote 12, CONAPO's migration intensity index is an average measure capturing the contribution to the local rate of population growth of net migration to the U.S. as well as the proportion of household in the municipality receiving remittances or having household members living in the United States. In an attempt to control for deterrence factors we use the real per capita expenditure on security and social works at the municipal level. The prior here is that more expenditure in security should reduce homicides rates.[20]

4.3 Evidence

The empirical models presented in this section are estimated using OLS with robust standard errors of the following form:

$$y_{ij} = \alpha + X_{ij}\,\beta + (M_{ij} / F_{ij})\chi + D_j\,\delta + \varepsilon_{ij}$$

[19] We use the 15 to 40 age category for the sex ratio calculation as it makes the most conceptual sense. Using other plausible sex ratio definitions does not alter the results. Similarly, the overall population over 12 years is used as denominator when relevant to calculate rates. This is done to avoid biases introduced by places with a large children population.

[20] Clearly, there is a simultaneity issue with this variable. Increased security expenditure may or may not reduce crime, but certainly is an increasing function of the crime rate. Levitt (1995) uses the timing of political elections to identify the effect of policing on crime. Instead of using expenditure averages, we tried 2000 data, as it coincided with a Presidential election in a country that back then was basically dominated by one party; the results were basically unchanged. This is an imperfect instrumentation of Levitt's procedure but yet a valid check.

where y_{ij} is the number of homicides per 100,000 inhabitants at municipality *i* in state *j*, X_{ij} is a vector of socioeconomic and deterrence factors, χ is the coefficient of interest on the municipal level sex ratio in the 15-40 age category, D_j is a dummy variable taking the value of 1 for all municipalities in state *j* and 0 otherwise, and ε_{ij} is an i.i.d. error term.

4.3.1 Homicide rates

Table 2 presents the first set of results for homicide rates. From the first two specifications, columns (1) and (2), one may conclude that, as expected, there is a significant positive empirical correlation between sex ratios and homicide rates. Statistical significance seems robust to the introduction of socioeconomic and deterrence factors. But it vanishes once one control for state level fixed effects (column (3)). As we show in the next sub-section, when results are discussed in greater detail, the effect survives the introduction of state level fixed effects when we use violent deaths by aggression as dependent variable. As we argue below, this may be a more accurate approximation to the true municipal level homicide rate because it is independent of peculiarities of the legal systems and definitions at the state level.

However, the result in specification (3) is important in reference to previous work by Drezé and Khera (2000) where they use similar judicial records and failed to control for fixed effects in a more aggregated sample (district level) and a larger and more heterogeneous country (India).

Specifications (4) and (5) in Table 1, use the homicide rate per 100,000 *males* as the dependent variable. The coefficient of the sex ratio measure is indistinguishable from zero in both specifications. This suggests that the effect found in columns (1) and (2) is likely to be the result of the "*incapacitation*" effect of predominantly male migration rather than due to a reduction in violence *per male*.

Clearly, there may be several problems with the regressions results shown above. The next subsection focuses on the issue of underreporting. Typically, measurement error of the dependent variable does not lead to serious estimation biases as long as it is not correlated with the independent variables. Unfortunately, it is likely that measurement error in the present case is correlated with regressors such as urbanization, schooling, income and others. To address this issue we use data on "violent deaths due to aggression by another human being" recorded by INEGI's vital statistics directly from death certificates. Villarreal (2002) points out that "this is the best source for homicide rate in Mexican municipalities because, unlike estimates based on crimes reported by the [state] prosecutor's office, they are not affected by state-level differences in the legal definition of homicide or biases in the prosecution of defenders."

4.3.2 Addressing Measurement Error (Violent Deaths by Aggression)

The specifications in Table 3 are in exactly the same spirit as those in Table 2 except that now, the rate of violent deaths per 100,000 inhabitants is used as a dependent variable. The coefficient of interest now enters the model significantly at the 3% confidence level and with the correct sign even once state level fixed effects are controlled for. Specification (3) implies that for the average municipality in Mexico losing one male per 100 females translates into a reduction of 0.43 violent deaths by aggression per each 100,000 inhabitants over the age of 12. Specifications (1) through (3) suggest that real GDP per capita, urbanization and social expenditure per capita are significant determinants of violent death rates in Mexico. However, real GDP per capita is not statistically different from zero once one control for state level fixed effects. Interestingly, results imply that violent deaths are an increasing function of social expenditure and decreasing on the level of urbanization.[21] Contrary to what Becker's model would predict, neither employment nor poverty indicators enter specifications (1)-(3) in a significant way.

Specifications (4) and (5), where the rate of violent deaths per *male* is used, yield similar results as before. With and without state level fix effect, the coefficient on sex ratios is statistically indistinguishable from zero. Interestingly, in addition to urbanization and social expenditure, poverty is now a significant correlate of homicide rates.[22]

In all, results thus far suggest there is a positive and statistically significant correlation between municipal level sex ratios and rates of violent deaths by aggression. The fact that violence *per male* is not explained by sex ratios in our sample suggest that this correlation is driven by an *incapacitation* effect whereby lower sex ratios translate into reduced violence simply because males are less likely to incur in violent behavior rather than by a reduction in violence *per male* induced by the taming effects of marriage or a less competitive mating environment, associated with female surpluses.[23]

Results thus far have addressed a potential measurement error problem by using a second, more refined dependent variable. However, one potential problem remains. If

[21] The variable "urbanization" captures the proportion of the population within each municipality leaving in rural communities (< 5,000 inhabitants) and, thus, a positive coefficient means that homicide rates are a decreasing function of urbanization (people living in communities > 5,000 inhabitants).
[22] The sign is as expected; since poorest municipalities carry a negative index score, poverty is associated with higher homicide rates.
[23] We do not discard the existence of such interaction effect that would reduce homicide rates per males. In fact, we do not think that the evidence presented thus far rules it out. However, it remains speculative at this point how sex ratios affect homicide rates per male. A closer inspection into this issue is left for future research.

municipal level sex ratios are largely determined by migration and underlying local economic conditions affect both the extent of migration and homicide rates then our OLS estimates may be biased. In the next section, we use a two stage instrumental variable approach in order to isolate the *causal* effect of sex ratios on homicide rates.

5 Cross Sectional IV Evidence and Causation

In order to get to the causal effect that Mexican emigration to the U.S. may have on crime via sex ratios we run the following two-stage OLS procedure with heteroskedastic-consistent standard errors:

$$\text{First stage: } (M_{ij} / F_{ij}) = \alpha + X_{ij}\,\beta + Z_{ij}\,\varphi + D_j\,\delta + \zeta_{ij}$$

$$\text{Second stage: } y_{ij} = \alpha + X_{ij}\,\beta + \widehat{(M_{ij} / F_{ij})}\,\kappa + D_j\,\delta + \psi_{ij}$$

In the first stage regression the municipal level sex ratio is regressed against a set of controls X_{ij} (the same as those included in the second stage regression) and a vector Z_{ij} of instrumental variables. As before, D_j is a dummy variable taking the value of 1 for all municipalities in state j and 0 otherwise. $\widehat{(M_{ij} / F_{ij})}$ is the fitted value of the first stage regression and the new variable of interest in that it captures the, arguably, exogenous effect of migration on homicides via sex ratios. Our prior here is for κ to have a positive sign. This is consistent with the sociological literature in that we expect that Mexico's predominantly male migration should have a reducing impact on crime via the change that it has on average in the demographic composition of municipalities.

5.1 Migration Intensity Instruments

In specifications (1) and (2) of Table 4, we use as instruments the percentage of households within the municipality with family members residing in the U.S. and CONAPO's migration intensity index. Admittedly, these are less than perfect instruments because sending municipalities may be economically worse off, thus making it difficult to identify whether homicide rates responds to sex ratio imbalances or simply to local economic conditions. We include these specifications because, contrary to what one may think, at the municipality level, migration intensity is weakly and negatively correlated with per capita GDP (-0.01) and weakly and positively correlated with HDI (0.04). Indeed, Figure A2a in the appendix plots migration rates against GDP per capita and human development at the state level. From these, one can conclude that migration do not necessarily responds to economic conditions. Keeping in mind that the northern part of Mexico is significantly more developed economically than the south, Figure A2b in the appendix suggests that states in the central portion of Mexico's income distribution are the most intensely senders of migrants to the U.S. (above) and that there is a significant amount of municipal variation (below) even within these states.

Not surprisingly, columns (1) and (2) of Table 4 show a very strong and significant first stage relationship between sex ratios and migration indicators. However, these estimates are not our preferred ones given the concerns alluded above. Yet, we would like to note that the coefficients of interest are both positive, significant and their magnitude suggests that the equivalent OLS estimates on homicide rates (Table 2) are biased downward (0.03 vs. 0.24).

5.2 Exogenous Migration Push Instrument: Natural Disasters

In specifications (3) through (5) of Table 4, we use data on the occurrence of natural disasters at the municipal level in 1999 as an exogenous migration *push* instrument.[24] The instrument is a dummy taking a value of 1 if any natural disasters were registered during 1999. In all, about 500 municipalities registered natural disasters for this year. There are two critical assumptions for the validity of this instrument. First, a one-year lag relative to the general data set is used assuming that this is approximately the average time lag needed to migrate after a natural disaster takes place. Second, and perhaps more controversially, we assume that the economic distress followed by a natural disaster may affect material crimes such as robberies but is unrelated to violent behavior.[25]

Specification (3), (4) and (5) use as dependent variables the rates of homicides, violent deaths by aggression and general violent deaths (including suicides but excluding traffic accidents), respectively. The first stage regression is significant and with the expected sign. Although the coefficient of interest in specifications (4) and (5) are not very precisely estimated, the balance of the evidence presented here suggest that there is indeed a *causal* effect of sex ratios on violent crime operating through migration. Furthermore, IV estimates suggest that OLS estimates are biased downward.

6 Panel evidence

As a robustness check to our cross-sectional results, we use Mexico's 1990 and 2000

[24] The data on natural disasters is by desinventar.org. They use 14 different classifications ranging from droughts to floods and earthquakes.

[25] To assess the validity of this assumption one may run state level fix effect regressions on homicide and robbery rates entering directly the natural disaster instrument, in addition to all the available control variables. From running this exercise, we find that there exist a large, positive and statistically significant empirical correlation between robbery rates per 100,000 inhabitants and the natural disaster dummy variable. On the other hand, the empirical correlation, controlling for socioeconomic characteristics and state level fix effect, between natural disasters and homicide rates is statistically undistinguishable from zero. Alternatively one may also use the predicted residuals from a regression of homicides on natural disasters as an instrument. The interpretation here is that the component of natural disasters unrelated to homicide rates is used as an instrument for sex ratios. After running this exercise, the conclusions presented in this paper are unchanged.

censuses along with INEGI's 1995 and 2005 population and housing surveys to construct a panel data set. Although the information in the panel is not as detailed as the one in the 2000 cross section, one advantage of using panel data is that it is possible to control for time-invariant unobservable factors at the municipal level, which in the case of Mexico's multi-cultural and multi-ethnic society may be relevant. In addition, the time dimension of the panel also allows us to control for year specific unobservable factors. Only a subset of the variables shown in Table 1 is used. The main components missing in the panel are income level and employment, which are not available in the 1995 and 2005 population surveys.

The models take the following form:

$$y_{it} = \alpha + X_{it}\,\beta + (M_{it} / F_{it})\,\chi + \eta_i + \varepsilon_{it}$$

where y_{it} is the rate of violent deaths per 100,000 people at municipality i and time period t; X_{it} is a vector of municipal level regressors followed throughout the 1990-2005 period, which includes: literacy, level of urbanization, ethnicity and real per capita expenditure in security and public works; χ is again our coefficient of interest, η_i is a vector of municipal-specific unobservable factors that are assumed constant in time and ε_{it} is an i.i.d. error term.

Initially, we applied three different estimation procedures to the panel: pooled OLS with municipal level dummy variables, fixed and random effects models. However, we restrict our attention to municipal level fixed effect models in this section because Hausman tests show that, although more efficient, random effects estimates are inconsistent.

Specification (1) in Table 5 corroborates our cross-sectional results. Even after one controls for municipal level fixed effects, there is a positive and significant correlation between sex ratios and the rate of violent deaths. The magnitude of the coefficient of interest in the vicinity of those reported in Table 3. The coefficient is reduced to about a fifth of its size once one introduces time dummies into the analysis and it is less precisely estimated (column (3)). Specification (2) confirms that the sex ratio effect is likely to be due to the incapacitation of males since the coefficient of interest is statistically insignificant when we use the rate of violent deaths per male. Finally, in column (4) we present estimation results equivalent to the two-stagesIV estimation ones presented in section 5. We use natural disasters as instrument. Although the first stage procedure now is not as strong as in the cross section, our result suggests that there exists a casual effect running from sex ratios to violent deaths. Given that the instrument used is an exogenous migration push factor, we are in effect capturing the effect that migration to the U.S. has on homicide rates via the changes it induces on the demographic composition at the local level in Mexico. As before, results seem to be consistent with "testosterone-driven" theories of violent crime which imply that migration has provided Mexico with a significant escape valve to crime.

7 Conclusions

This paper explores empirically the connection between Mexico's predominantly male emigration flows, its resulting sex imbalances and homicide rates at the municipal level. The data set used in this study is superior to others used in the existing empirical crime literature for developing countries in two respects. First, two different variables are available to capture the rate of homicides at the smallest possible unit, which allows us to validate our findings and alleviate measurement error concerns. Second, the panel dimension of the data set allows us to control for unobservable factors at the municipality level, which should further ease concerns on spurious results and other omitted variable biases.

Our findings seem to be consistent with "testosterone-driven" theories of crime and suggest that Mexican migration to the U.S. has provided Mexico with an escape valve to violent crime. Our preferred OLS estimation suggests that a reduction in one male per every 100 females results in a reduction of 0.4 homicides per 100,000 inhabitants over the age of 12. Fixed effect panel estimates place this effect at 0.6 homicides per 100,000 inhabitants. In both panel and cross sectional exercises the evidence for an effect of sex ratios on homicide rates per males was much weaker. This leads us to conclude that the resulting surplus of females resulting from Mexico's migration patterns has had an incapacitation effect on crime via the reduction in the number of young males rather than a taming effect on male violence per se. The greatest room for improvement of this paper is on the proper instrumentation of the sex ratio at the municipal level. As a first attempt we have argued that one can use natural disasters as an exogenous migration push instrument to obtain the causal effect of sex ratios on crime. Both panel and cross sectional evidence suggests that, indeed, there is a causal effect running from sex ratios to homicide rates operating through the migration instrument. The magnitude on the IV estimates suggests that OLS estimates may be biased downward.

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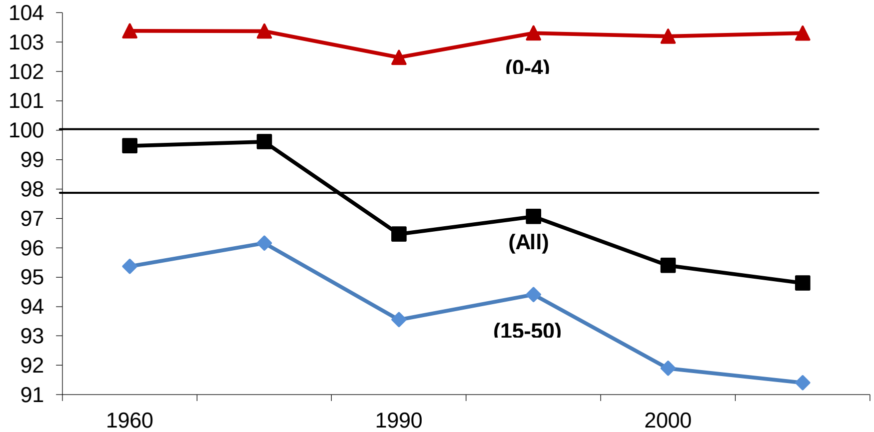
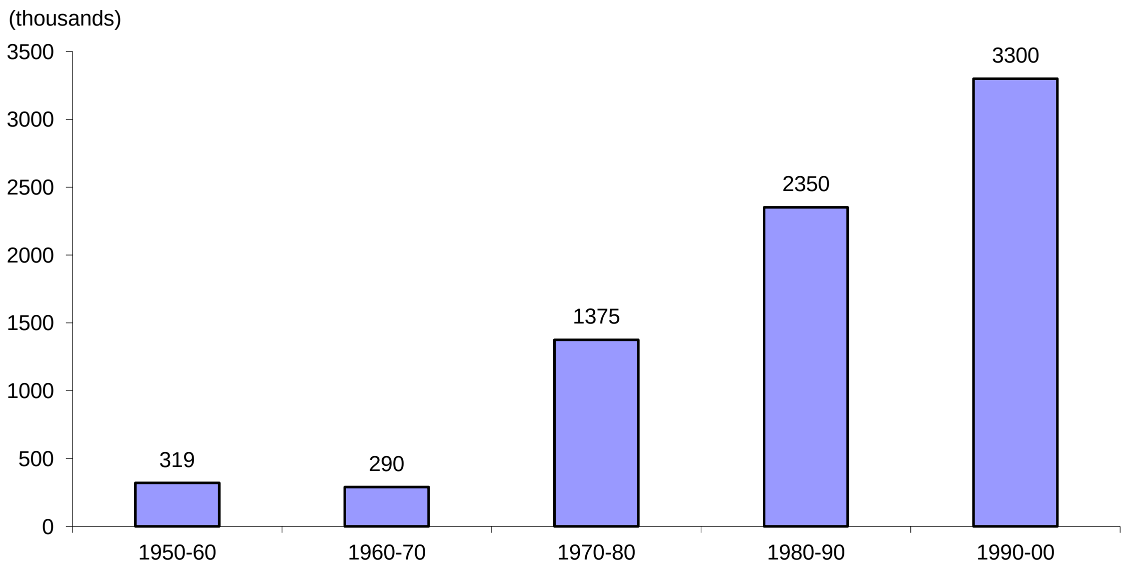
FIGURE 1: SEX-RATIOS IN MEXICO, BY AGE GROUPS (1960-2005)



Source: INEGI's Estadisticas Historicas de Mexico.

FIGURE 2: HISTORICAL MEXICAN (LEGAL) MIGRATION FLOWS TO THE U.S.



Source: CONAPO

TABLE 1: REGRESSION VARIABLES AND MEAN VALUES

Variable	Definitions (all data at the municipal level)	Mean
Dependent variables		
Crime rates		
Homicides[a]	Homicides per 100,000 (unweighted annual average 1998-2002, source: INEGI)	20
Per young male	Homicides per 100,000 males in the 15-40 age bracket	79
Violent deaths[b]	Death by aggression per 100,000 (unweighed annual avg. 1998-2002, source: INEGI)	40
Per young male	Violent deaths per 100,000 in the 15-40 age bracket	165
Variable of interest		
Sex-ratio[c]	Male-female ratio: males per 100 females in 2000	91
Control variables		
Socio-economic		
GDP per capita	GDP per capita index for 2000 (based on PPP adjusted data, source: CONAPO)	0.55
Employment	% of population employed in 2000 (two minumum wages or more, source: CONAPO)	73
Poverty[d]	CONAPO's municipal "marginalidad" index in 2000 (source: CONAPO)	0.00062
Schooling[e]	% population 6-24 years old in school in 2000 (source: CONAPO)	60
Ethnicity	% of population who speaks an indigenous language in 2000 (source: INEGI)	20
Urbanization	% of localities with population < 5,000 in 2000 (source: CONAPO)	74
Social expenditure[f]	Real per capita expenditure on security and social works (source: INEGI)	317
Migration indicators		
Remittances	% of households receiving remittances from the USA in 2000 (Source: CONAPO)	7.00
Migrants	% of households with members in the U.S. over last 5 years (Source: CONAPO)	7.00
Migration intensity[g]	CONAPO's migration intensity index for 2000	1.04

[a] Homicide rates include sentenced and alleged crimes. Regression results are robust to using sentenced and alleged series individually and annual crime rates instead of five year averages. Total population above 12 years old is used as denominator.

[b] Fatalities due to aggression are a subset of general violent deaths and exclude suicides and other accidents.

[c] The sex-ratio measure is for population in the 15-40 age interval. For the most part, results are robust to using the "crude" (all population) sex-ratio (mean: 96) and the "broad" (population over 12 years old) sex-ratio (mean:94).

[d] This is a comprehensive summary measure including nine indicators: literacy, schooling, employment, income, locality size and housing characteristics as it pertains to sanitary services and dirt floors, drinking water, electricity and sleeping quarters separate from common areas.

[e] Results are robust to using % of population with completed primary school and % of literate population over 15 years old.

[f] Admittedly this is an imperfect measure of security expenditure but is the best one can get at the municipal level. Results are unchanged when using 2000 data instead of a 5-year average centered in 2000.

[g] CONAPO's migration intensity index is a summary measure capturing four indicators: 1) % of households receiving remittances from abroad, 2) % of households with migrants in the U.S. in the last five years, 3) % of households with circular migrants in the last five years, that is, household members going back and forward to the U.S. and 4) % of households with returning members from the U.S. during the last five years.

TABLE 2: CORRELATES OF HOMICIDE RATES IN MEXICO IN 2000, MUNICIPAL DATA

	Homicides				
	Per 100,000 inhabitants			Per 100,000 young males	
	(1)	(2)	(3)	(4)	(5)
Sex-imbalance					
Male-female ratio	0.15***	0.15***	0.03	0.14	-0.32
	(2.58)	*(2.62)*	*(0.44)*	*(0.53)*	*(-1.00)*
Control Variables					
GDP per capita	-2.19	2.16	31.48**	-16.75	93.85*
	(-0.19)	*(0.22)*	*(2.58)*	*(-0.37)*	*(1.80)*
Employment	-0.59***	-0.57***	-0.23***	-1.80***	-0.49
	(-6.94)	*(-6.29)*	*(-2.84)*	*(-4.35)*	*(-1.44)*
Poverty	15.29***	15.36***	16.95***	49.71***	54.27***
	(6.60)	*(6.80)*	*(6.39)*	*(4.64)*	*(4.20)*
Schooling	-0.34*	-0.35	-0.33	-1.45	-1.57
	(-1.69)	*(-1.73)*	*(-1.28)*	*(-1.34)*	*(-1.09)*
Urbanization	-0.032**	-0.05***	-0.13***	-0.13***	-0.41***
	(-2.08)	*(2.63)*	*(-6.77)*	*(-1.50)*	*(-5.88)*
Ethnicity	-0.11***	-0.11***	-0.11***	-0.44***	-0.46***
	(-4.17)	*(-4.13)*	*(-3.48)*	*(-3.98)*	*(-3.48)*
Social expenditure		0.010	0.009	0.057	0.055
		(1.60)	*(1.28)*	*(1.63)*	*(1.37)*
State-level fixed effects	No	No	Yes	No	Yes
R^2	0.09	0.10	0.18	0.07	0.14
Observations	2,402	2,386	2,386	2,386	2,386

Note: t-ratios in italics; significance at 1%(***), 5%(**) and 10%(*) levels.

TABLE 3: CORRELATES OF MORTALITY RATES (VIOLENT DEATHS) IN MEXICO IN 2000, MUNICIPAL DATA

	Violent deaths				
	Per 100,000 inhabitants			Per 100,000 young males	
	(1)	(2)	(3)	(4)	(5)
Sex-imbalance					
Male-female ratio	0.44***	0.50***	0.43**	0.43	-0.03
	(3.19)	*(3.66)*	*(2.23)*	*(0.65)*	*(-0.04)*
Control Variables					
GDP per capita	-117.7**	-115.0**	-51.7	-574.5**	-347.9
	(-2.37)	*(-2.21)*	*(-0.78)*	*(-2.83)*	*(1.38)*
Employment	-0.17	0.087	0.13	0.59	1.23
	(-0.95)	*(-0.46)*	*(-0.40)*	*(-0.76)*	*(0.96)*
Poverty	-2.61	-4.19	-1.28	-50.02***	-41-98***
	(-0.75)	*(-1.21)*	*(-0.35)*	*(-3.00)*	*(-2.34)*
Schooling	0.53	0.45	0.037	2.55*	0.60
	(1.58)	*(1.32)*	*(0.10)*	*(1.86)*	*(0.41)*
Urbanization	-0.36**	-0.31***	-0.19***	1.52***	1.04***
	(6.10)	*(5.67)*	*(4.02)*	*(6.89)*	*(-5.06)*
Ethnicity	0.13	0.14	-0.12	0.8	-0.35
	(1.06)	*(1.12)*	*(-0.86)*	*(1.64)*	*(-0.65)*
Social expenditure		0.033***	0.043***	0.17***	0.23***
		(3.10)	*(3.83)*	*(3.25)*	*(3.89)*
State-level fixed effects	No	No	Yes	No	Yes
R^2	0.09	0.10	0.20	0.13	0.24
Observations	2,002	1,986	1,986	1,986	1,986

Note: t-ratios in italics; significance at 1%(***), 5%(**) and 10%(*) levels.

TABLE 4: IV ESTIMATES USING MEXICAN 2000 MUNICIPAL DATA

	Homicides			Violent deaths[a]	
	(1)	(2)	(3)	(4)	(5)
Instrumental variable:	% HH w/ family in the U.S.	CONAPO's migration intensity	Any natural disaster in 1999	Any natural disaster in 1999	Any natural disaster in 1999
First stage	-0.81***	-4.86	-0.99**	-0.99**	-0.99**
	(-23.69)	(-21.67)	(-2.40)	(-2.40)	(-2.40)
R^2	0.52	0.047	0.32	0.32	0.32
Observations	2,178	2,386	2,386	2,386	2,386
Sex-imbalance					
Male-female ratio	0.24**	0.24*	1.66	2.00	6.52**
	(2.35)	*(1.82)*	*(1.62)*	*(0.78)*	*(2.33)*
Control Variables					
GDP per capita	39.12***	27.6	1.58	-78.0	-199.2**
	(3.68)	*(2.30)*	*(0.07)*	*(-0.52)*	*(-2.87)*
Employment	-0.22***	-0.25***	-0.37	-0.006	-0.13*
	(-2.78)	*(-3.00)*	*(-3.15)*	*(-0.01)*	*(-0.41)*
Poverty	18.46***	16.35***	12.33***	-5.13	-35.00***
	(9.00)	*(6.09)*	*(2.78)*	*(-0.32)*	*(-3.24)*
Schooling	-0.055	-0.32	-0.52	0.14	-0.17
	(-0.50)	*(-1.25)*	*(-1.00)*	*(0.29)*	*(-0.45)*
Urbanization	-0.13***	-0.12***	-0.11***	0.21***	-0.22***
	(-6.86)	*(-6.81)*	*(-5.12)*	*(3.07)*	*(3.44)*
Ethnicity	-0.079**	-0.104***	-0.070*	-0.083	0.014
	(-2.17)	*(-3.36)*	*(-1.81)*	*(-0.62)*	*(0.08)*
Social expenditure	0.005**	0.009	0.008	0.042***	0.104
	(2.01)	*(1.26)*	*(-1.15)*	*(3.30)*	*(5.04)*
State-level fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.24	0.24	0.18	0.20	0.20
Observations	2,178	2,178	2,386	1,986	2,361

Note: t-ratios in italics; significance at 1%(***), 5%(**) and 10%(*) levels.

[a] Includes all violent deaths including suicides and non-traffic accidents

TABLE 5: FIXED EFFECTS ESTIMATION USING MEXICAN MUNICIPAL LEVEL DATA 1990-2005

	Violent deaths by aggression per 100,000 inhabitants			
	(1)	(2)	(3)[a]	(4)[b]
Sex-imbalance				
Male-female ratio (level)	0.61***	0.35	0.14	21.6***
	(6.41)	*(0.76)*	*(1.40)*	*(3.04)*
Control Variables				
Literacy	2.77***	9.27***	0.65**	3.15***
	(12.86)	*(8.95)*	*(2.30)*	*(3.61)*
Urbanization	0.10	0.42	0.02	0.36***
	(1.31)	*(1.12)*	*(0.27)*	*(2.64)*
Ethnicity	0.39*	3.31**	0.22	1.32***
	(1.64)	*(2.92)*	*(0.93)*	*(3.03)*
Social expenditure	-0.08***	-0.36***	-0.043***	0.078*
	(-8.52)	*(-7.90)*	*(-4.22)*	*(1.89)*
First stage: Disaster				0.38
				(1.20)
Time dummies	No	No	Yes	Yes
Observations	9,526	9,526	9,526	9,526

Note: t-ratios in italics; significance at 1%(***), 5%(**) and 10%(*) levels.

[a] Dependent variable is violent deaths per 100,000 males

[b] IV estimation.

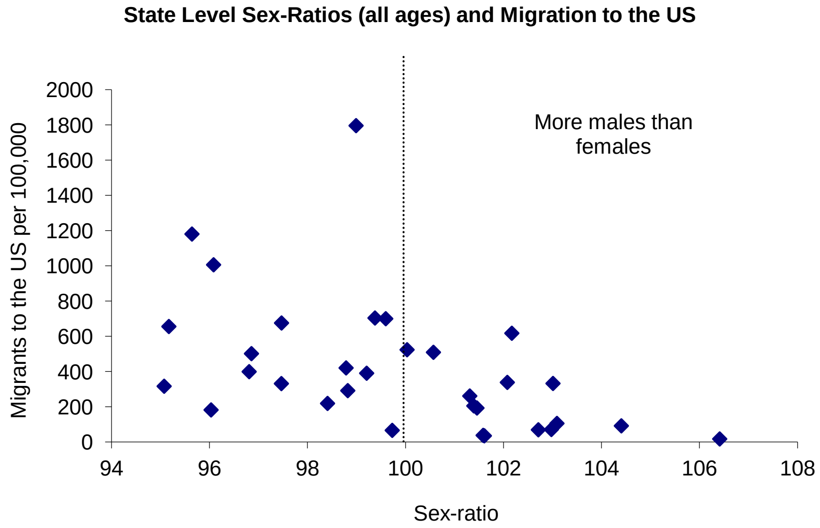
Appendix

TABLE A1: SOCIO-DEOMOGRAPHIC CHARACTERISTICS OF MEXICAN MIGRANTS TO THE U.S.

	1993 - 1997	1998 - 2001	2001 - 2003
Males (%)	97.6	93.1	94.1
Age (%)	100.0	100.0	100.0
From 25 to 44 (%)	60.2	64.4	62.7
Over 45 (%)	10.6	13.8	14.1
Average age (years)	31.1	33.2	33.3
Schooling (%)	100.0	100.0	100.0
Literate (%)	92.9	95.1	96.2
Average schooling (years)	6.0	6.5	6.8
Married (%)	62.5	65.1	71.0
Head of household (%)	68.5	69.2	70.4
Speaks indigenous language (	---	7.1	3.7

Source: Estimates by the Mexican Council of Population (CONAPO) based on internal surveys (www.conapo.gob.mx).

FIGURE A1: MIGRATION AND SEX-RATIOS AT THE STATE AND MUNICIPAL LEVEL IN 2001



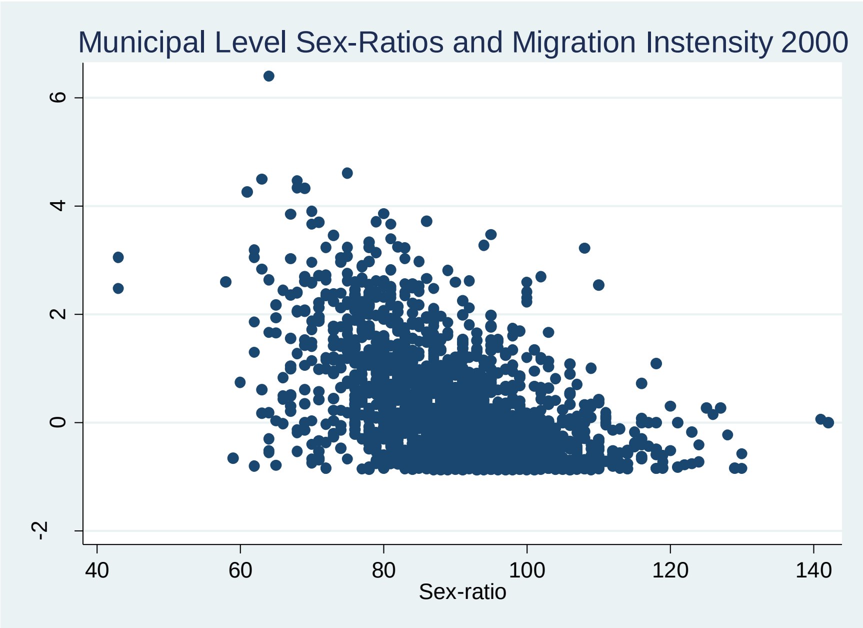
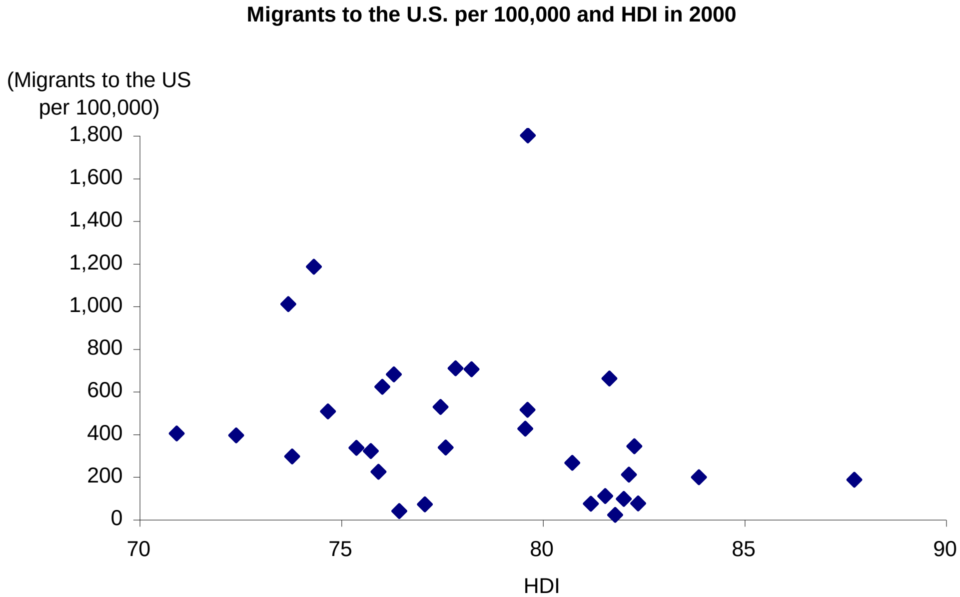


FIGURE A2a: MIGRATION AND ECONOMIC DEVELOPMENT, BY STATE



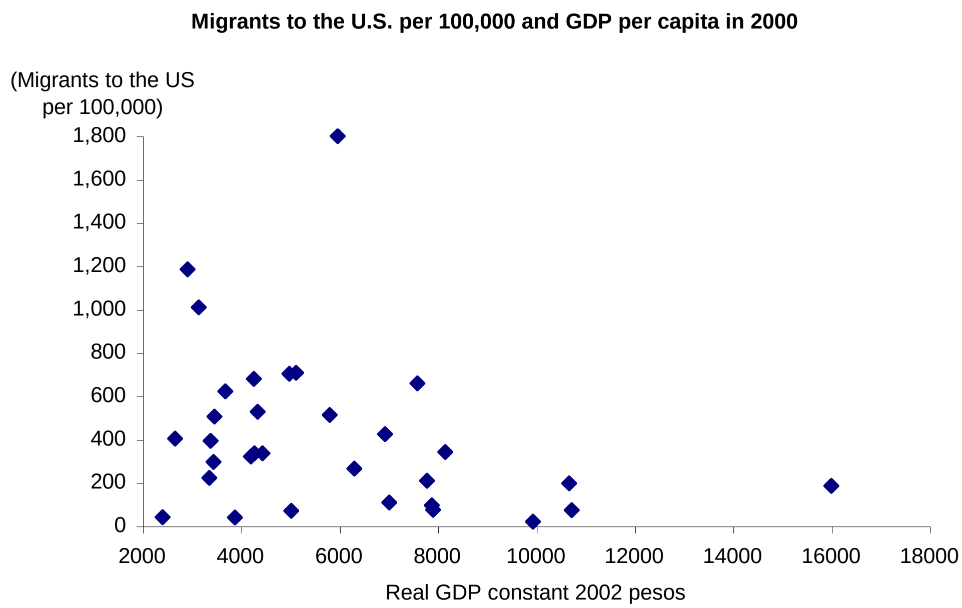
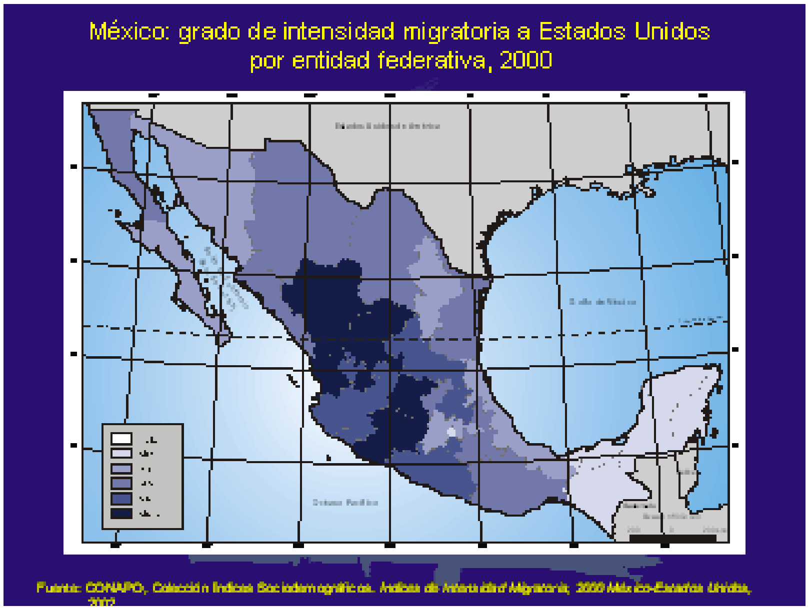


FIGURE A2b: INTENSITY OF MIGRATION TO THE U.S. IN 2000, BY STATE AND MUNICIPALITY



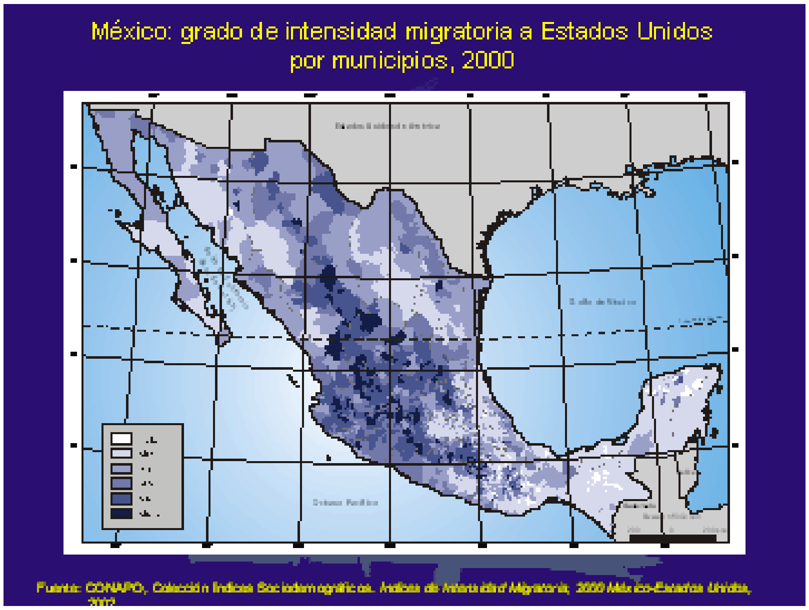


TABLE A2: MUNICIPAL LEVEL SUMMARY STATISTICS, 2000 SAMPLE MUNICIPAL DATA

Variable	Obs.	Mean	St. Dev.	Min	Max
Homicide	2,402	20.1	28.8	0.0	655.7
Per young male	2,402	79.3	124.6	0.0	3,636.0
Death by agression	2,002	39.9	70.3	1.4	2,024.0
Per young male	2,002	164.8	293.2	4.2	7,500.0
GDP per capita	2,402	0.6	0.1	0.07	1.0
Schooling	2,402	60.3	6.3	27.5	87.1
Urbanization	2,402	74.2	34.1	0.0	100.0
Poverty	2,402	0.0006	1.0	-2.4	3.4
Ethnicity	2,402	20.5	32.4	0.0	100.0
Employment	2,402	73.1	16.6	18.4	98.9
Remittances	2,240	7.0	7.8	0.02	53.7
Migrants	2,194	7.0	6.9	0.02	46.7
Migration intensity	2,402	1.0	1.1	0.0	8.3

Source: Estimates by the Mexican Council of Population (CONAPO)
based on internal surveys,

TABLE A3: PANEL 1990 - 1995 SUMMARY STATISTICS
MUNICIPAL DATA

Variable	Obs.	Mean	St. Dev.	Min	Max
Homicide	9,590	22.7	39.7	0.0	926.3
Per young male	9,589	86.2	188.4	0.0	7,639.0
Death by agression	9,590	41.1	71.5	0.0	2,024.0
Per young male	9,590	160.4	318.3	0.0	7,500.0
Literacy	9,590	18.3	11.9	0.8	83.4
Urbanization	9,590	74.8	33.9	0.0	100.0
Ethnicity	9,590	20.4	32.6	0.0	100.0
Expenditure	9,526	38.2	71.1	0.0	5141.0