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FERTILITY AND THE SIZE OF THE MEXICAN-BORN

FEMALE POPULATION IN THE U.S

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Abstract

This dissertation consist of three separate papers that address the a) the fertility contribution of Mexican-born immigrants to the future U.S. population, b) the impact of immigrants on high U.S. TFR and c) the use of vital rates to estimate the size of the Mexican-born female population in the U.S. In the first paper a new method is proposed to project the contribution of immigration to a receiving country's population that obviates the need to project the number of immigrants by using the full sending-country birth cohort as the risk group to project their receiving-country childbearing. The new method is found to perform dramatically better than conventional methods when projecting to 1999 from selected base years in the past. Projecting forward from 1999, the research estimated the cumulative contribution of Mexican immigrant fertility from the 1980s to 2040 of 36 million births, including 25% to 50% more births after 1995 than are projected using conventional methods. The second paper consists of a decomposition analysis of the recent U.S. TFR into fertility and composition effects of Mexican-born and other foreign-born immigrants. The results show that 6% of the U.S. TFR is attributable to a higher ASFR of immigrant women. About 63% of the foreign-born effect in 1990 and 71% in 2000 is attributable to Mexican-born woman. Approximately 11% of the Mexican-born contribution to the TFR is due to an age composition of the Mexican-born that favors the high-ASFR ages. The large increase in the size of the foreign-born population in the U.S. from 1990–2000 is mostly offset by reduced TFR of both the foreign-born and the native-born population. Finally the dissertation explores the usability of vital rates in combination with registered number of vital events to estimate the Mexican-born population in the U.S. The results show that the intuitively simple and mathematically sound method is unsuitable for population estimates when mortality rates are bias and sampling error reduces the preciseness of fertility rates.

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Chapter 1

INTRODUCTION

Oscar Handlin, in his classical book on immigrants' experience in the U.S., states that he "discovered that the immigrants *were* American history" (Handlin 1973, p. 3). Those words, originally published in 1951, are still valid now as they were in the latter half of the 20th century U.S. history. Given the fact that about 42.5 million immigrants were admitted to the U.S. from 1901 to 1995 (Bean et al. 1998) and many of them had children and grandchildren, we can expect that most current U.S. family histories have a strong base in immigration experience.

In the same sense that American history is a history of immigration, social relations in American society reflect the experiences of diverse race and ethnic groups. American sociology has from the early years been deeply influenced by immigration and ethnic and race relations. A large body of literature on assimilation in a multicultural society includes work from Robert Park (Park and Burgess 1969 originally published in 1921), to more recent work such as Wilson (1980), Massey (1993) Anderson (1990) and Hirschman (2005) to name just few.

Not only is the study of immigration important on its own, but the scientific study of immigrants' experience, uncertainties, expectation and wishes reveals a valuable knowledge of the structure and function of the host society. The research literature on the connection between the immigration and fertility draws from the large body of sociological literature on the division and integration of nationality and ethnicity in multicultural society. It is impossible to understand the fertility behavior of new immigrants without building on the accumulated knowledge of ethnic relations. At the same time, deeper understanding of fertility intention and behavior of immigrants can provide a better understanding of immigrant's assimilation to a new society.

The immigration debate has been a part of the entire U.S. history (Borjas 1999). While the origin of the immigrants has shifted, the debate has been couched in fundamentally demographic terms involving size and characteristics. The question of how many and which immigrants the U.S. is willing to admit to their country of immigrants and their descendants, has been the key issue in continuous immigration policy making and reform.

Recent estimates indicate that about 11.7% of the U.S. population are foreign-born and 53% of the foreign-born are born in the Latin America (Larsen 2004) . The immigration stream that gradually started after the 1930s and increased fast in the 1980s, has been to a large degree driven by immigration from Mexico in the past decades. While the recent migration stream from Mexico is large, by historical standards, it is based on long history and both formal and informal structural connection between the two populous neighbors. The North American Trade Agreement (NAFTA) set in 1992 has been an important mechanism that not only increases the flow of goods and services across the Mexico-U.S. border but is also believed to have tightened the social network across the border. These social network in turn eased Mexican migration to the U.S. by reducing the physical and social cost associated with the migration process (Massey, Durand and Malone 2002). The early prediction that NAFTA would foster growth of illegal immigration from Mexico (Acevedo and Espenshade 1992) is, however, impossible to evaluate precisely because of other social changes that have taken place since the adoption of NAFTA.

Mexican immigration, both before and after NAFTA went into effect, has had a large economic impact in the U.S. The large number of working-age legal and undocumented immigrants are both producer and consumer of goods and services and are thus, just by their number, bound to have substantial economic effect. The large number of immigrants has, however, fostered debates on the possibility that immigrants take jobs from the native-born and that increased labor supply reduces wage rate of the low-skilled workers (Borjas 1999). In addition to potential effect of immigration on the local level labor-market with increased labor supply and consumption, immigration can potentially have an effect on the age structure of the population in both the sending and receiving population (Greenwood and Tienda 1998).

The potential effect of Mexican immigration on the age structure and size of the future U.S. population is inherent in both the large migratory flows over the past two decades (Bean et al. 1998) and in higher and earlier fertility among Mexican-origin and Mexican-born women. The combined effects of large Mexican immigration and higher Mexican-immigrant fertility have resulted in more than a doubling of births to Mexican-born mothers as a proportion of all U.S. births in the past two decades, from 3.1% of female births in 1979 to 8.5% of female births in 1999 (author's calculations from National Center for Health Statistics, NCHS). This potential rejuvenating effect of immigrants fertility is, however, often overlooked in the formal demographic literature, partly because of the traditional stable population model that assumes a population closed to immigration, with important exceptions (Espenshade 1986; Preston and Wang 2007).

The demographic literature has contributed extensively to the understanding of the dynamics of migration and immigrant fertility in the Mexican-U.S. migration system. Large numbers of studies have contributed to the quantification of the foreign-born population (see review and results in; Bean et al. 2001; Bean et al. 1998; Passel 2007; Passel, Van Hook and Bean 2004; Van Hook and Bean 1998) and a related body of literature has enhanced our knowledge about the dynamics of fertility of Mexican-born and Mexican-origin population in the U.S. (see review and results in; Bean, Swicegood and Berg 2000; Frank and Heuveline 2005; Frejka 2004; Glusker 2003; Kahn 1994; Parrado and Morgan 2008; Stephen and Bean 1992) and the contribution of the foreign-born female population to current high U.S. total fertility rate.

One of the major strengths of demography as a social science is that it is based on three clearly defined events; births, deaths and migration. However, a substantial part of demographic research deals with the project of making sense and use of incomplete data. Unlike many other social sciences where quantitative researchers develop measurement theory and techniques to completely quantify a specified human cognition, opinion, idea, value or behavior with reliable and valid measurement instrument, the formal demographic research paradigm works on methods to utilize available data sources to capture the size, distribution, characteristics and transition probabilities of a complete specified population.

Of the three events, migration is the most difficult to measure. The common demographic approach to infer about the migration event from measurements of residence at two point in time, (e.g. with a census question on place of residence five years earlier and asking about country of birth), is only providing a partial answer to the question on the number of immigrants as a substantial part of the foreign-born population is un-enumerated in the U.S. Census.

As population size, growth rate, composition (such as age-sex structure, and race-ethnic make-up) are the fundamental attributes of population dynamics, much emphasis in the demographic literature has been on finding methods to utilize available data to capture changes in the size and characteristics of the foreign-born population with special emphasis on the Mexican-born and the unauthorized part of foreign-born population. Bean, et al. (2001) estimate that in 1996 there were about 2.54 million undocumented Mexican-born immigrants in the U.S. The fact that a large number of the undocumented immigrants are either with ambiguous immigration status and their migration pattern is circular with repeated crossing of the Mexican-U.S. border suggests that the estimates are problematic to apply to the estimation of age-specific vital rates, as the circular flow of migrants might either influence the location of death and birth or might be influenced by fertility intention. Some immigrants might return to their home country when they become sick or they might be less likely to come back to the U.S. if returning to their home country.

In addition to their importance for the estimation of vital rates, population estimates are also necessary in order to increase our understanding of expected future populations size and composition as population projections depend on the size and composition of current population and assumptions about changes in current fertility and mortality rates. While the Census data for the total and more specifically, the foreign-born population, suffer from a high undercount rate (United State Department of the Commerce 2002), (Schenker 1993) that reduces the quality of population estimates, the coverage of the birth registration system is generally believed to be of high quality.

The three papers that follow exploit the completeness of the birth registration system to answer three separate questions about the Mexican-born female population.

1. What is the expected fertility contribution of the Mexican-born female population to the future U.S. age structure?
2. What was the total contribution of all foreign-born and more specifically the Mexican-born to the U.S. TFR's in 1990 and 2000?
3. Can vital rates and the registered number of births and deaths be used to estimate the Mexican-born population resident in the U.S.?

The three research questions address the broader issue of Mexican impact on the U.S. demographic system by examining the effect of immigration on the current and future U.S. population, and by focusing on fertility among immigrants (but less so on the migration process itself). The common elements to the following three papers are the age-specific fertility rates and the derived period measure of total fertility rate, developed in the formal demographic literature. The papers examine the nature, utilization and quality of age-specific fertility (and to an extent, mortality) rates that are the foundation of the cohort component population projection model. When addressing the questions on the nature of the immigrants' vital rates, a number of more challenging questions on the causes and consequences of population change emerge. The nature of the Mexican-U.S. migration system with substantial level of circular and invisible migration is of central importance, when using the formal demographic fertility rates to capture the underlying dynamics of immigrants' fertility behavior.

The three research papers that follow do not directly address theories in the economic and sociological literature on the causes of migration. The papers are, however, influenced by the theoretical and empirical literature on immigrants' assimilation and on the fertility differentials by immigrants' generations, when evaluating first generation fertility level. The more macro level formal demographic theories on population growth, formulated in the basic demographic equation, the stable population model and the cohort component model, have gradually been developed to better incorporate the effect of immigration and immigrants' fertility. The papers that follow contribute to improved knowledge of the effect of immigrants' fertility on the U.S. demographic system with improved analysis of the actual and projected contribution of Mexican-born immigrants to the U.S. demographic system, building on a large body of empirical literature in addition to published work on demographic modeling and simulations of the possible effect of immigrants fertility.

In chapter 2 the long-term contribution of Mexican fertility to the U.S. population is projected, using a new method that is based on age-specific U.S. childbearing rate of Mexican birth cohorts. By basing the rates on the size of the Mexican birth cohort, the method leaps over survivorship and Mexico-U.S. migration. This simplification is driven by the lack of complete data on the Mexico-U.S. migration stream that is necessary for the conventional cohort-component projection model. Several projections are performed with the new proposed method and compared to results from conventional cohort component models. Projecting forward from 1999, the model projects a cumulative contribution of Mexican immigrant fertility from the 1980s to 2040 of 36 million births, including 25% to 50% more births after 1995 than are projected using conventional methods.

The paper in chapter 3 addresses the level and the nature of the contribution of foreign-born female fertility to the high U.S. total fertility rate. A decomposition of the recent U.S. TFR into fertility and composition effects of Mexican-born and other foreign-born immigrants show that 6% of the U.S. TFR is attributable to a higher ASFR of immigrant women. About 63% of the foreign-born effect in 1990 and 71% in 2000 is attributable to Mexican-born woman. Approximately 11% of the Mexican-born contribution to the TFR is due to an age composition of the Mexican-born that favours the high-ASFR ages. The large increase in the size of the foreign-born population in the U.S. from 1990–2000 is mostly offset by reduced TFR of both the foreign-born and the native-born population.

The paper in chapter 4 explores the feasibility of using vital rates and registered number of vital events to estimate the Mexican-born female population in their childbearing ages. With several estimates and assumptions about the fertility and mortality rates and registered number of births and deaths produced, the population resulting estimates are compared to Census count estimates to evaluate the Census coverage. The results show that the intuitively simple and mathematically sound method is unsuitable for population estimates when mortality rates are bias and sampling error reduces the accuracy of fertility rates.

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Chapter 2

THE FERTILITY CONTRIBUTION OF MEXICAN IMMIGRATION TO THE UNITED STATES

Abstract[1]

Crucial to the long-term contribution of immigration to a receiving country's population is the extent to which the immigrants reproduce themselves in subsequent, native-born generations. Using conventional projection methodologies, this fertility contribution may be poorly estimated primarily because of problems in projecting the number of immigrants who are at risk of childbearing. We propose an alternative method that obviates the need to project the number of immigrants by using the full sending-country birth cohort as the risk group to project their receiving-country childbearing. This "sending-country birth cohort" method is found to perform dramatically better than conventional methods when projecting to 1999 from base years both before and after the large increase in inflows of Mexican immigrants to the United States in the late 1980s. Projecting forward from 1999, we estimate a cumulative contribution of Mexican immigrant fertility from the 1980s to 2040 of 36 million births, including 25% to 50% more births after 1995 than are projected using conventional methods.

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Introduction

Although immigration is commonly assumed to be a potential solution to the aging of populations in the developed world, the consensus of opinion among demographers is that the likely efficacy of the immigration solution is limited. A recent United Nations (2000) report portrayed scenarios of huge levels of immigration being necessary to sustain current ratios of working-age to old-age populations in low-fertility European and East-Asian countries. Espenshade (1994) similarly asserted the futility of immigration as a means of arresting the inevitable aging of the U.S. population. In common with the consensus of demographic opinion, his main argument was that because immigrants themselves age, immigration does little to address the root cause of population aging, which is fertility decline.

Simulations in stable and stationary population models in which the fertility of immigrants differs from the fertility of native-born persons (Feichtinger and Steinmann 1992; Schmertmann 1992) have found that the age and foreign- versus native-born structure of the stable or stationary population may be changed substantially by higher immigrant than native-born fertility. Schmertmann concluded (p. 611) that the rejuvenating effects of immigration are obtained primarily through the births they contribute and therefore that the short-term impacts may differ from those that are seen in a stable or stationary population simulation.

Good empirical evidence for the effects of the fertility of immigrants within the period of real population projections, however, is difficult to find. A direct effect of immigration fertility was implicitly ruled out in both the Espenshade (1994) and the United Nations (2000) studies, because their projections assumed that immigrants' fertility will equal that of the native-born population of the receiving country. In both cases, this assumption was made only for simplicity of calculation, and no attempt was made to justify it substantively. Espenshade's (1986) earlier work, meanwhile, discussed a significant contribution of higher fertility among mainly Turkish immigrants to delaying a decline in the population in Germany in the 1980s. The German situation of the substantial immigration of low - skilled individuals from developing countries may have considerable generality, including to that of the United States in its relationship with Mexico.

The goal of the study presented here was to project the childbearing contribution of recent decades of Mexican immigration to the United States. We did so by developing and applying a novel method, which we refer to as the sending-country birth cohort (SCBC) method. This method replaces the projection of the dual processes of immigration and immigrants' fertility with the projection of a single process of births in the receiving country to women born 15–44 years earlier in the sending country. The major advantage of this method is that the number in the Mexican birth cohort is likely to be known with much greater certainty than is the number of Mexican-born women who are resident in the United States during the various points in the projection period.

The possibility of a substantial rejuvenating effect of Mexican immigration on the future U.S. population is suggested by the combination of large migratory flows over the past two decades (Bean et al. 1998) and of higher and earlier fertility among Mexican-origin and Mexican-born women. In 2000, the total fertility rate (TFR) for all Mexican-origin women in the United States was 3.3, with almost half this TFR accounted for by ages less than 25 (Martin et al. 2002, and the authors' calculations therefrom). Higher and earlier fertility was also found among both Mexican-born women and U.S.-born women of Mexican origin (Bean, Swicegood, and Berg 2000), although it was more pronounced among more recent immigrant generations.

The joint effects of increasing Mexican immigration and higher Mexican-immigrant fertility have led to more than a doubling of births to Mexican-born mothers as a proportion of all U.S. births in the past two decades, from 3.1% of female births in 1979 to 8.5% of female births in 1999 (authors' calculations from National Center for Health Statistics, NCHS, various years; for 1999, see also Ventura et al. 2001: table 14). Mexican-born women's share of all foreign-born mothers increased from 31.3% in 1979 to 43.8% in 1999, while among all Hispanic-origin mothers in 1999, 70.7% were of Mexican-origin and 43.4% were Mexican born (Ventura et al. 2001). In this context, a remarkable growth in importance of Mexican-born and Mexican-origin fertility for the overall U.S. population is implied by the U.S. Census Bureau's projections (Day 1996) that "after 2020 the Hispanic population is projected to add more people to the United States every year than would all other race/ethnic groups combined" (p. 1) and that by 2050, one in three births will be to a Hispanic woman (table O). The projections further imply a large dependence of the overall U.S. projection on the data and methods used to project the Mexican contribution to future U.S. fertility.

The Census Bureau currently separately projects the Hispanic population, but not specifically the Mexican-origin population. In common with practically all other national and international statistical agencies, the Census Bureau uses the cohort-component projection model (e.g., Smith 1992: chap. 8). The fundamental element of this model is the birth cohort, which is survived and has fertility rates applied to it during its reproductive ages. Immigration is handled in the model with some unease, essentially as an add-on. "Net immigrants," instead of being produced from the application of age- and sex- specific demographic rates to birth cohorts, are simply inserted into the population at each year of the projection as total numbers with given age-sex distributions. While demographic theory and analysis related to the cohort-component model's parameters for age-specific fertility and mortality are plentiful, the net-immigrant numbers and distributions have a much more ad hoc empirical quality (Rogers 1990). In practice, the net- immigrant assumptions are usually derived from the number and distribution of immigrants observed in recent years. In the Mexico-U.S. case, these data are known to be subject to a large measurement error (Bean et al. 2001). Thus, immigration is both a theoretical and an empirical "weak link" in the cohort-component projection methodology. The ramifications of this weak link have been seen recently in the greater-than-expected population count in the United States in 2000 (Waldrop and Long 2002), largely because of the underestimation of the Hispanic-origin component of the population. Although Hispanics had been projected to overtake the black population by 2010 (Day 1996), they had already done so by 2000.

The problems of cohort-component projections of the Mexican- or Hispanic-origin population in the United States, however, need not be seen as arising from a fundamental flaw of the cohort-component model. We argue that they may instead be seen as arising from major problems in the data used to estimate the projection parameters and, more fundamentally, from the need to expand the current cohort-component model into one that explicitly accounts for Mexican, as well as U.S., birth cohorts. While immigration may satisfactorily be treated as an ad hoc add-on in the case that its impact is relatively small or may have to be treated as an ad hoc add-on in the case that the major immigrant source countries are dispersed, neither of these conditions describes the present situation of the United States regarding immigration. The impact of immigration to the United States is large and increasing, and one sending country dominates all the others. The U.S. population's dynamics are increasingly linked to those of its southern neighbor, and thus it may be appropriate now to consider projection models that better account for this interdependence

Cohort-component projection theory points, in the case of interdependent populations, to a "multiregion" model (Rogers 1995). In this model, cohorts are survived and exposed to fertility in the regions (e.g., countries) of their birth, but are also exposed to rates of migration between regions and to rates of fertility and survival in other regions. These rates generally differ according to their region of current residence. The formal demographic theory and projection methodology for the multiregion cohort-component model is well established. Its implementation in national population projections, however, has foundered on the lack of data to estimate the multiregion parameters. In the Mexico-U.S. case, neither Mexico-U.S. nor U.S.-Mexico migration rates are readily available. Nor are there reliable, regular series of U.S. fertility rates to Mexican-born women (Schmertmann, Swicegood, and Sobczak 2002). Finally, the mortality rates of the Mexican-born population in the United States are not regularly available, while differences in the mortality of Mexicans in Mexico versus in the United States are substantial (Shai and Rosenwaike 1991).

In the present study, we developed and implemented a projection model that applies the theoretical foundation of the multiregional cohort-component model to the "two-region" Mexico-U.S. case, but with a major simplification to avoid the empirical difficulties of estimating accurately the migration, survivorship, and U.S. fertility rates of Mexican-born cohorts. This simplification involves "leaping over" survivorship and Mexico-U.S. migration and arriving directly at the event of a birth in the receiving country (the United States) to women who were born in the sending country (Mexico). Only one new demographic rate therefore needs to be estimated—a Mexican birth cohort's (period t) U.S. childbearing rate, whose numerator is births in the United States to Mexican-born mothers aged x, and whose denominator is the size of the Mexican female birth cohort (adjusted for infant survival) t–x years before. This SCBC model then applies the estimated Mexican birth cohort's U.S. childbearing rate to successive Mexican birth cohorts to project annual numbers of births in the United States to Mexican-born mothers.

The SCBC model can thus be implemented without the heavy additional data requirements of a standard multiregional cohort-component model. Its data requirements are less, too, than those of the standard, single-country cohort-component projection model: immigrant numbers and age-sex distributions are no longer required, while the new childbearing rate substitutes for the resident fertility rate applied to immigrants. Furthermore, the new childbearing rate has a denominator that, deficiencies in the Mexican birth-registration system notwithstanding, is likely to be more reliable and certainly more readily available than is the denominator of Mexican-born women who are resident in the United States. We demonstrate later that current deficiencies in measurement with respect to the foreign-born U.S. Hispanic population severely undermine the accuracy of projections in the single-country cohort-component model, irrespective of whether immigrant and nonimmigrant fertility are differentiated.

Data and methods

The basic principle of the SCBC projection method is to extend the idea of a population at risk, so that it captures a multiregion population system. In our study, we applied it to a two-country system between Mexico and the United States in which the focus is the U.S. population. The underlying assumption of this framework is that women who were born in Mexico can theoretically give birth in the United States during their reproductive ages, and thus a female Mexican birth cohort has both a U.S. and a Mexican component of its cohort fertility. We applied the U.S. component directly to current and future Mexican female birth cohorts to project the number of U.S. births to Mexican-born women. In so doing, we projected Mexican-immigrant childbearing and ignored the problem of estimating immigration. This is the essence of our projection method's difference from conventional projection methods.

Because we are interested in the longer-term population consequences of this immigrant childbearing, we also projected births to second- and third-generation immigrants using fertility rates that are generation specific. This second step was done as a simplified application of the method of the National Research Council's (NRC; Smith and Edmonston 1997) generation-specific, cohort-component projection method. The resulting third- and fourth-generation births, then, allowed us to estimate the contribution of births to Mexican-born women to total female births (i.e., including descendant births) during the projection period.

To evaluate the SCBC method against other methods, we selected and adapted the two projections that appear to be the closest to ours: the projections of the Hispanic population from 1995 to 2050 by the U.S. Census Bureau (Day 1996) and by the NRC (Smith and Edmonston 1997: chap. 3), plus an earlier projection of the Hispanic population from 1983 to 2080 by the Census Bureau (Spencer 1986). The Census Bureau's and the NRC's projections both use "single-country" cohort-component models, since they project the foreign-born component of the U.S. resident female population as survivors of annual net flows of immigrants. We refer to our implementation of the NRC model hereafter as the "immigrant generation-specific" (IGS) model and to our implementation of the Census Bureau's as the "immigrant generation-neutral" (IGN) model.[2] We extracted as well as we could from these projections of the Hispanic population the component that is common between ours and theirs, namely, projected births to Mexican-born women and their descendants. By doing no more than deriving a Mexican-born component as a proportion of the total Hispanic base population and of

[2] The IGS model, as developed and applied by Smith and Edmonston (1997) and Edmonston and Passel (1999), further allows for a consideration of ethnicity attribution by children who are born in exogamic unions. We ignored this aspect of their model so that ancestry (descent from a Mexican-born woman) is the defining characteristic of births in the IGS (and IGN) model as it is for the SCBC model. The results of the NRC's and Census Bureau's middle-series projections are almost identical with respect to the total 2050 Hispanic popula-tion-94.7 million and 96.5 million, respectively. However, these totals were produced in different ways. The NRC model projects more births to Hispanic women, but then marries and "attributes" out a substantial number of these births from the Hispanic population into other, principally non-Hispanic white, racial-ethnic groups.

total Hispanic net immigrant streams (and as a ratio of the all-Hispanic or generation-specific Hispanic fertility rates), we ensured that the IGS/IGN projections were made from only the knowledge that could be assumed to be available to the researcher at the time the projection was based (around the 1982 and 1994 base years, respectively).

We specified all three models (SCBC, IGS, and IGN) as female only and with single- year ages and projection intervals. The unique features of the SCBC model are limited to its method for projecting of U.S. births to Mexican-born women (that is, births of second-generation immigrants to first-generation immigrants). The IGS and SCBC models are identical from the survival and childbearing of the second immigrant generation onward.

The SCBC model's age-specific U.S. childbearing rate of Mexican birth cohorts, $c_{2m}(a,t)$, is defined by

$$c_{2m}(a,t) = B_{2m}(a,t) / P_m(0,t-a) \qquad (2\text{-}1)$$

where again all the quantities are female only. Estimation of this rate is from U.S. registrations of births to Mexican-born mothers (NCHS various years) and from population estimates and projections of 0 year olds in Mexico (Economic Commission for Latin America and the Caribbean, ECLAC 2000b).

In the SCBC model, births of second-generation females at time t are given by

$$B_{2m}(t) = \sum_{a=15}^{44} c_{2m}(a,t) P_m(0,t-a) \qquad (2\text{-}2)$$

where the subscript *2m* designates second-generation (female) births to Mexican-born mothers aged *a* at time *t*. To simplify the notation, we omit a female subscript throughout our presentation of the models. The term $P_m(O,t-a)$ thus refers to the age-0 female population of Mexico a years before. We began from estimates of 0 year olds instead of from births because of data problems with Mexican birth registrations (Campos 1998; United Nations, various years)[3]. Doing so also had the advantage of taking into account survival to midyear age 0. Changes over time in this component of survivorship are likely to account for a substantial proportion of changes in total survivorship into the reproductive ages. Attempts to account for survivorship after age 0 would be complicated by the substantial differences in survival between Mexicans in Mexico and those who immigrate to the United States (Shai and Rosenwaike 1991). Taking into account these differences would then require projecting immigration of Mexican-born women to the United States, a task we explicitly rejected in our model.

The corresponding equation of the IGS and IGN models to produce second-generation births is

$$B_{2m}(t) = \sum_{a=15}^{49} f_1(a) P_{1m}(a,t) \tag{2-3}$$

where $f_1(a)$ refers to the age-specific fertility rates of first-generation Mexican immigrants (Mexican-born women who are resident in the United States), and $Pm(a,t)$ refers to the Mexican-born female population who are resident at age a in the United States at time t. The IGS and IGN models differ only by their fertility term. Whereas the fertility of first-generation immigrants, $f(a)$, is higher in the IGS model than is the fertility of subsequent generations, in the IGN model, fertility is not differentiated by generation.

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[3] We thank R. McCaa and B. Campos for their advice and references about the Mexican birth-registration problems and the alternative 0-year-old series

The IGS and IGN population $P_{lm}(a,t)$ is produced differently according to the time in the projection. In the base year, it is purely an estimate of the resident population. In practice, this estimate comes from the Census Bureau's projecting forward to the base year the population counted at the previous census, using postcensus counts of births and deaths and postcensus counts and estimates of immigrants. As the projection proceeds, more and more of $P_{1m}(a,t)$ is produced endogenously through the projection of immigrants and their subsequent survival. In equation form,

$$P_{1m}(a,t) = \sum_{z=0}^{a} I_m(x,t-x)S(x,a) \tag{2-4}$$

where I_m indicates immigrants from Mexico, allowing for immigrants to have arrived at any age from 0 to a, x indexes the arrival age of the immigrants, and $S(x,a)$ indicates the probability of survival from age x to age a, $I_m(x,t-x)$.

Although all three projection methods allow for changes in the component parameters over the projection period, in all our projections, we held them constant throughout the projection period. Doing so is consistent with the Census Bureau's and NRC's middle-series projections and more easily allows for sources of difference between the SCBC and other methods to be analyzed. In this latter respect, an interesting result emerged when we compared Eqs. 2-1 and 2-2 of the SCBC model with Eqs. 2-3 and 2-4 of the IGS and IGN models: while the number of second-generation births in the SCBC model (Eq. 2-2) continues to change for as long as the sizes of Mexican birth cohorts change from year to year, this number in the IGS and IGN models (Eq. 2-3) becomes more rapidly near-constant as it is increasingly formed by the constant-valued immigration term of Eq. 2-4. When viewed from the cohort perspective of the SCBC model, however, the constant immigrant-numbers term of Eq. 2-4 combines two changing components: the size of the Mexican birth cohort and the age-specific rates of migration between Mexico and the United States. The latter are forced to vary inversely with the size of the birth cohort by the IGS/IGN models' assumption of constant immigrant numbers and age-sex distribution.

The SCBC model's $c_{2m}(a,t)$ of Eq. 2-1 also implicitly combines two component rates: age-specific rates of Mexico-U.S. migration and age-specific rates of the fertility of Mexican-born U.S. residents.[4] However, when these latter fertility rates are assumed to be constant (as they are in the IGS and IGN models), then the implicit age-specific rates of immigration of the SCBC model are also constant. The fundamental conceptual drivers of different projection paths between the SCBC model and those of the IGS and IGN models, then, are the SCBC's implicit assumption of constant Mexico-U.S. age-specific migration rates and its explicit dependence on Mexican birth cohort sizes. We argue that these are attractive features of our SCBC model when contrasted with the implicit assumption of the IGS and IGN models that changes in the sending country cohorts' age-specific migration rates exactly counter changes in the sending country's birth cohort sizes.

Births of third- and later-generation Mexicans in the United States may be expressed identically for all three models (SCBC, IGS, and IGN). For the births of third-generation immigrants, the equation is (2-5)

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[4] Changes in mortality are disregarded from age 0 to age a, which will anyway be relatively small in their influence on the size of the population at risk.

$$B_{3m}(t) = \sum_{a=15}^{49} f_2(a) B_{2m}(t-a) S(0,t) \quad (2\text{-}5)$$

where $f_2(a)$ refers to the fertility rate of second-generation Mexican immigrant women, again for female births only. The definition of the equation for births of fourth and later generations follows directly from Eq. **2-5**. The SCBC and IGS models have identical $f_2(a)$ and $f_3(a)$ terms, with the former higher than the latter. In the IGN model, $f_1(a)$,$f_2(a)$, and $f_3(a)$ are all equal.

The values of the parameters of the SCBC projection model are described in the Results section. For the parameter values of the IGN and IGS models, we adapted the projection parameters of the middle-series versions of the Census Bureau's 1982 and 1994 base-year projections and the NRC's 1994 base-year projection to a "Mexican-only" model (described in Appendix A, along with details of other projection parameters). Because the Census Bureau and NRC middle series projections from 1994 use the same, constant annual net immigration level throughout their projection periods, we could focus on the immigrant fertility component as that which differentiates the three models.

Regarding fertility parameter values, the overall Hispanic TFRs of the Census Bureau's middle series for its 1994 base-year projections is higher than the NRC's (2.98 versus 3.23, 2.63, and 2.04, respectively, for first, second, and third and higher generations, and 2.63 overall). The Census Bureau's and NRC's fertility values are both from 1994 estimates of Hispanic fertility rates. But while the Census Bureau used vital statistics (NCHS) estimates from birth-registration numerators and the Census Bureau's population-estimate denominators, the NRC used the Current Population Survey (CPS). It is probable that the NCHS's estimates are upwardly biased because of underestimation of the denominator between 1990 and 2000 (Martin et al. 2002:3). Robinson, West, and Adlakha (2002:26) reported that the number of Hispanic-origin women aged 18–29 who were counted in the 2000 census exceeded the number from the Census Bureau's population estimates for 2000 by 17.2%. Moreover, this large deficit, for the age group whose fertility rates are the highest, occurred before any adjustment for the census undercount, which was estimated to be 5.0% overall for Hispanics (Guzman and Diaz McConnell 2002:121). On the other hand, the NRC's TFR estimates may be underestimated to the extent that the much higher fertility of recent Mexican immigrants (Schmertmann et al. 2002) is not adequately captured within the CPS's household sampling frame. To keep the focus on methodological differences among the three projection methods, we calibrated the NRC's TFRs to the levels of the Census Bureau's and retained the NRC's ratios of differences in TFRs by generation. The TFRs of each of the three methods are presented in Table 2-1. The ratios of Mexican TFR to all-Hispanic TFR for the 1994-based and 1982-based projections were obtained from NCHS estimates (Mathews et al. 1998; Ventura 1985).

Table 2-1: 1994 Base-Year Projection Total Fertility Rates

	Census Hispanic	IGN Mexican	NRC Hispanic	IGS Mexican	SCBC Mexican
First	2.98	3.18	3.23	3.90	–
Second	2.98	3.18	2.63	3.18	3.18
Third	2.98	3.18	2.04	2.46	2.46
Overall	2.98	3.18	2.63	–	–

To obtain fertility rates that differed by immigrant generation in the IGS model in 1982, we applied the NRC's overall Mexican-origin ASFRs, the ratios of Hispanic immigrant-generation TFRs, to the overall Hispanic TFR reported for 1994 assuming that these TFR ratios were the same in 1982 as in 1994. Thus, we assumed that the first, second, and third or later generations' fertility rates of the IGS model are, respectively, 1.228, 1.000, and 0.776 times the 1994 and 1982 all-Mexican-origin fertility rates of the IGN model.

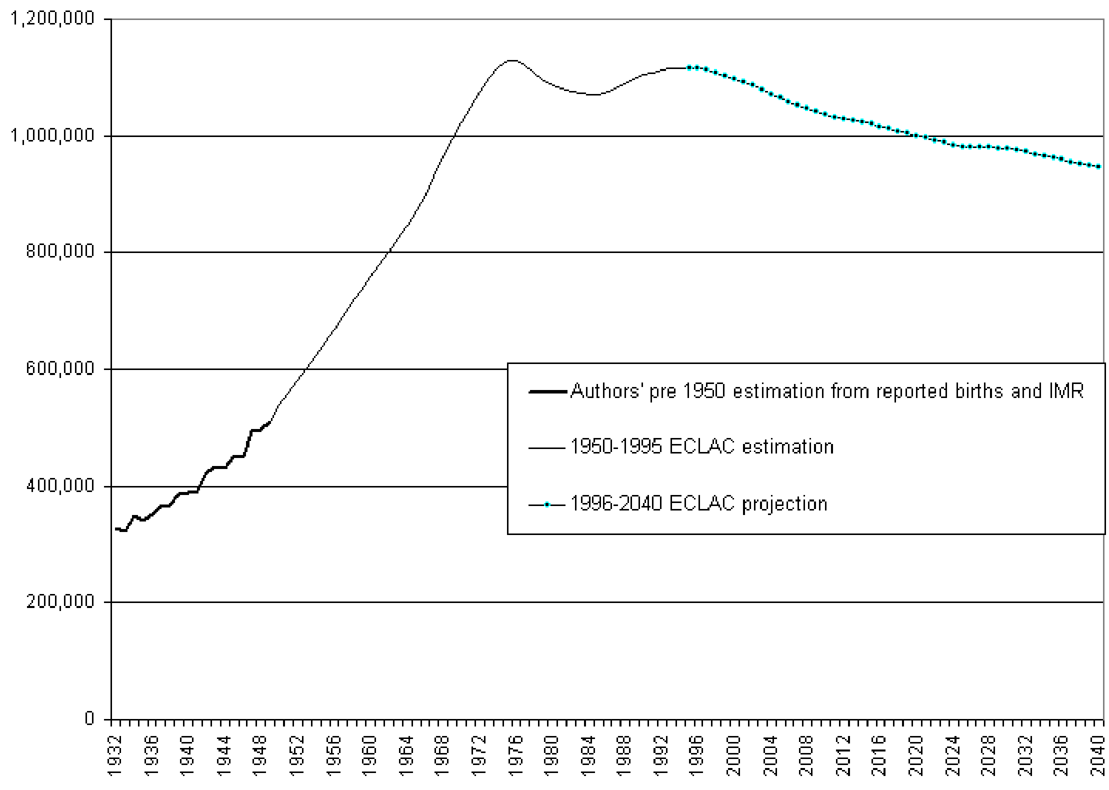

Figure 2-1: Mexican Female Birth Cohorts at Age 0

Sources: From authors' calculations of data from the U.S. Census Bureau (2000), ECLAC (2000b), and the NCHS (various years).

Results

Consistent with our female-only projection model, the results are for the female population only unless otherwise stated. We begin by describing the time series of Mexican female birth cohorts at age 0 (see Figure 2-1). The series includes projected values after 1995 (ECLAC 2000a, 2000b).[5] Two strongly distinct periods are seen in the series. Up to 1975, the number of new surviving female infants in Mexico increased steadily by over 2% per year, almost doubling between 1950 and 1975. This period was immediately followed, however, by a plateau and slight downward trend that is projected to continue into the twenty-first century. The large growth in the birth series through the mid-1970s implies lagged large increases in Mexican-born women in their childbearing years throughout the 1980s and most of the 1990s. In contrast, the number of children born in the United States reached a peak in 1957 (Farley 1996). The U.S. birth series in the 1980s and 1990s was strongly affected by this baby-boom bulge as these birth cohorts moved through their peak childbearing years. The conceptual principles of the two-region projection model of this study call for parallel attention to the lagged effect of the Mexican birth cohort series on the series of U.S. births to Mexican-born women.

[5] These projections necessarily include assumptions about migration between Mexico and the United States by Mexican-born women before and during childbearing ages. These uncertainties, however, will have a much smaller proportionate effect on the projected total Mexican resident population than they will on the smaller Mexican-born population who are resident in the United States

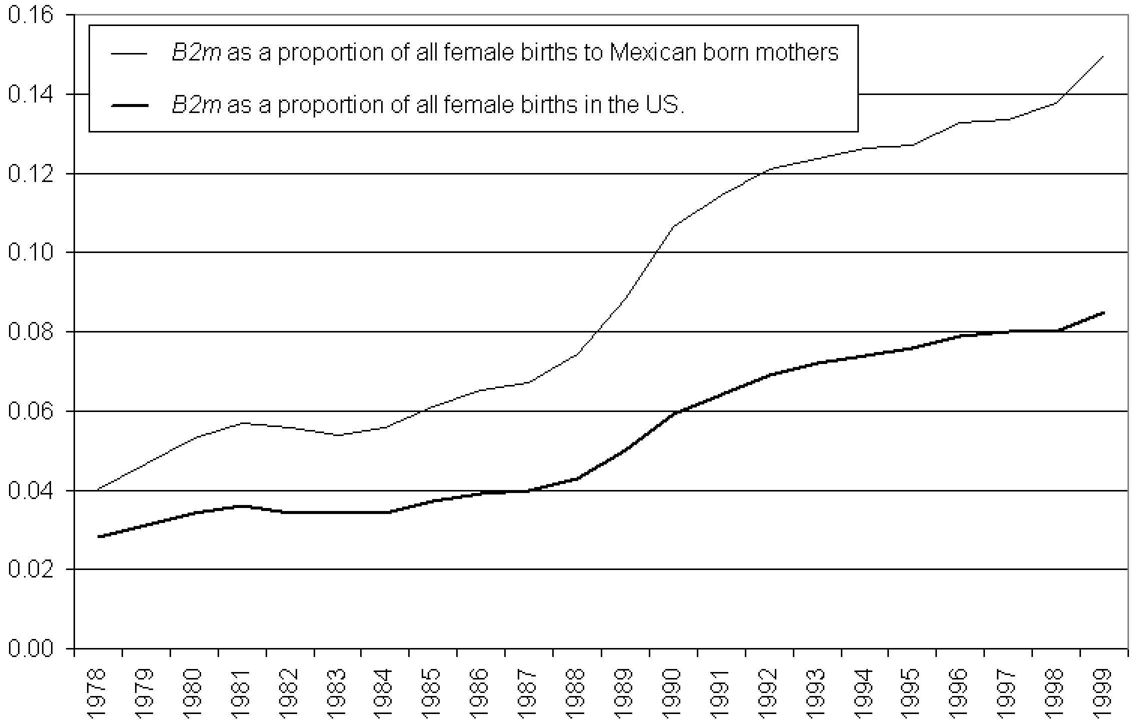

Figure 2-2: U.S. Female Births to Mexican-born Women (B_{2m}) as Proportions of Total (Mexican- Plus-U.S.) Female Births to Mexican-born Women and as Proportions of Total Female Births in the United States

Source: From authors calculations of data from the U.S. Census Bureau (U.S. Census Bureau 2000), ECLAC (ECLAC 2000) and the National Center for Health Statistics (National Center for Health Statistics (NCHS) Various Years).

Female births in the United States to Mexican-born women (B_{2m},) between 1978 and 1999 are plotted in Figure 2-2. We used two denominators to put these births into their sending-country (Mexico) context in addition to their receiving-country (U.S.) context. Looked at from Mexico, there were pronounced changes in where Mexican-born women gave birth to their children. Whereas in 1978, only 4.0% of their total (Mexico-plus-U.S.) childbearing took place in the United States, by 1999, it was up to 15.0%. A parallel rise occurred in the receiving country (the United States), where the proportion of total births that were to Mexican-born mothers rose from 2.8% in 1978 to 8.5% in 1999. The largely similar increases in these two time series were driven by both common and unique factors. The dominant common factor was migration from Mexico to the United States. This factor is seen especially in the large increase in both series that occurred between 1988 and 1992, the years following the passage of the 1986 Immigration Reform and Control Act (IRCA; Donato 1993).

Regarding factors that are unique to one or other series, the birth series whose denominator is births to Mexican-born women both in Mexico and the United States would have been driven upward partly by declining fertility rates in Mexico (U.S. Census Bureau 2000). The series whose denominator is all U.S. births, on the other hand, would have been driven upward by the more rapidly increasing Mexican birth-cohort sizes relative to those in the United States. That is, even at constant rates of emigration to the United States and at constant rates of fertility once in the United States, the number of U.S. births to Mexican-born women would have risen over these two decades.

We controlled for the effect of changes in the sizes of Mexican birth cohorts in Figure 2-3. Here, the U.S. childbearing rates of the Mexican-born women (c_{2m}) of Eq. 2-1 in the Data and Methods section are estimated for five-year age groups. These are thus the same fertility rates as those in the SCBC projection model, except that the latter are for single-year ages. Overall, the age-specific trends are similar to those seen for the all-birth proportions of Figure 2-2**.** The large increases in the age-specific fertility rates between 1988 to 1992 echo those seen in those earlier series, as do the upward trends in the late 1970s and the downward trend in the early 1980s. Notably different, however, are the slower increases and longer pauses in the trends of the age-specific fertility rates of

Figure 2-3, compared with the stronger and more consistently upward trends of Figure 2-2. Having now controlled for increasing sizes of Mexican birth cohorts is an important part of the reason for this flatter trend in these fertility rates, especially compared with the series for births to Mexican-born women as a proportion of all U.S. births.

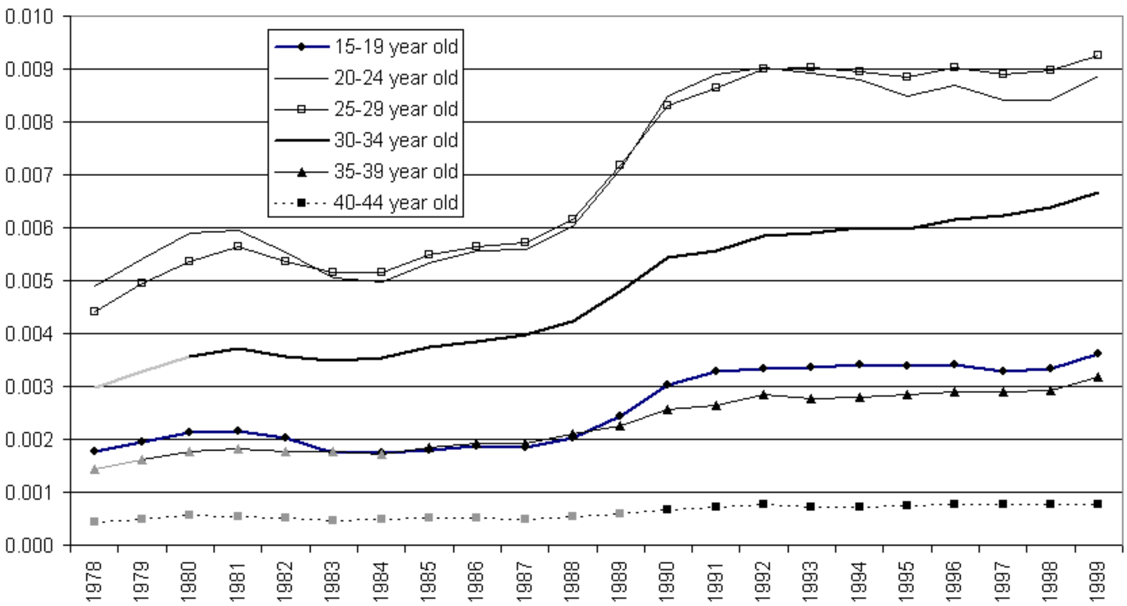

Figure 2-3: Sending-Country Birth Cohort (SCBC) U.S. Female Childbearing Rates of Mexican-born Women (c_{2m}) for Five-Year Age Groups

Notes: Rates represented by shaded marks and lines are based on birth registrations in Mexico before 1950,adjusted by the 1950 ratio of the reported number of female births in Mexico and estimated 0-year-oldfemales and changes in the infant mortality rate.

Relatively little is known about time trends in the fertility rates of Mexican-born women who are resident in the United States. However, the stability of these rates over the 1980s and 1990s is indicated both by the foreign-born Hispanic fertility rates, estimated from birth-registration data with intercensal population-estimate denominators estimated for the first half of the 1990s (Mathews et al. 1998) and by indirect estimates of Mexican Immigration Mexican-born, U.S.-resident fertility rates between 1980 and 2000 from open-birth-interval data (Schmertmann et al. 2002). This finding suggests that the main underlying force driving the trends of the fertility rates of Figure 2-3 is immigration. It aids in the interpretation of differences in the fertility trends by age group. One feature here is that the fertility rates for women who are older than age 30 is partly due to the greater sensitivity of the rates for women younger than age 30 to fluctuations in migration during these high-migration ages. It may also be partly due to the aging into their 30s over the 1990s of the large immigrant inflow of Mexican women in their 20s in the immediate post-IRCA period.

A further feature, seen for all age groups in Figure 2-3 and in the all-births series of Figure 2-2, is the sharp upward movement again in 1999. The latest aggregate birth statistics from the United States (Martin et al. 2002) confirmed that this upward movement continued at least into 2000. The robustness of such movements in the series is unsurprising, given (1) their likely dependence on increases in the exposed population of Mexican-born women who are resident in the United States, since it is unlikely to be reversed from one year to the next, and (2) the precision of the U.S. birth-registration statistics, compiled with greater than 99% overall completeness (Martin et al. 2002). This robustness contrasts markedly with statistics on immigration that fluctuate from year to year in ways that have as much to do with their method of collection or estimation as with real year-to-year trends (witness the large 1991 spike in the number of immigrants recorded as part of the IRCA legalization program). Above all, though, we see in Figure 2-3 a relatively well-behaved set of age-specific fertility rates that broadly reflect both known migration trends and known differences in fertility by age. Thus, these previously untested rates (the c_{2m}) are likely to behave reasonably as parameters of a projection model. We now turn to those results.

Projections to 1999

We compare the performance of our SCBC projections with those of the two single-region cohort-component models (the IGN and IGS) against observed data on births. We first project U.S. births to Mexican-born women up to 1999 from the same two base years, 1982 and 1994, used in projections of the Hispanic population by the U.S. Census Bureau (Day 1996; Spencer 1986) and, for 1994, as used in the NRC's projection of the Hispanic population (Smith and Edmonston 1997). The two different base years, 1982 and 1994, allow for comparative evaluation of the SCBC model over periods that began both before and after the big rise in the U.S. childbearing rates of Mexican-born women (the c_{2m} of Figure 2-3). Projection to 1999 also allows us to focus on differences between the SCBC and IGN and IGS models in the process of generating births of second-generation immigrants-in our terminology, the B_{2m}.[6] Recall that this is the only part for which the SCBC model is unique. The SCBC projections hold the single-year age-specific c_{2m} rates constant at their values in the 1982 and 1994 base years, respectively, and apply them to the female 0-year-old time series of Figure 2-1. The separate

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[6]The second-generation immigrant females born in 1983 were only 16 years old in 1999 and by then had few children themselves. The U.S. birth-registration system did not allow us to identify births specific to the birthplaces of the grandmothers. Therefore, we omitted the few B,3 that emerged in the last years of the projec-tion. We further note that 0.87% B,2 in 1999 were to Mexican-born mothers who reported Mexico as their country of residence and so speak only loosely of "immigrant fertility" when discussing the B2m. We included these U.S. births to Mexican-resident women because our goal was to project U.S. births to Mexican-born women without regard to the women's immigration status.

immigration and fertility parameters of the IGS and IGN projections are as described in the Data and Methods section.

The results of the projections to 1999 are given in Table 2-2. In the 1982 base-year projection, all three methods substantially underpredict births to Mexican-born mothers, as we would expect in view of the large rise in Mexican immigration in the late 1980s to early 1990s associated with the IRCA "shock" to the Mexico-U.S. immigration process. The SCBC method, however, performs far better than either the IGN or IGS methods. The 96,484 births to Mexican-born mothers that are estimated for 1999 using the SCBC method are 58.4% of the observed 1999 births, whereas the IGN and IGS methods project only 18.9% and 23.2% of observed births, respectively.

Table 2-2: Projected Number of U.S. Female Births to Mexican-born Women (B_{2m}) in 1999

Method	Base Year 1982 B_{2m}(1999)		Base Year 1994 B_{2m}(1999)	
IGN	31,212	(18.9)	96,826	(58.6)
IGS	38,333	(23.2)	118,916	(72.0)
SCBC	96,484	(58.4)	157,201	(95,2)
Observed	165,116		165,116	

Notes: Numbers in parentheses are percent of observed B_{2m}.

The second column of Table 2-2, for base year 1994, also reveals a much better forecasting performance for the SCBC method than for either the IGN or the IGS method. From 1994 to 1999, the observed number of U.S. births to Mexican-born mothers rose by 14.9%, from 143,731 to 165,116. The SCBC method predicts the part of this increase that is accounted for by increasing sizes of successive Mexican female birth cohorts. Thus, our forecast is only 6.2% lower than the observed number of births. The IGN approach, meanwhile, underpredicts by as much as 41.4% of the observed 1999 target. Allowing for higher fertility rates for the first-generation immigrants in the IGS approach reduces this error to 28.0%.

In one way, the implied comparison between the Census Bureau's and the NRC's methodologies is unfair because the higher fertility rates of third- and higher-generation Hispanics in the Census Bureau's method will compensate, to some degree, for the lower first-generation immigrants' rates – and here we used only the first-generation immigrants' rates.[7] Hence, the results from the two methods would be closer if the methods had been adapted to project all Mexican-origin births and population – a goal that is closer to the stated goal of the Census Bureau's projections of the Hispanic-origin births and population. We should note that in a period of high immigration, such as the 1980s and 1990s, however, the Census Bureau's immigrant-generation-neutral approach to fertility will fail to account for changes in fertility that originate in the changing generational composition of the Hispanic- or Mexican-origin population.

The most striking finding of these comparisons, though, is that the SCBC model's performance is so much better than the performance of either the IGN or IGS methods. That is, the application of the U.S. childbearing rates of Mexican-born women (the c_{2m},) directly to the Mexican birth cohorts results in predictions that are much closer to those of observed births than to those from applying any kind of resident fertility rate to projections of the Mexican-born U.S.-resident women. This finding suggests that a substantial part of the errors of the IGN and IGS methods may be rooted in the projected

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[7] In a longer-term projection, when some of the second-generation immigrants become grandmothers, we would observe a compensating effect with the IGN approach, in which the fertility rates for third- and later-generation immigrants are higher than the IGS approach uses. No such compensating effect is observed in the projection to 1999 because of the short time span and because no second- or later-generation immigrants were included in the initial population

populations of U.S.-resident Mexican-born women of childbearing ages. These errors can arise from either the projection base-year estimates or from projected net immigration in the subsequent five years, or both. Our suspicion that errors in estimating the base-population immigrant stocks may be a major factor was raised by our noting that the projection described in the U.S. Census Bureau (Day 1996:26) uses a base-year population that is not adjusted for population underenumeration.[8] Corrections for census underenumeration are especially difficult to make for populations with substantial proportions of non-native-born people because the cohort-survival basis of corrections by the demographic-analysis method is undermined. The presence of a substantial number of individuals with irregular legal residence status, as is the case among Mexican-born U.S. residents, makes the correction for underenumeration still more difficult, but also more necessary.

Table 2-3: Projection From 1990 to 1991 of U.S. Female Births to Mexican-born Women (B_{2m})

Method	IGN	IGS	SCBC	Observed
No immigration post census date	75,763(61.8)	93,048(75.8)	–[a]	–[a]
½ annual immigration added	78,357(63.9)	96,233(78.4)	–[a]	–[a]
No Immigration assumption	–[a]	–[a]	123,928(95.6)	–[a]
Observed 1991 births	–[a]	–[a]	–[a]	129,610

Notes: Numbers in parentheses are percent of observed B_{2m}.
[a] Not applicable

We explored the problem of census underenumeration as distinct from problems of estimating intercensal immigration in a supplementary projection from the 1990 census year to just one year ahead for births in 1991. The aim of the short projection

[8] The inflation-deflation variant, however, adjusts the population for an undercount before the fertility rates are applied to get the number of births in each year of the projection

period of our 1990 to 1991 projections is to minimize the effect of errors in the estimates of net migration flows and of changes in fertility rates, allowing us to draw some tentative inferences about the impact on projection error of underestimation of immigrant stocks in the census. To account for the potential effect of the immigrants who did arrive in this short time, we conducted the projection alternately with and without immigration.[9]

Table 2-3 presents the projected number of births one year ahead with 1990 as the base year, using the three different projection methods. The IGN forecast with no immigration between 1990 and 1991 is a striking 38.2% short of the observed 1991 births to Mexican-born women. By including half the estimated annual net immigration, we found that the resulting 2,594 births reduce the shortfall by only about 2.1 percentage points. When we introduced generation-specific fertility rates into the calculation, we saw a large improvement in the projection. The error component is reduced to either a 21.6% or 24.2% short-fall, depending on whether we added immigration. The SCBC projection (column 3 of Table 2-3) shows that the remaining problems of underestimating the stocks of Mexican-born females who are resident in the United States can be largely overcome by applying the c_{2m} rates directly to the Mexican birth cohort, without explicitly estimating their migration flows to and from the United States. The SCBC projection misses only 4.4% of the observed number of births. (Note that if the SCBC approach were used with 1990 c_{2m} rates to produce 1990 B_{2m}, we would, by definition, get exactly the registered number of births.) We thus conclude that the large errors in the IGN and

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[9] Because we do not know the month of entry of those immigrants, we assume uniform distribution in the 12 months. By this method, each net immigrant would, on average, be half a year in the United States. Thus, we add half of annual immigration in the beginning of the interval

IGS projections of births to 1999 arose not only because of problems of estimating annual net immigration but also because of problems with the census enumeration that feeds into estimates of the base-year resident Mexican-born female population. Because these errors

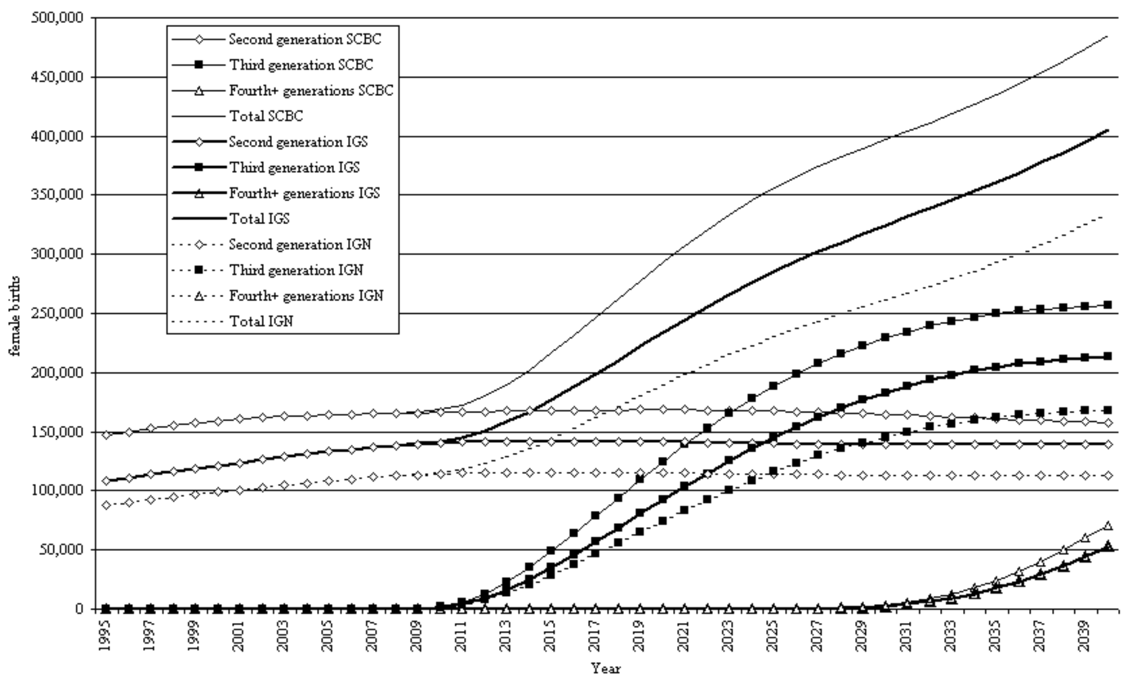

Figure 2-4: U.S. Female Births to Mexican-born Women (B_{2m}) and Descendants of These B_{2m} From the Sending-Country Birth Cohort (SCBC), Immigrant Generation-Specific (IGS), and Immigrant Generation-Neutral (IGN) Projection Methods, 1995–2040

are in the projection base-year population, their effect will carry over into all years of a projection, so we can expect a substantial resulting downward bias in both the Census Bureau's and NRC's projections from 1995 to 2040.

Projection from 1995 to 2040

The results for the three models' projections of the number of births in each generation and for the total number of births each year to 2040 from the 1994 base year are presented in Figure 2-4. The projection series conveys information that is different from the projections of Day (1996) and Smith and Edmonston (1997), since we focused only on the Mexican-born female population and their U.S. descendants who were born after the base year. Because we focused on this specific subgroup of the population, the relative differences in the size of the total number of births projected from each of the three methods is time dependent. In the first 15 years when only second-generation births (B_{2m}) are produced, the difference between the SCBC projection and the projections of the IGS and IGN models is the greatest. In 1995, the first year of the projection, the SCBC approach results in 67.0% more B_{2m} than the IGN approach and 35.9% more than the IGS approach. From the first year to 2010, these percentages slowly decline to 45.8% and 18.9%, respectively, and then increase again to a second peak in 2022 (55.0% and 25.6%). Thereafter, the proportions decline again until they reach 45.0% and 19.9%, respectively, in 2040. This second decline follows the slowly declining sizes of the Mexican birth cohorts that were observed from the late 1980s and are projected to continue into the twenty-first century. This dependence on the sizes of the Mexican birth cohorts, following the principles of cohort-component models for demographic projection, differentiates it strongly from a purely time-series approach to exploiting the U.S. and Mexican birth-registration data.

When third-generation births (B_{3m}) start to emerge, we observe a stabilizing effect on the comparisons, since all three methods assume the same ASFRs for second-generation Mexican immigrants (the TFR for second-generation Hispanic immigrants in Smith and Edmonston 1997 is the same as for all Hispanic immigrant generations combined). The IGS approach produces 22.8% more total births in 1995 than does the IGN approach.[10] This difference is approximately constant until it starts to increase slowly from 2012, peaks in 2030 at 24.3%, and declines again to 21.1% at the end of the projection.

Table 2-4: Projected Number of Female Births in 2040, by Generation: U.S. Births to Mexican-born Women (B_{2m}) and Descendant Births (B_{3m} and B_{4+m}) After 1994

Method	B_{2m}	B_{3m}	B_{4+m}	Total
IGN	*112,870*	168,125	53,243	334,238
IGS	*138,778*	213,308	52,772	404,858
SCBC	*157,623*	256,490	71,290	485,404

Births in the year 2040 alone are presented in Table 2-4. By 2040, third-generation births are produced in greater numbers than are second-generation births because of the above-replacement fertility levels of second-generation immigrants, combined with the first-generation resident immigrants gradually becoming constant in number and composition under the IGN and IGS approaches, and with the decline in

[10] This proportional difference is, by the model definitions, exactly the same as between the TFR for first-generation Hispanic immigrants and all Hispanic generations combined that was reported in Smith and Edmonston (1997:434).

Mexican 0-year-old females beginning in 1996 under the SCBC approach. By 2040, descendant granddaughters have also produced a sizeable fourth generation.[11]

Table 2-5: Cumulative Total Number of Female Births From 1995 to Selected Years, Summed Across Generations, 1995–2040 Projection

Year	IGN	IGS	SCBC
2000	561,566	689,679	920,983
2005	1,085,200	1,332,774	1,733,965
2010	1,649,084	2,025,302	2,565,293
2015	2,299,568	2,824,272	3,527,334
2020	3,156,266	3,877,601	4,838,986
2025	4,230,869	5,205,177	6,502,683
2030	5,477,501	6,753,078	8,412,023
2035	6,875,483	8,484,611	10,508,635
2040	8,459,378	10,418,065	12,829,301

When the total number of births in the entire projection period is summed across all generations (see Table 2-5), large cumulative differences among the three methods are seen. The overall contribution of female births to Mexican-born mothers after 1994 is, for all three methods, substantial-8.5, 10.4, and 12.8 million additional female births from the IGN, IGS, and SCBC models, respectively. The 51.7% more births that are produced by the SCBC method than by the IGN method represents about 2.3 times a complete female birth cohort in the United States at current levels. Almost half this difference is picked up by the IGS approach, again reflecting the importance of allowing for different fertility

[11] When comparing the B_{4m} projected by the IGS and IGN approaches, we noted a pivoting effect of the ratios of TFRs for different Mexican immigration generations that results in almost an exactly equal number of births of fourth-generation females in 2040. Although the number of third-generation births (B3,) is consistently smaller in the IGN approach than in the IGS approach, these births are later, when old enough, exposed to higher fertility rates in the IGN approach than they are in the IGS approach, and the two factors cancel each other out.

rates for different immigrant generations. Thus, the cumulative births from the SCBC model are still 23.1% greater than those projected by the IGS model.

Accumulating Observed Births From 1982 to 1999 and Projected Births From 2000 to 2040.

The 1995–2040 projections estimate the number of direct and descendant-generation births to Mexican-born woman after the base year. An estimate that speaks more to the total impact of recent decades of Mexican immigration comes from our accumulating births to Mexican immigrants and their descendants from 1982 to 2040, observed up to 1999, and then projected using the SCBC model from 2000. Here, we use Mexican birth cohort rates of childbearing in the United States (c_{2m}) from 1999, the latest year for which data on U.S. births are available. The projected births include third- and later-generation births descending from women born in the United States after 1981 to Mexican-born mothers, both descending from those women whose own births were observed from 1982 to 1999, and descending from those women whose own births were projected from 2000 to 2025. These descendant births are projected with the same assumptions of a constant fertility rate as used in the 1994 base-year IGS and SCBC projections discussed earlier, since we lack more recent U.S.-resident Mexican fertility rates.

The results are presented in Figure 2-5. As before, we see a sharp increase in the size of B_{2m} in the late 1980s and early 1990s. Unlike the total births of the 1995–2040 projection for the SCBC shown in Figure 2-3, we now see that as early as 1997–1998, the total number of births started to exceed the B_{2m}. By then, those born in 1982 had reached the reproductive years, so third-generation births B_{3m} slowly start to emerge. By 1996, Mexican-born women were giving birth to about 151,000 daughters in the United States. We project that this number will rise to a peak of 177,300 per year in 2019. By 2018, B_{3m} will overtake B_{2m}, and by 2032, there will be more than half a million additional female births in the United States per year that are due to post-1981 U.S. births to Mexican-born women, either directly or through the childbearing of their U.S.-born daughters; granddaughters; and, in some cases, great-granddaughters.[12]

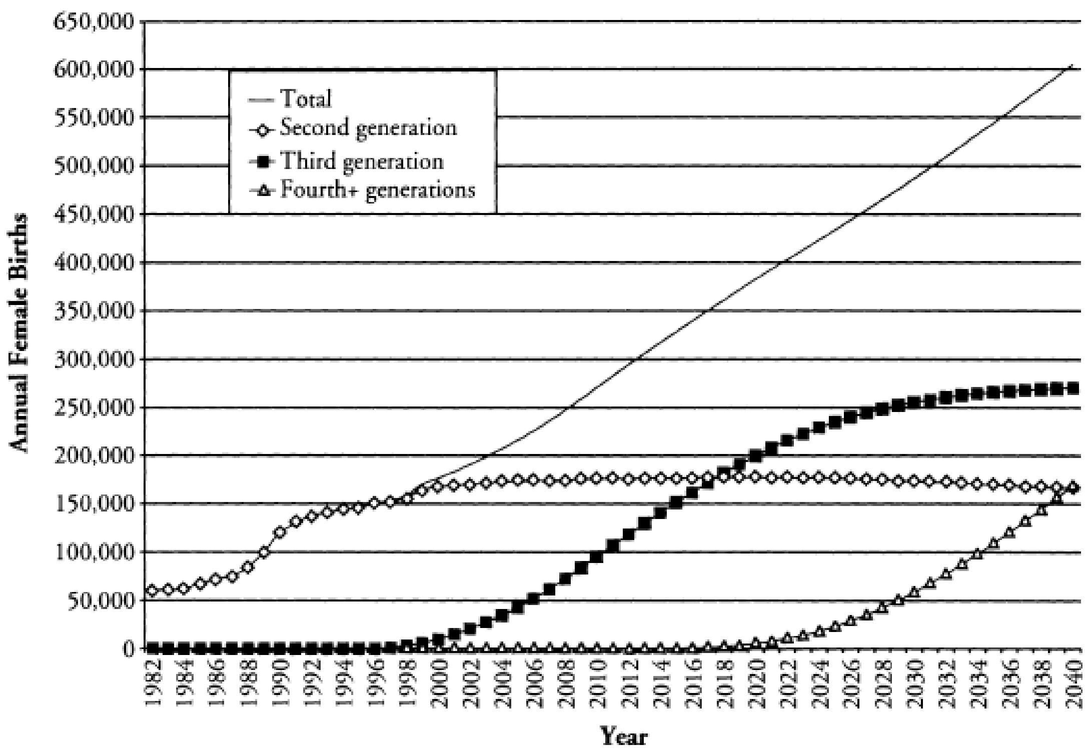

Figure 2-5: Female Births to Mexican-born Women (B,) and Female Descendants of These B_{2m}, Observed From 1982–1999 and Projected by the Sending-Country Birth Cohort (SCBC) Method From 2000–2040

[12] The total accumulated number of births in the last column of Table 5 cannot be compared directly to the accumulated number for the SCBC approach in Table 6 because of the number of factors that are different

Table 2-6 reports an accumulation of the number of births for selected years presented in Figure 2-4. There were approximately 2.2 million female births to Mexican-born women from 1982 to 2000. Thereafter, the births are projected to accumulate at a rate of approximately 1.7 million per decade, with the 2010–2020 decade seeing a peak accumulation of 1.77 million. The rate of total births contributed, including descendant births, continues to increase throughout the projection period, reaching 5.5 million in the 2030–2040 decade. A total of 17.7 million female births are accumulated over the entire 1982–2040 period as a result of Mexican immigrants' fertility after 1981.

We put this estimate of the cumulative contribution of Mexican immigration since the early 1980s to subsequent years' U.S. fertility into the perspective of the total projected working-age and elderly populations in the United States. We again focus on the year 2040. This is about the peak year for the percentage of older persons in the U.S. population, following the major waves of baby boomers' entry to old age. We estimate that of the total 36.2 million additional male and female births (applying a factor of 2.05, the usual sex ratio at birth) projected to 2040, 19.3 million of them would be aged 16 to 58 (if they were still alive), and the remaining 16.9 million would be aged 0 to 15. Neither figure, however, is adjusted down for mortality or emigration. Furthermore, we do not make any projections of first-generation Mexican immigrants as they age or of Mexican parent or grandparent generations that may be added to the U.S. population as they join their U.S. descendants. Bearing these provisos in mind, in the "middle series" projection of Day (1996), the total U.S. population aged 65 and older is 75.2 million, and

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(births before 1995, different SCBC fertility rates, more births observed than projected from 1995 to 1999, and interactions among those factors).

the projected number aged 16 to 64 is 215.9 million. Thus, as a rough approximation, the post-1981 Mexican migration flows have a potential to generate up to 1 additional working-age person for every 4 retirement-age Americans and for every 10 working-age Americans in 2040.

Table 2-6: Accumulation of Observed (to 1999) and Projected Second- (B_{2m}) and Later-Generation (B_{3m} and B_{4+m}) Female Births From 1982 to Selected Years (SCBC Method Projection)

Year	B_{2m}	B_{3m}	B_{4+m}	Total
1982	61,788	0	0	61,788
1990	699,571	0	0	699,571
1995	1,395,579	0	0	1,395,579
2000	2,184,674	18,183	0	2,202,856
2010	3,914,536	519,618	1	4,434,155
2020	5,682,432	2,069,287	13,865	7,765,585
2025	6,565,970	3,178,228	86,819	9,831,017
2030	7,437,747	4,417,950	300,500	12,156,196
2040	9,127,257	7,072,480	1,460,282	17,660,020

Summary and conclusion

In one sense, it is axiomatic that the long-term contribution of immigration to a receiving country's population depends on the immigrants' reproducing themselves in subsequent, native-born generations. The results from stable-population models, moreover, indicate that differences in the fertility of immigrants and the native born are likely to be the primary cause of any rejuvenation of the population induced by immigration. Previous projections that addressed the potential for immigration to check the aging of low-fertility populations, however, have emphasized the number and age distribution of immigrants, not their fertility.

This study took an opposite tack, ignoring the process of taking up residence in the receiving country, and instead picking up the immigrants' contribution to the receiving country's population from the time that the immigrants give birth there. In doing so, we moved the focus of questions about the impact of immigration directly to the issue of how many young people are introduced to the receiving country's population. We estimated that Mexican immigration since the early 1980s will have produced 36.2 million additional births in the United States up to 2040, slightly more than half of which will have occurred by 2023. By around 2031, the annual additional births contributed by ongoing flows of Mexican immigrants, together with the births of second-generation immigrants after 1981 and all their U.S. descendant generations, will rise to over a million. Currently about 4 million births occur annually in the United States, just under 9% of which are to Mexican-born mothers.

We projected these sizable contributions of Mexican immigration to U.S. fertility by developing and applying a novel method, which we referred to as the SCBC method. This method replaces the projection of the dual processes of immigration and immigrants' fertility with the projection of a single process of births in the receiving country to women who were born 15 to 44 years earlier in the sending country. The major advantage of the SCBC method is that the denominators for the fertility rates-the female Mexican birth cohorts-are also our estimates of the women who are projected to be at risk of giving birth in the United States. The number of these Mexican birth cohorts is likely to be known with much greater certainty than is the number of Mexican-born women who are resident in the United States during the various points in the projection period. We have shown in this study that the childbearing rates that are calculated by combining U.S. births to Mexican-born mothers with the earlier Mexican female birth cohort denominators were relatively stable through most of the 1980s and 1990s, broken by a steep rise in the late 1980s. Their relative stability, especially in the 1990s, provides a promising first indicator of their usefulness for projection.

More promising still for the potential merits of the SCBC method, however, are the comparisons we made between the SCBC and traditional projection methods over periods for which we have observed births. Projecting to 1999 alternately from the 1982 and 1994 base years, we found that all the methods underpredicted 1999 births to Mexican-born mothers. However, the level of the SCBC's underprediction is much less than that of the more conventional methods (between one-tenth and one-half of their error). The SCBC method predicted 58% of the 1999 births when data only up to 1982 were used and 95% of the 1999 births when data up to 1994 were used. In contrast, the conventional methods predicted only 19% to 23% of the 1999 births when data only up to 1982 were used and only 59% to 72% of the 1999 births when data up to 1994 were used. When we further projected the number of births to Mexican-born mothers and consequent generations from 1995 to 2040, we found that the accumulated 12.8 million female births by 2040 projected by the SCBC method exceeded that of the conventional methods by 2.4 and 4.4 million, respectively. Thus, we conclude that to the extent that the Census Bureau's and NRC's latest projections of the Hispanic population have been relied on to assess the role of Mexican immigration, the future impact of Mexican immigration on the future U.S. population has heretofore been significantly underestimated.

Our comparisons of the IGS and IGN methods indicate that the Census Bureau's generation-neutral method of averaging fertility rates across immigrant generations results in too few projected births to first-generation Mexican immigrants. The generation-neutral method will therefore also underpredict the total births across immigrant generations when flows of new immigrants increase, as they have done recently in the United States. However, the projection deficits of the IGS and IGN approaches also have a large common factor, that of the underestimation of the base population. In diagnosing the defects of the conventional, single-region cohort-component methods, we found the degree of underestimation of Mexican-born, census-enumerated base population to be surprisingly large and influential. As we noted, correction for the census's underenumeration of the Mexican-born population presents much greater challenges than for the native-born population, both for technical reasons (demographic analysis is a cohort-survival technique and so is better suited to estimating the underenumeration of native-born populations) and because of the greater problems in enumerating a foreign-born population containing a substantial number with irregular legal statuses in the United States. The large degree of empirical inaccuracies in observing international migration processes (both immigration and emigration) makes estimation of a base population of Mexican-born persons in a year between censuses even more subject to error. Thus, the problems for projection are deeper than can be handled by improving the specificity of fertility rates to account for differences in fertility among generations. The NRC's IGS method, which we presented as a variant of the Census Bureau's IGN approach, inherits the same fundamental data problems.

The advantages of the SCBC approach are that it combines (1) the data advantages of a more time-series-oriented approach to first-generation fertility (by using the U.S. birth registrations to Mexican-born mothers) with (2) a more thoroughgoing application of cohort-component principles than are found in the conventional single-country projection models (by using the Mexican birth cohorts as the base to project U.S. fertility to Mexican born women). Over a short time, the main reason the SCBC approach performs better is that it is more akin to a simple time-series forecast, using the previous year's births to project the next year's births. The advantages of this time-series approach are in both the timeliness and accuracy of these U.S. birth-registration data. These advantages are especially important in the difficult-to-observe spheres of demographic activity of international migration and immigrants' fertility. To emphasize the problems of the more standard projection approaches with respect to both the timing and accuracy of the required input data sources, only by waiting until the 2000 census was it found how deficient have been the data on both the Hispanic immigrant stocks and the flows of immigrants and the Hispanic immigrant fertility rates that rely on estimates of the resident immigrant population for their denominator. All these parameters (immigrant stocks and flows and resident-immigrant fertility rates) are required by the conventional projection models, while none of them are required by the SCBC model. The results presented here lead us to believe that data on recent births implicitly also capture the postcensal immigration of childbearing-age women more effectively than do methods that attempt to estimate this immigration directly. This advantage will then carry over into the projection period. Poorly measured net-immigration numbers and immigrants' age-sex composition are likely to be a poor basis for forecasting the number of immigrants and the age-sex composition of immigrants during the projection period.

Over a longer horizon, the U.S. time-series element of the SCBC projection is gradually less important, and trends in the Mexican birth-cohort time series become increasingly important. Here, the effect of applying the SCBC approach to Mexican-born women's U.S. fertility is first to model the U.S. fertility impact of the substantial increases in the sizes of Mexican cohorts who entered the peak childbearing (and peak migrating) ages in the 1980s and 1990s and then to model the impact of the leveling off and decline of these cohort sizes that is set to occur in the early twenty-first century. The overall trend of a decline in the sizes of Mexican birth cohorts from their mid-1970s peak also means that our projections are implicitly based on assumptions about trends in net immigration that quickly become more conservative than the assumptions of a constant number of immigrants of the Census Bureau and NRC projections of the Hispanic-origin population in the United States to the middle of this century. Thus, our results indicating a much higher contribution of ongoing and recent decades' Mexican immigration to fertility in the United States in the late twentieth and early-to-middle twenty-first centuries are rooted much more in better exploitation of the available data on what has already occurred than they are on assumptions about what has yet to occur.

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Appendix A:

Estimation of the Parameters of the three Projection Models

Details are given in this appendix of the methods used to estimate the parameters of the three different projection models. The 1994-based and 1982-based projection parameters are described, along with modifications for the 1990-to-1991 projection.

The Sending Country Birth Cohort (SCBC) Model

The SCBC model projects US births to Mexican-born women who survive to completed-age 0 (on average, approximately 0.5 years old). The cohorts of 0 year-olds who would be aged *a* in year *t*, $P_m(0,t\text{-}a)$, are obtained from population estimates (1950–1995) and projection (1996–2050) of the Mexican population by single year of age and sex published by the Economic Commission for Latin America and the Caribbean (ECLAC 2000a, 2000b). For the 1994- and 1982-base-year SCBC projections, 1945–1949 and 1933–49 cohorts respectively are also needed. The number of zero-year old women in year t <1950 is estimated as:

$$P_m(0,t)=B_m(t)\frac{P_m(0,1950)}{B_m(1950)}*\frac{1-IMR(t)}{1-IMR(1950)} \qquad \text{(A1)}$$

where IMR(t) is the Mexican infant mortality rate in year t, and is obtained, along with pre-1950 Mexican birth registration numbers from United Nations (various years).

The use of ratio of the two infant survivor probabilities is to account for changes in the IMR, assuming constant level of registration errors in all five years. This assumption is based on parallel trends in registered number of births and the number of zero-year olds from 1950 to about 1970, when registration problems seem to have worsened.

The SCBC model's age-specific fertility rates (c_{2m}) use as their denominators the Mexican 0 year-olds who would attain ages 15 to 44 by 1994 or 1982 respectively, estimated as described immediately above. Their numerators of US female births to Mexican-born mothers, B_{2m}, by age of mother and year, are obtained from the public use data files of the National Center for Health Statistics (various years). We allocate the small numbers of recorded births to 10–14 year-old and to over 44 year-old mothers to 15–year-old and 44-year-old women respectively.

We use estimates of 0 year-old Mexican females instead of Mexican female births primarily because of deficiencies in the Mexican birth registration system. In particular, the quality of the birth registration in Mexico declined in the early 1970s. Registered births are reported by the year of registration, not the year of the birth. In 1935, 4.5% of all birth registrations took place after the first birthday of the child, but this proportion that had risen to 32.6% in 1974 (Campos 1998). Part of this large proportion is a result of late registration, which is associated with out-of-wedlock births. An unknown, presumably substantial, proportion of registration of 1 year-olds results from the fact that it is easier to get a new birth certificate, swearing the child has not been registered before, rather than going through the problems associated with requesting a certified copy of an existing one. The magnitudes of such double counting is unknown, and there appears to be no official series available that includes a correction for this problem.

Immigrant Generation Neutral (IGN) and Immigrant Generation Specific (IGS) Population Projection Parameters

The IGN and IGS methods respectively correspond to Mexican-only (and female-only) versions of the Census Bureau's and National Research Council’s (NRC) Hispanic projection methods (Smith and Edmonston 1997), with the NRC’s method simplified to exclude the possibility of self-attributing out of the Hispanic population. All projections (except for the 1990 projections) are from January 1st to December 31st to capture annual number in a calendar year of births consistent with the birth registration system.

For the IGN projection, we replicate as closely as possible the middle series projection parameters stated in the respective publications (Day 1996; Spencer 1986). The NRC projection uses the same base-population and immigration parameters as the 1994-based Census projection, and both use 1994 age-specific fertility rates. The only difference is that NRC’s fertility rates are immigrant-generation specific (and estimated from the CPS instead of registered births combined with population estimates). We are therefore able use the same assumptions to transform the projection parameters for the Hispanic-origin population into those for the Mexican-origin population in both the IGN and IGS models.

Day (1996) uses Hispanic population estimates from Byerly and Deardorff (1995), which are based on the 1990 census count with modification such as adjustment for age heaping but not for census undercount. Our initial population consists of 0–49 year old Mexican-born women in the US from the 5% public use micro sample (PUMS) from the 1990 US census (US Census Bureau 1992), aged and survived three fourths of a year ahead to January 1, 1991, and annually thereafter to December 31, 1994. Further, we add three fourths of the 1990 annual immigration, and annual amounts to December 31, 1994. Immigration numbers (of Mexican-born women) for these four years (1990–1994) are obtained from the United States Immigration and Naturalization Service (1999) and United States Immigration and Naturalization Service and United States Bureau of International Labor Affairs (1999). Footnote 14 on page 28 in Day (1996) suggests the immigration assumptions in the projection are consistent with the population estimates from 1990–1994 in Byerly and Deardorff (1995). Consequently, our method of obtaining net-immigration of Mexican-born from the net-immigration of the Hispanic origin applies average annual net immigration, as is described in the paragraph immediately below. In moving their base population forward after 1994, the Census Bureau uses an inflation-deflation variant of the cohort-component projection method. The race-, age-, and sex-specific inflation-deflation factors used in the Census Projection are by policy not publicly available, and so they cannot be implemented in current study. The Census Bureau applies to white-Hispanic females the same factors as for all white females (G. Spencer, personal communication). Thus they will anyway miss the higher undercount of the Hispanic foreign-born population.

Immigration assumptions for the 1994 base year projections are derived from the method and numbers for Hispanic-origin immigrants described in Day (1996) and additional sources to extract the Mexican-born immigrants from stated assumption about Hispanic-origin immigration. The immigration assumptions are derived by the following steps.

First we identify the net-immigration of Hispanics in the Census Bureau projection in Day (1996) and for the population estimates from 1990–1994 in Hollmann et al (1998).

From the 1990 Census PUMS data we identify the proportion of the immigrants for each Hispanic-origin country that identify themselves as Hispanic. This method is in line with method employed in the US Census Bureau (1997).

Based on these proportions and immigration numbers from the INS (United States Immigration and Naturalization Service 1999) in 1980–1989 we find the proportion of legal Hispanic immigrants that are from Mexico.

Using estimates of emigration (Ahmed and Robinson 1994) from the US, we find annual emigration of Mexican of 20,068, and 23,807 other Hispanic emigration.

For the undocumented immigrants we find that of the 225,000 annual net increase of undocumented immigrants used in the Census population estimates (US Census Bureau 1997), 150,000 are believed to be Mexican (US Immigration and Naturalization Service and US Bureau of International Labor Affairs 1999). We estimate that 37% of the remaining 75,000 are of other Hispanic-origin based on numbers from Table 2.4 in Woodrow and Passel (1990) and Hispanic-origin proportion of persons in the 1990 PUMS (authors' tabulation), born in the same world regions as specified in that table. This calculation suggests that of the 225,000 undocumented immigrants, 34,069 (15.14%) of those are of other Hispanic-origin (Hispanic origin population born in other continents than Europe, North- and South America are small enough to ignore).

Combining the numbers from b) to e) above, we find that Mexican are 67.2% of Hispanic net-immigration to the U.S. from 1980–1989.

With the proportion from f) and numbers from a) we get the estimated net-immigration from Mexico year by year for 1990–1994 estimates and 1995 onwards for the projections.

We distribute the Mexican-born net-immigration to age/sex groups in the same proportions as net-immigration is reported in Day (1996). From this population we extract the female population 0–49 year-olds.

Mortality for the 1990–1994 population estimates and the US survivorship functions are obtained from the life table that yields life expectancy at birth for Hispanic-origin females that is consistent with the middle mortality series in Day (1996). In all projections we assume that mortality rates for the first 50 years of life for the Mexican-origin female population are each equal to the mortality rate for the corresponding age groups in the total Hispanic population. We further assume that mortality rates are the same for all immigrant generations (recalling that mortality rates are applied only up to the end of the reproductive ages).

Fertility rates are specified for the Hispanic population in Day (1996 table A-7), using the middle fertility assumptions. We distribute the rates to single years of age such that the rates are equal to single-year-age-specific Hispanic fertility rates in 1999 in the 1999–2100-population projection (Hollmann, Mulder and Kallan 2000) times a constant equal to the ratio of corresponding five year ASFR in Day (1996) and Hollmann et al (2000). In this and all other IGN and IGS projections, the age-specific fertility rates (ASFRs) are divided by 2.05 to project female births only. To allow for higher estimated fertility rates for Mexican-origin population (in the US), we multiply single year ASFR by the ratio of Mexican-origin ASFR over Hispanic-origin ASFR reported in Table 1 in Mathews et al (1998).

ASFRs for the IGS approach are derived from the rates above. Since ASFRs specific for different Mexican-origin immigrant generations are not available, we assume the ratios of TFRs in table 3.3 in Smith and Edmonston (1997) for different Hispanic-generation immigrants applies to the Mexican-origin population. We multiply each ASFR rate described above by the ratio of the appropriate Hispanic generation's TFR to the overall (all-generations) Hispanic TFR. The ratio of first-generation to all-generations TFR is 3.23/2.63 = 1.228, the ratio of second-generation to all-generations TFR is 2.63/2.63 = 1.000 and third-plus generations to all-generations is 2.04/2.63 = 0.776.

The infant survivorship term to survive births to 0-year old is defined as S(0.5) = L(1)/l(0). For our 1995–2040 and 1999–2040 projections, the values of L(1) are obtained from those used in the Census Bureau projections for 1999–2100 (U.S. Census Bureau 2000b), where single-year age survivorship terms are reported. For the 1982-based projections, the values are taken from the projection in Spencer (1986).

1982 Base Year Projections

The initial population for the 1983–1999 projection is estimated at December 31, 1982. We start with the Mexican born females from 0–49 year of age in the 1980 5% PUMS. We add three-eighths of the 1980 Mexican born immigrants to the census count population (assuming that post-census 1980 immigrants arrived on average half-way into the post-census interval). Then we survive this population three-quarters of a year to

December 31, 1980, and add the remaining three-eighths of the 1980 immigrants. This step is repeated for the complete years 1981 and 1982 to get the December 31, 1982 Mexican-born female population. Consistent with Spencer (1986) middle series that assumes no undocumented immigration, the immigration added to the 1980 census count consists entirely of those documented by the INS (US Immigration and Naturalization Service various years).

Immigration in the 1983–1999 projection is derived from the middle assumption described as being constant at a level close to the immigration in the preceding decade (Spencer 1984, 1986). Since this middle net immigration assumption assumes no undocumented immigration, we go directly to the INS publication compute the mean annual immigration from Mexico. We distribute the immigrants in age/sex groups in same proportions as observed in Spencer (1986). Because we lack data to estimate the return migration to Mexico, we set this return migration rate to zero rather than risking a too high assumed return migration, and so we instead risk overestimating the net immigration of Mexican born relative to the method which we seek to replicate.

In adapting the all-Hispanic fertility rates reported in Table A-1 of Spencer (1986) to Mexican-origin women, we note that the TFR for Mexican-origin women is not available for 1982. Ventura (1985), however, reports the general fertility rate for Mexican-origin and all Hispanic-origin females. Despite its limitations, we use this ratio as the only one available to inflate the ASFR Hispanic-fertility rates to represent Mexican fertility in the IGN and IGS projections. As there are also no available estimates of fertility in different Mexican immigrant generations in or before 1982, we use the 1994 TFR ratios described above.

The 1990 Projection

Unlike the other IGN projections presented in this paper, the 1990 projections are not replications of other published population projections. The base year population is the 1990 census count, tabulated from the 5% PUMS. Total fertility rates are those reported for Mexican-origin women in 1990 in National Center for Health Statistics (1993, table 24). We again obtain single year age-specific rates by distributing the TFRs consistently with single-year ASFRs in US Census Bureau (2000b). As for the 1983–1999 projection, we do not have available estimated fertility level of different generation immigrants from Mexico. Again we use the ratios of Hispanic TFRs by generation in Smith and Edmonston (1997).

Chapter 3

THE CONTRIBUTION OF THE FOREIGN-BORN POPULATION TO U.S. FERTILITY: TOTAL FERTILITY RATE DECOMPOSITION

Abstract

When many industrial countries experience a fertility level well below replacement level, researchers have asked why U.S. fertility remains relatively high, with TFR at 2.08. Below-replacement fertility in the absence of migration will, in the long run, result in a diminishing population with a higher elderly dependency ratio that has a number of socioeconomic consequences, such as increased weight on the pension systems. While the cultural, sociological, and economic foundation of the migration-fertility link of Mexican immigrants has received considerable attention in the demographic literature, too little emphasis is placed on the nature of the demographic impact of the fertility contribution of immigration in the U.S. Lack of understanding of the formal demographic effect of immigration fertility may deter knowledge of the sociodemographic effect of an increase in immigrants with a high fertility schedule. A decomposition of the recent U.S. TFR into fertility and composition effects of Mexican-born and other foreign-born immigrants show that 6% of the U.S. TFR is attributable to a higher ASFR of immigrant women. About 63% of the foreign-born effect in 1990 and 71% in 2000 is attributable to Mexican-born woman. Approximately 11% of the Mexican-born contribution to the TFR is due to an age composition of the Mexican-born that favors the high-ASFR ages. The large increase in the size of the foreign-born population in the U.S. from 1990–2000 is mostly offset by reduced TFR of both the foreign-born and the native-born population.

Introduction

The question of why U.S. fertility remains relatively high has been of interest to demographers for some time (see 2001a). The total fertility rate (TFR) in the U.S. was 2.48 in 1970 (Ventura et al. 1999) and 2.04 in 2003 (Martin et al. 2005), and at the same time, Europe has experienced a much greater fertility decline, with countries like Germany, Spain, Italy, and Greece having a total fertility from 1.30–1.40 and the overall European total fertility rate at 1.5 (Population Reference Bureau 2007). Low fertility rates have raised concerns about economic and social issues such as reduced productivity and the future of the pension system (Europe) and Social Security System (U.S.) (Commission of the Europeans Communities 2005; Social Security Administration 2008). Despite widespread interest in the social and economic consequences of immigration, the importance of immigrant fertility to the demographics of the receiving population has received surprisingly little attention in the formal demographic literature.

Many western societies have experienced a fundamental change in family demographic processes over the last few decades. The OECD countries experienced a decline in total fertility rate from 2.9 in 1960 to 1.6 in the late 1990s (Adserà 2004). In the early 21st century, several southern European countries and Japan have a total fertility rate close to or less than 1.3 (Population Reference Bureau 2007). Billari (2005) argues that the new demographic regime of Europe, characterized by postponed union formation with delayed and reduced fertility rates, is likely to persist due to long-standing macro-level changes including cultural factors and family policies.

The long-term implication of an era of a reduced fertility level of a population after a long-term high fertility schedule is well documented. Due to population momentum, the population will continue to grow for some time before it will start to decline (Bongaarts and Bulato 1999). During the process, changes in the age structure of a population will be characterized by population aging, which is another aspect of population momentum (Kim and Schoen 1997). The aging population will continue to have substantial social and economic impact in most parts of the world, for instance on the pension systems, national productivity, labor force participation and increased need of a labor force to care for the sick and disabled elderly. A diminishing and aging population will also alter the size and age composition of consumers, voters, and investors, with widespread social impact.

The impact of a lasting below-replacement fertility schedule can be estimated by analyzing population changes in low-fertility countries (such as other OECD countries), by calculation of stable population parameters with or without migration (Preston and Wang 2007) or by varying the fertility schedule in population projections where other components of population change are held constant. In population projections by the U.S. Census Bureau, the fertility rate: allows for a 15% decrease from 1990 to 2010 for all race and ethnic groups under the low-fertility assumption; allows for a 15 percent increase from 1990 to 2010 under the high-fertility assumption, and maintains a constant rate from 2010 to 2050. These different assumptions produce strikingly different projected populations from 1990 to 2050. The low-fertility assumption yields a total population size of about 345 million in 2050, whereas the high-fertility assumption results in 518 million in 2050, a difference in magnitude of about half of the current U.S. population.

The question of why U.S. fertility is high compared to many other industrial countries has been addressed by a number of scholars after the TFR rates between the U.S. and Europe started to diverge in the 1980s. A number of possible explanations have been raised in reference to characteristics of the U.S. population that includes references to religiosity, a child friendly society, social acceptance of large families, an earlier start to childbearing, a higher contraceptive failure rate, inadequate education and a more favourable economic situation that supports childrearing, in addition to differential fertility attributable to immigration, ethnicity, nativity, and race (see discussion in U.S. Census Bureau 2001a). Whether or not those factors will maintain a high fertility rate in the future is not clear.

At the same time that a number of factors are proposed to explain high fertility, others point out that social changes in recent years should contribute to a reduced fertility level. Caldwell and Schindlmayr (2003) argue that even though Latin American immigration ascribes part of the high U.S. fertility, the curiously-high fertility level needs to be explained, as the main processes that account for the fertility decline in most developed countries are also present in the U.S. Lesthaeghe and Neidert (2006) argue that the U.S. is moving progressively through the so-called second demographic transition (SDT) where the mean age at marriage is increasing, the remarriage rate is declining, the rate of cohabitation is increasing, the number of single-person households is increasing, and fertility rates are decreasing for a defined subpopulation in the U.S. and becoming similar to the status in western Europe.

In light of the increasing volume of immigrants to the U.S. in the past decades, policy makers have paid more and more attention to the influence of immigration on the structure of the current and future U.S. population (Stephen and Bean 1992). The fertility of the Mexican-born and Mexican-origin population in the U.S. has received considerable attention, as they constitute a large part of both the immigrant and total population.

The National Vital Statistics Report publish annual fertility rates for specific groups of the population (see e.g. Martin et al. 2005). Fertility rates are reported for race and ethnic groups (including the Mexican origin population) but not for the native- and foreign-born. In 1990, the Mexican-origin[13] TFR was estimated to be 3.2, and in 2000, it was down to 2.9; at the same time the TFR for the total female U.S. population was 2.08 in 1990 and 2.06 in 2000 (Hamilton, Sutton and Ventura 2005). In 1990, the TFR in Mexico was 3.6, and in 2000, it was 2.7 (United Nations 2008).

Schmertmann, Swicegood and Bean (2004) report TFR by nativity in their analysis of the CPS data. The TFR for the foreign-born population was 2.7 (3.4 for the Mexican-born and 2.3 other-foreign born), for native-born population 2.1 and for the total population 2.2. This suggests that the large Mexican-born population in the U.S. with high fertility rate can have a substantial impact of the overall U.S. TFR.

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[13] Mexican origin refers to Mexican-born population (1st generation immigrant) their descendants (later generation immigrants) and descendants of the Mexican population resident in former Mexican regions that were annexed to the U.S.A. in 1845 and 1848. (Part of Texas in 1845, and in 1848 California, Nevada, Utah, and part of Arizona, New Mexico, Colorado and Wyoming. The Mexican-origin population in the U.S. is measured in the 1990 and 2000 Census forms with a question on ethnicity: “Is this person Spanish/Hispanic/Latino?” The answer: “Yes, Mexican, Mexican Am., Chicano” defines the Mexican origin ethnic group.

Prior studies have examined the contribution of immigration to a nation's fertility schedule. Heran and Pison (2007) estimated the contribution of immigrants to the France TFR and find that the foreign population in France has a modest effect on the national fertility rate by adding 0.1 children per women to the nation's TFR. Dunnel (2007) estimates the contribution of immigrants to the fertility schedule in the U.K, where she finds that increased ASFR among the 25–34 year-old foreign-born women and 20–24 year-old native born women contributed to the increased fertility rates in recent years. The overall TFR in the U.K. increased by 11% from 2002 to 2006 (up to 1.84) while the estimated TFR for the native increased by 13% and the foreign-born by 9% (Native TFR rose from 1.5 to 17, foreign-born from 2.3 to 2.5 and overall from 1.70 to 1.84). The compositional effect of women in the U.K. was not estimated in the analysis.

A number of previous studies (e.g. Schmertmann et al. 2004, Glutsker 2003) have addressed the native and foreign-born fertility schedule in the U.S. but the components of this effect over time have not been examined in detail. In this paper the following research questions will be addressed.

1. What was the total contribution of all foreign-born, i.e. Mexican-born and other foreign-born women, to the U.S. TFR's in 1990 and 2000?
2. How much of these contributions were due to: (a) higher ASFR's; (b) age distributions of reproductive age women that favor the high-ASFR ages?
3. How much of the difference between the 1990 and 2000 contribution was due to (a) more immigrants overall in the childbearing ages; (b) changes in the ASFR's of foreign-born; (c) changes in the age distribution of the native-born population, that is,

did the aging of the native-born baby boom cohorts increase the relative contribution of immigrant fertility?

By addressing these questions, this paper contributes to an improved understanding of the impact of immigration to hosting country fertility rates, by analyzing the U.S. fertility schedule in similar manner as prior studies have done with the TFR in France and the U.K. where there is a large foreign born population. As Mexicans comprise the dominant immigrant group in the U.S with high fertility, this paper focuses specially on the importance of Mexican-born immigrants. A second contribution of this paper is the extension of previous immigrant fertility studies and official statistics by looking at the age distribution of immigrant and native-born women in their reproductive ages.

The age patterns of migration are well documented (Raymer and Rogers 2007; Rogers and Castro 1981; Rogers and Rajbhandary 1997; Rogers, Raquillet and Castro 1978). Age specific migration rates typically peak around age 20, following young adult's family formation. This age pattern of migration can in the long run result in an age composition of immigrants that is different from the age composition in both the sending and the receiving population. A substantial part of the U.S. Mexico migration flow is circular (Bean et al. 2001), which may have different effect on the age composition of the foreign-born population than it would if the emigration rate of foreign-born were low. Most migration patterns, both with and without circular migration, will produce an age distribution with fewer teenagers than people in the twenties when the migration rate peaks in the early twenties.

While TFR is always subject to estimation errors both for the estimated resident population and, to a lesser extent, for the number of births by mothers origin; the magnitude of the fertility differentials for the Mexican-born and the native population justifies exploration of the sources of this difference. When analyzing the contribution of immigrants to the U.S. fertility schedule, the fertility differential and size of the Mexican-born population resident in the U.S. highlights the importance of examining the Mexican-born population separately from other foreign-born populations.

One of the main advantages of the TFR is that it provides a useful, easily interpretable summary measure of period fertility that takes fully into account the age composition of the female population. When, however, age specific fertility rates differ between subgroups of the population, the age composition of the subgroups can have an impact on the estimated TFR for the total population. Table 3-7 in Appendix B provides an example of two scenarios with two hypothetical subpopulations where the age composition of each subgroup influence the overall TFR. If the ASFR for different subgroups do not differ, age composition has no effect on the TFR estimates. Prior studies in this area have focused on calculation of TFR’s with and without the presence of immigrants. This paper goes beyond this approach by examining how recent U.S. TFR are affected by the age distribution of the foreign-born population, which is shaped by recent and past age pattern of immigration and emigration rates.

The literature on the fertility behavior following migration proposes four main theoretical hypotheses to account for the link between migration and fertility:

socialization[14], selection, disruption, and adaptation (Frank and Heuveline 2005; Kulu 2005; Milewski 2007)

The socialization hypothesis suggests that changes in fertility following migration are different for first-generation immigrants than changes in fertility across later generations. According to this hypothesis, first-generation immigrants do not experience much change in their fertility behavior because socialization during childhood is the primary determinant for fertility behavior in adulthood both in the sending and destination country. The longer the family experiences new norms and beliefs, the more similar each generation gradually becomes to the natives. Hervitz (1985) found support for this hypotheses in certain parts of Brazil, but the hypothesis has received little empirical support for Mexican immigrants in the U.S.

In contrast to the socialization hypothesis that focuses on processes and belief system in the immigrants' home (sending) country or region, the adaptation hypothesis focuses on the socialization processes in the new country in which norms and the value system influences immigrants' fertility intentions and behaviour such that the fertility will gradually resemble that of the people in the country of destination. This adaptation may take several years but affects both the first and later generations of immigrants where the socialization hypothesis predicts no change in fertility behaviour of first generation immigrants. In 1986–1988 the Mexican-origin female population had significantly lower fertility rates than Mexican women in Mexico in accordance with the assimilation theory. A decade later, the difference was reversed for women 15–24 years

[14] according to Kahn (1994), some use the term assimilation rather than socialization while others use the term assimilation with different meaning

old and for all ages when looking only at Mexican-born females in the U.S., rather than all those of Mexican origins. Frank and Heuveline (2005) point out that the adaptation theory does not explain fertility differentials between natives and immigrants from Mexico because immigrant fertility rates are seemingly higher among Mexican immigrants in the U.S. than among Mexicans in Mexico in recent years. They question if the high fertility rates soon after the act of migration is explained by a lack of assimilation due to the short residence in the U.S. or if the interruptive process of migrating affected their fertility intentions and behavior (Frank and Heuveline 2005)

The selectivity hypothesis proposes that the differences between fertility behavior of immigrants and those that do not migrate can be explained by the characteristics of the migrants, such as age, education, occupation, motivation, and marital status (Stephen and Bean 1992). In addition to differences in age and sex composition, the selectivity hypothesis suggests that the lower fertility of women who migrate compared to those who stay, is explained by the fact that migrating women already have lower fertility intentions than those that do not migrate, as groups with lower fertility may have better access to migration opportunities (Pessar 2003). The selectivity hypothesis is put forward to explain lower fertility rates of those that migrate than those who stay. Number of studies do however show a higher fertility rate for first generation Mexican-born immigrants than Mexicans in Mexico (Frank and Heuveline 2005). A more recent study that takes a closer look at generation completed fertility show opposed to cross-sectional studies, that fertility of Mexican-origin women resembles that of whites with each immigrant generation (Parrado and Morgan 2008a)

The disruption hypothesis suggests that the event of migration disrupts people's life such that migrants experience lower fertility before and after arrival in a new country or region. Couples may not migrate simultaneously, which may result in extended separation and postponed conception. Later, after couples reside together in a new society, they might experience increased fertility when they intentionally or unintentionally catch up to lost time, and their fertility increases again.

In addition to the four main hypotheses of assimilation, adaptation, selectivity, and disruption, the idea of interrelation of events has been proposed to account for the association between migration and elevated fertility after migration (Milewski 2007; Mulder and Wagner 1993). The observed increase in birth rate shortly after migration may be a part of the interrelation of migration, union formation and first birth but not necessarily a sign of catch-up time for separated couples, a pattern that resembles what has been called demographically dense years .

The adaptation hypothesis remains the dominant model in explaining the migration-fertility link for Mexican immigrants in the U.S. The cultural settings in Mexico "reinforce[s] and encourage[s] adherence to traditional pronatalist norms" (Frank and Heuveline 2005). The attachment to the pronatalist norms is especially strong for the Mexican-origin population due in part to proximity to Mexico, circular migration across the border and visits to Mexico.

The high-fertility schedule observed for the Mexican-born women in the U.S. may in part be explained by biased estimated fertility rates in addition to ethnic differentials. A substantial part of the Mexican-born population in the U.S. is undocumented for number of reasons. They may have entered the country illegally or may have overstayed their visa requirements and might thus be unwilling to report their residence to the authorities in a census or a survey. Part of the large migration between Mexico and the U.S. is circular migration as people cross the border repeatedly, even over the course of one year (Bean et al. 2001). U.S. citizenship for the child and the quality of the health care system in the U.S. may further promote temporary residence in the U.S. and possibly misreported U.S. residence on birth certificates by Mexican-born women that give birth in the U.S. The estimated fertility rates for Mexican-born mothers may thus be inflated by upwardly biased numbers of births, as the residence status of mothers is over-reported and likely downwardly biased population estimates, as the number of migrants is under-reported. In spite of a growing body of research literature on the nature of fertility behavior, following migration to the U.S. and the contribution of immigrant fertility to the U.S. demographics, Frank and Heuveline (2005) state that the "fertility behavior of Mexican-origin women remains poorly understood" (p. 78) when they question the validity of this model and propose that higher Mexican-origin fertility rates should be viewed through a racial-stratified perspective.

At the same time that knowledge of the social and economic foundation of the migration-fertility link accumulates, the need increases for improved understanding of the formal demographic dynamics of Mexican immigration and the effect it has on the U.S. population. A large body of research has evaluated the stock and flow of both Mexican immigration and more generally Hispanic immigration to the U.S (Bean et al. 1998; Smith and Edmonston 1997b). The effect of immigration on the population growth, age structure, and spatial distribution in the U.S., has gained considerable attention (Greenwood and Tienda 1998). The research literature on the demographic effect of migration is to a large extent descriptive in nature, based on standard population counts, fertility rates calculations and population projection methods with different schedules of immigration and fertility, which yield different population size and compositions. Development of demographic methods to analyze the effect of immigration on population growth and characteristics has been slow, partly because of the traditional stable population model that assumes a population closed to immigration, with important exceptions (Espenshade 1986; Preston and Wang 2007) that elaborate immigration to classical demographic models.

A report by the Commission of the European Communities addresses the importance of policy that focuses on getting people to jobs, such as the old, the young, and women, in order to meet the challenging consequences of population aging, and described the demographics as “[the] Union no longer has a ‘demographic motor’” (Commission of the Europeans Communities 2005 p. 4). With the current fertility and immigration rates, the dynamics of population aging in the U.S. are very different than those in other industrial countries. A considerable part of the U.S. ‘demographic motor’ is imported from Mexico, but the mechanics of the concurrence with the domestic motor are not completely understood.

While the Mexican-born population is of central interest in this analysis, the non-Mexican foreign-born population exceeds the Mexican-born in number and its fertility is significantly different from the Mexican-born. The non-Mexican foreign born are included in the analysis for completeness and for reference to the Mexican-born population. The non-Mexican foreign-born population is both large and diverse group that arguably justifies more detailed breakdown of country of birth. However, for simplicity, Mexico is the only specified country of birth in the analysis due in part to the size of the immigration stream and the geographical proximity to the U.S.

Data and methods

Decomposition and standardization of rates of vital events are effective tools to control for or to extract extraneous and pertinent effect of demographic conditions on vital rates. Conventional decomposition techniques provide important insight into the nature of differences between rates in two or more populations. Standardization and decomposition can be reduced to analyze the components of vital rates attributable to a specific group of population. Questions for the decomposition analysis in this paper are a matter of contribution of age composition and age-specific fertility rates (ASFR) of immigrants, especially Mexicans, to the overall total fertility rates of the U.S. population. When analyzing the components of the recent U.S. TFR, no attempt is made to argue that the components are independent or if they imply a causal relationship, as causal inferences “are beyond the scope of decomposition analysis” (Gupta 1993).

Total fertility rates and corresponding age-specific fertility rates were calculated from tabulations of public-use micro data. Estimates for the United States’ 1990 and 2000 population were obtained from tabulations of 5% of U.S. census data from the Integrated Public Use Micro Data Series (Ruggles et al. 2008). Estimates of the number of births by nativity and age of mother are obtained from tabulated natality micro data for 1990 and 2000 available from the National Center for Health Statistics (Various years).

The 1990 and 2000 Censuses data are chosen to analyze the effect of recent increases in the foreign-born population on the U.S. TFR. The Census data are well suited to estimate the foreign-born population resident in the U.S. with sufficiently large sample size to detect the effect of small population changes with minimal sampling error. The Census data do however incorporate bias in the denominator due to census undercount. The undercount of the Latino population was estimated 5.0% in the 1990 (U.S. Department of Commerce 1997). Analysis of the 2000 Census data resulted in large changes in previous population estimates for the 1990s. After the 2000 Census the NCHS re-estimated the national TFR for 1991–2000 (Hamilton, Sutton and Ventura 2005) with inter-censal population estimates in stead of previous post-censal estimated. The changes in the two series of population estimates where huge as the inter-censal estimates incorporated unexpected large increase in the size of the Latino population in the 2000 Census. The new ASFRs for the 1990s were consequently considerably lower than previously published.

The seemingly larger undercount of Hispanic population in the 1990 Census than in the 2000 Census may result in two sets of fertility rates have different levels of bias. I nevertheless opt to use the 1990 and 2000 Census data for calculating TFR in order to remain consistent with official estimates of recent fertility schedules, but awareness of the bias is important.

In addition to the census undercount, the foreign-born TFR calculations may result in “too high” estimates for two main reasons. First, in the presence of circular migration (Bean et al. 2001) the average circular migrants may be more likely to stay and give birth in U.S. rather than return to their home country. Second, the TFR does not take into account that migration is associated with union formation and childbearing that may inflate the estimated lifetime TFR of migrants.

Information on country of birth was used to create three nativity categories. The native born are those born in any of the 50 states of the U.S., the District of Columbia and any of the U.S. territories (American Samoa, Guam, U.S. Virgin Islands, Midway Islands, Wake Island, Howland Island, and Puerto Rico). The second category consists of Mexican-born women, and the third category consists of all other foreign-born women. In the natality data file, births were categorised by mother's country of birth by the same categories as those in the population estimates. Births to females less than 15 years old were assigned to those 15 years old and births to females older than 49 were assigned to those 49 years old. About 260,000 (0.38%) 15– to 49-year-old women in the 1990 census had unclassifiable place of births. Those women were distributed to the three categories in same proportions as the known place of birth. The same procedure was used in the 1990 natality data file with the 7,983 (0.19%) occurrences for which the mother's place of birth was not classifiable. The corresponding number in the 2000 natality file was 12,107 (0.30%).

As the Census Day is April 1st, but age-specific rates are based on the mid-year population, it was necessary to "age" the April 1st population to July 1st. Monthly estimates of immigration, emigration, and deaths by age, sex, and country of birth are not publicly available; each age group of women were aged 3 months by using the ratio of female population estimates on July 1 over April 1 by age for the 2000 population and separately for the foreign-born and native-born in 1990. These monthly estimates are provided by the U.S. Census Bureau (U.S. Census Bureau 2005).

Calculation of births and rates

Total fertility rates for the entire U.S. female population are defined as the sum of age-specific fertility rates in Eq. (3-1), (Preston, Heuveline and Guillot 2001; Smith 1992)

$$TFR_{us} = \sum_{x=15}^{49} f_{us}(x) \tag{3-1}$$

where all quantities in Eq. (3-1) and later equations, are for females only except for births (*B*) that represent both male and female births. The letter *f* represents the age-specific fertility rate for females age *x* to *x+1*, and the subscript *us* stands for the U.S. population. For the purpose of this paper, the U.S. total fertility rate consists of ASFR and population composition of three separate subgroups of the population: the native-born (*n*) population, the Mexican-born (*m*) population resident in the U.S. and other (*o*) (non-Mexican) foreign-born population resident in the U.S. The corresponding fertility rates are defined in Eqs. (3-2) to (3-4)

$$f_n(x) = \frac{B_n(x)}{N_n(x)} \tag{3-2}$$

$$f_m(x) = \frac{B_m(x)}{N_m(x)} \tag{3-3}$$

$$f_o(x) = \frac{B_o(x)}{N_o(x)} \tag{3-4}$$

Summing up age-specific fertility rate for each group, we have a nativity-specific total fertility rate as defined in Eq. (3-5), (3-6), and (3-7).

$$TFR_n = \sum_{x=15}^{49} f_n(x) \tag{3-5}$$

$$TFR_m = \sum_{x=15}^{49} f_m(x) \tag{3-6}$$

$$TFR_o = \sum_{x=15}^{49} f_o(x) \tag{3-7}$$

The difference between Eqs. (3-1) and (3-5) reveals the overall contribution of the foreign-born population to the U.S. total fertility rate. Decomposing the TFR into the effects of ASFR and age composition that are attributable to Mexican-born and other foreign-born is calculated separately due to the large fraction of the Mexican-born female population of all foreign-born resident population in the U.S.

To attribute part of the high U.S. fertility to the foreign-born who have a higher-than-average TFR, the age composition of the foreign-born population must be taken into account. If the resident Mexican-born population in the U.S. is younger, the higher ASFR in the younger age group can potentially have an inflating effect on the TFR of the resident U.S. female population. In order to evaluate the impact of the foreign-born population on the U.S. TFR, it is essential to take into account both ASFR and age composition, as the U.S. TFR population is not only a weighted average of the three total fertility rates by nativity defined in Eqs. (3-5), (3-6), and (3-7).

The total fertility rate for the U.S. in the absence of all Mexican-born female populations is defined in Eq. (3-8) and without the other foreign-born population in Eq.

(3-9). The subscript *n+o* stands for native- and other (non-Mexican) foreign-born population.

$$TFR_{n+o} = \sum_{x=15}^{49} f_{n+o}(x) = \sum_{x=15}^{49} \frac{B_n(x) + B_o(x)}{N_n(x) + N_o(x)} \qquad (3\text{-}8)$$

$$TFR_{n+m} = \sum_{x=15}^{49} f_{n+m}(x) = \sum_{x=15}^{49} \frac{B_n(x) + B_m(x)}{N_n(x) + N_m(x)} \qquad (3\text{-}9)$$

To specify the contribution of the Mexican and other foreign-born population to the U.S. TFR, a vector for the age composition of the native-born population is introduced in Eq. (3-10).

$$C_n(x) = \frac{N(x)}{\sum_{x=15}^{49} N(x)} \qquad (3\text{-}10)$$

It follows that the sum of the age composition vector equals unity (3-11). It should be emphasized that the age composition effects are based on the population composition of women age 15–49 year old only.

$$\sum_{x=15}^{49} C_n(x) = 1.0 \qquad (3\text{-}11)$$

The number of births to a cohort of Mexican-born women by age, if the age composition of the Mexican-born were the same as the composition of the native-born (*Cn*) population, is defined as the product of the total Mexican-born female population, the age composition value of the native born, and the age-specific fertility rate for the Mexican-born female population resident in the U.S. defined in Eq. (3-12) and in (3-13) for the other foreign-born.

$$B_{m(Cn)}(x) = N_m \cdot C_n(x) \cdot f_m(x) \tag{3-12}$$

$$B_{o(Cn)}(x) = N_o \cdot C_n(x) \cdot f_o(x) \tag{3-13}$$

From Eqs. (3-12) and (3-13), the foreign-born age-composition-adjusted total fertility rates for the U.S. population can be calculated by summing up age-specific fertility rates with modified number of births to foreign-born as defined in Eqs. (3-14) and (3-15)

$$f_{n+m(Cn)+o}(x) = \frac{B_n(x) + B_{m(Cn)}(x) + B_o(x)}{N_n(x) + N_m \cdot Cn(x) + N_o(x)} \tag{3-14}$$

$$f_{n+m+o(Cn)}(x) = \frac{B_n(x) + B_m(x) + B_{o(Cn)}(x)}{N_n(x) + N_m(x) + N_o \cdot Cn(x)} \tag{3-15}$$

Summing Eqs. (3-14) and (3-15) give a TFR with adjusted age composition of the Mexican-born population (3-16) and other foreign-born female population (3-17). The modified total fertility rates that follow in Eq. (3-16) to (3-29) are standardized for different components. Those rates are compared to the usual overall TFR defined in (Eq. (3-1) in order to evaluate the contribution of various components,

$$TFR_{n+m(Cn)+o} = \sum_{x=15}^{49} f_{n+m(Cn)+o}(x) \tag{3-16}$$

$$TFR_{n+m+o(Cn)} = \sum_{x=15}^{49} f_{n+m+o(Cn)}(x) \tag{3-17}$$

To estimate the contribution of higher ASFR of the foreign-born population to the U.S. TFR, the number of births to Mexican-born female population is calculated as if they had same ASFR as the native-born population by multiplying the size of the female population by the corresponding native age-specific fertility rate (3-18) and similarly for other foreign-born (3-19)

$$B_{m(fn)}(x) = N_m(x) \cdot f_n(x) \tag{3-18}$$

$$B_{o(fn)}(x) = N_o(x) \cdot f_n(x) \tag{3-19}$$

Similar to Eqs. (3-14) and (3-15), the modified number of births in (3-18) and (3-19) are used to calculate the adjusted ASFR and corresponding TFR as defined in Eqs (3-20) and (3-21).

$$TFR_{n+m(fn)+o} = \sum_{x=15}^{49} \frac{B_n(x) + B_{m(fn)}(x) + B_o(x)}{N_n(x) + N_m(x) + N_o(x)} \tag{3-20}$$

$$TFR_{n+m+o(fn)} = \sum_{x=15}^{49} \frac{B_n(x) + B_m(x) + B_{o(fn)}(x)}{N_n(x) + N_m(x) + N_o(x)} \tag{3-21}$$

Four more equations are defined to capture the composition effects of the foreign-born. First the fertility rates for the native-born and Mexican-born with the age composition of the natives and other-foreign born population absent (3-22) and the corresponding TFR for the natives and other foreign-born with the age composition of the natives and the Mexican-born population absent (3-23). The same logic applies to define TFR with the entire foreign-born population present with age composition that of the natives (3-24).

$$TFR_{n+m(Cn)} = \sum_{x=15}^{49} f_{n+m(Cn)}(x) \tag{3-22}$$

$$TFR_{n+o(Cn)} = \sum_{x=15}^{49} f_{n+o(Cn)}(x) \tag{3-23}$$

$$TFR_{n+m(Cn)+o(Cn)} = \sum_{x=15}^{49} f_{n+m(Cn)+o(Cn)}(x) \tag{3-24}$$

All equations above are time invariant and time superscript thus omitted. In the last set of equation defined below, time superscripts are added, 90 for 1990 and 00 for 2000. The last set of equations is defined to capture selected components of change in TFR from 1990–2000. The effect of the aging native population from 1990–2000 can be found from Eq. (3-25) with superscript 90 that represents age composition of the natives in 1990 but all other quantities are for the year 2000 with subscript omitted for simplicity. This equation addresses the changes in ASFR due to changes in the age structure of the native population relative to the foreign born.

$$TFR_{n(Cn_{1990})+m+o} = \sum_{x=15}^{49} f_{n(Cn_{1990})+m+o}(x) \tag{3-25}$$

To answer the question how much the increase in the foreign-born population from 1990–2000 affected the overall TFR, we define ASFR's for 2000 with the foreign-born population in 1990 with fertility rates of 1990–2000. In other words, the ASFR for the three groups are kept as observed in 2000 constant from 1990–2000 with the observed increased in the size of each of the two foreign-born all three groups in turn. In Eq. (3-26) the Mexican-born population in 1990 is exposed to the 2000 ASFR's, allowing the effect of increased volume and changed composition of the Mexican-born population from 1990–2000 to surface. The corresponding effect for other foreign born is defined by Eq.

(3-27) and when both groups of foreign-born population is kept constant in size and age composition, Eq. (3-28) emerges.

Finally to address the question concerning the extent to which changes in the ASFR of the foreign-born population from 1990–2000 affected the TFR in the U.S., Eq. (3-29) defines the TFR in the situation when both the Mexican-born and the other foreign-born populations experienced the same ASFR in 2000 as they did in 1990.

$$TFR(n+m(N_{90})+o)\sum_{x=15}^{49} = \frac{B_{n(x)}^{00} + \left(N_m^{90}(x) * f_m^{00}(x)\right) + B_o^{00}}{N_n^{00}(x) + N_m^{90}(x) + N_o^{00}(x)} \quad (3\text{-}26)$$

$$TFR(n+m(N_{90})+o)\sum_{x=15}^{49} = \frac{B_{n(x)}^{00} + B_m^{00}(x) + \left(N_o^{90}(x) * f_o^{00}(x)\right)}{N_n^{00}(x) + N_m^{00}(x) + N_o^{90}(x)} \quad (3\text{-}27)$$

$$TFR(n+m(N_{90})+o(N_{90}))\sum_{x=15}^{49} = \frac{B_{n(x)}^{00} + \left(N_m^{90}(x) * f_m^{00}(x)\right) + \left(N_o^{90}(x) * f_o^{00}(x)\right)}{N_n^{00}(x) + N_m^{90}(x) + N_o^{90}(x)} \quad (3\text{-}28)$$

$$TFR\left(n+m\left(f_{90}\right)+o\left(f_{90}\right)\right)\sum_{x=15}^{49} = \frac{B_{n(x)}^{00} + \left(N_m^{00}(x) * f_m^{90}(x)\right) + \left(N_o^{00}(x) * f_o^{90}(x)\right)}{N_n^{00}(x) + N_m^{00}(x) + N_o^{00}(x)} \quad (3\text{-}29)$$

Results

The age-specific fertility rates are displayed in Figure 3-1 for the total U.S. resident population and the three nativity components: native, Mexican-born and other foreign-born. The high ASFR's for the Mexican-born population are evident across all age groups. The ASFR for the other foreign-born population is noticeably lower for ages 15–21 but higher for all age groups above 21. In addition to this large difference in fertility schedules between natives and Mexican-born, Figure 3-2 shows differences in the age composition of the Mexican-born, other foreign-born and the native-born female populations. Among women in their reproductive ages, proportionately more Mexican women are in the 19–31 age group and fewer are in the 15–19 age group, an age pattern that results from classic age patterns of migration, that often peaks close to age 20 (Rogers and Castro 1981).

The different age composition of the foreign-born compared with the natives in combination with large difference in ASFR suggests that the age composition of immigrants can have substantial impact on the overall U.S. TFR.

When the age composition and age-specific fertility rates are combined, we observe the distribution of the number of births by age of mother. In 1990, the median age of Mexican-born mothers is 25, for native born mothers, it is 26, and for the other foreign-born mothers, it is 28. Figures 3-6 and 3 (see Appendix B) show the cumulative proportion of births by single year of age by nativity groups.

Figure 3-3 shows the age-specific fertility rate for the same three nativity groups in 2000. The large difference between the Mexican-born and natives reduced considerably from 1990. Age-specific fertility rates for the Mexican-born females reduced by a factor of 1.17–1.40 from 1990–2000. Changes in ASFR’s from 1990–2000 for natives show a clear pattern of delayed childbearing as reported by a number of previous studies (Bongaarts and Feeney 1998). The changes for the other foreign-born population also show a pattern that may reflect delayed childbearing in combination with a reduced overall fertility. The nativity composition of the broad grouping “other foreign born” might have changed during the decade.

Figure 3-4 shows the age composition for the three nativity groups in the year 2000. The most noticeable change from 1990 is the predictable aging of the 24- to 34-year-old group in 1990 to 34–44 years old in 2000. Changes in the age composition of the foreign-born population are less predictable than for natives. In addition to the aging of those living in the U.S. in both years, the age composition of foreign-born population is more affected by both immigration and emigration than are the natives. A cautionary note should be made for looking at proportional distribution, as it hides a large increase in the number of immigrants 15–49 years old between the two censuses.

The calculation of total fertility rates take into account differences in age composition within groups, but the observed differences in both the fertility schedule and age composition between nativity groups can have a potentially significant effect on the overall total fertility rate when the age distribution in one group favors ages with higher fertility than other nativity groups.

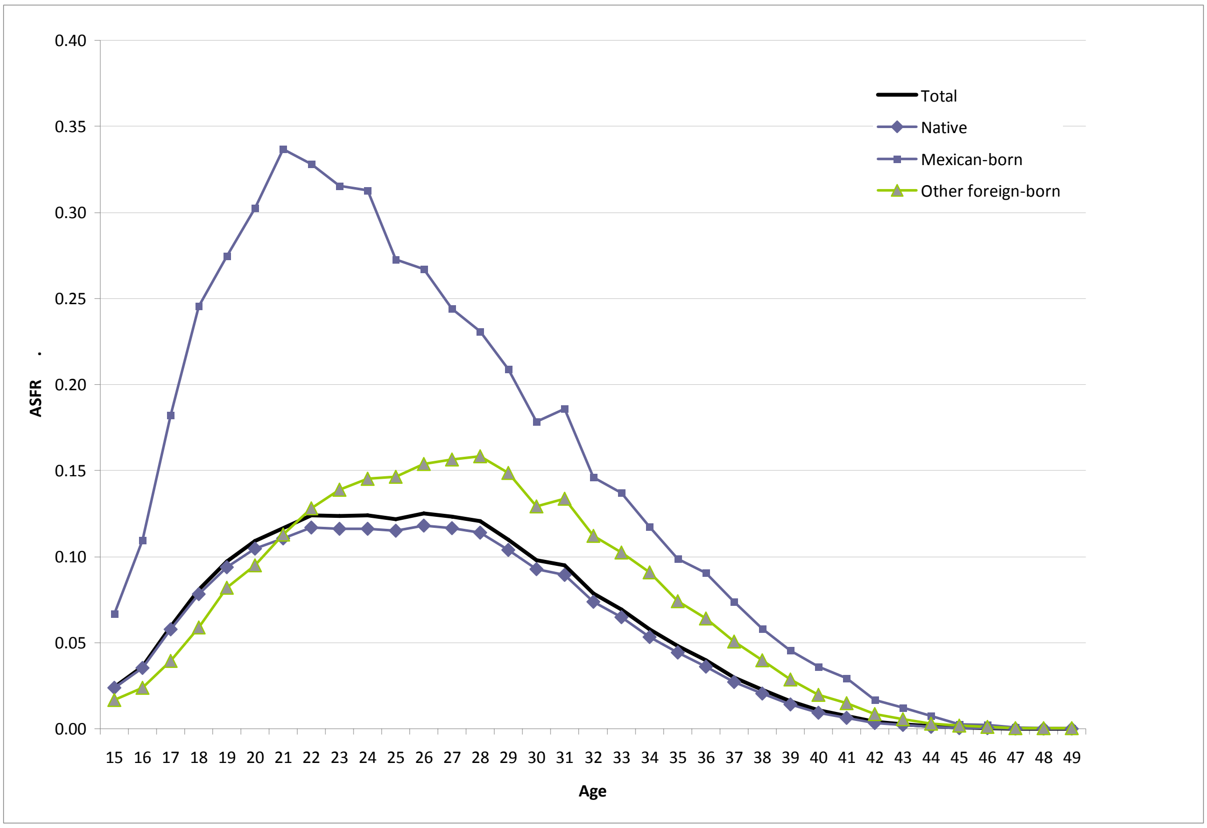

Figure 3-1: Age-specific fertility rate (ASFR) for three components of the U.S. female population in 1990

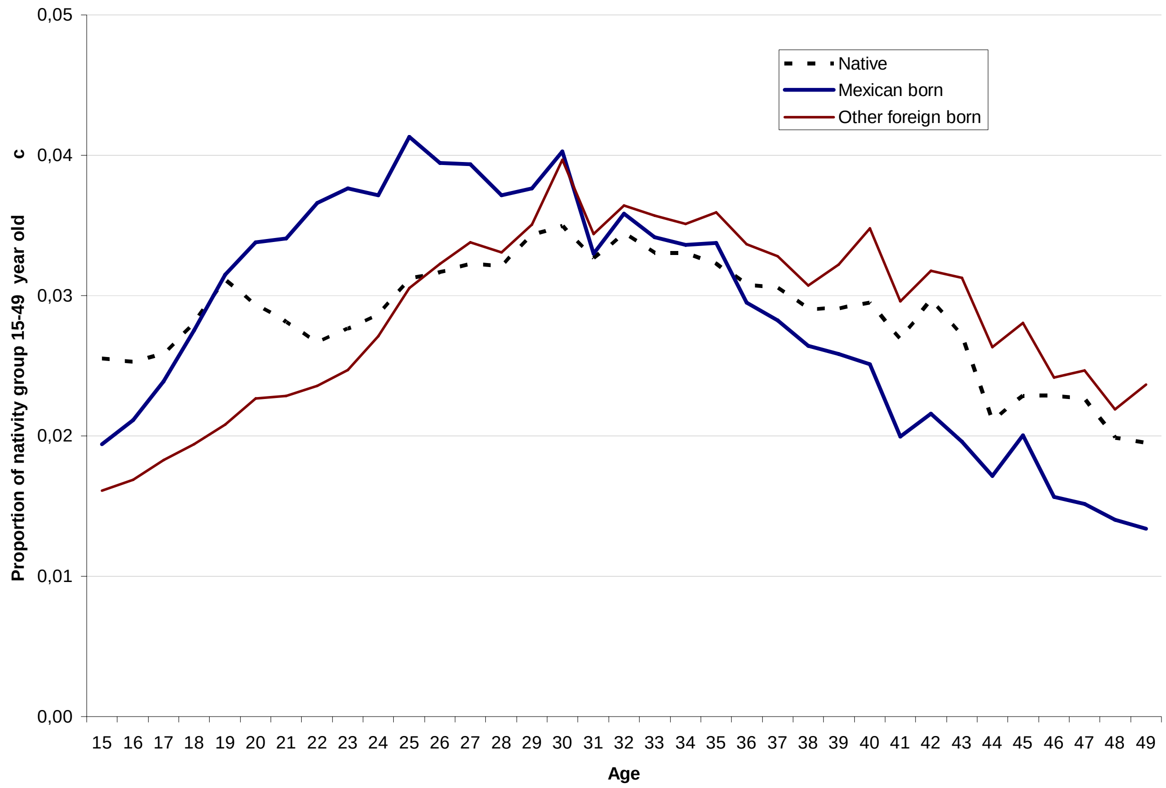

Figure 3-2: Age composition of three groups by nativity in 1990

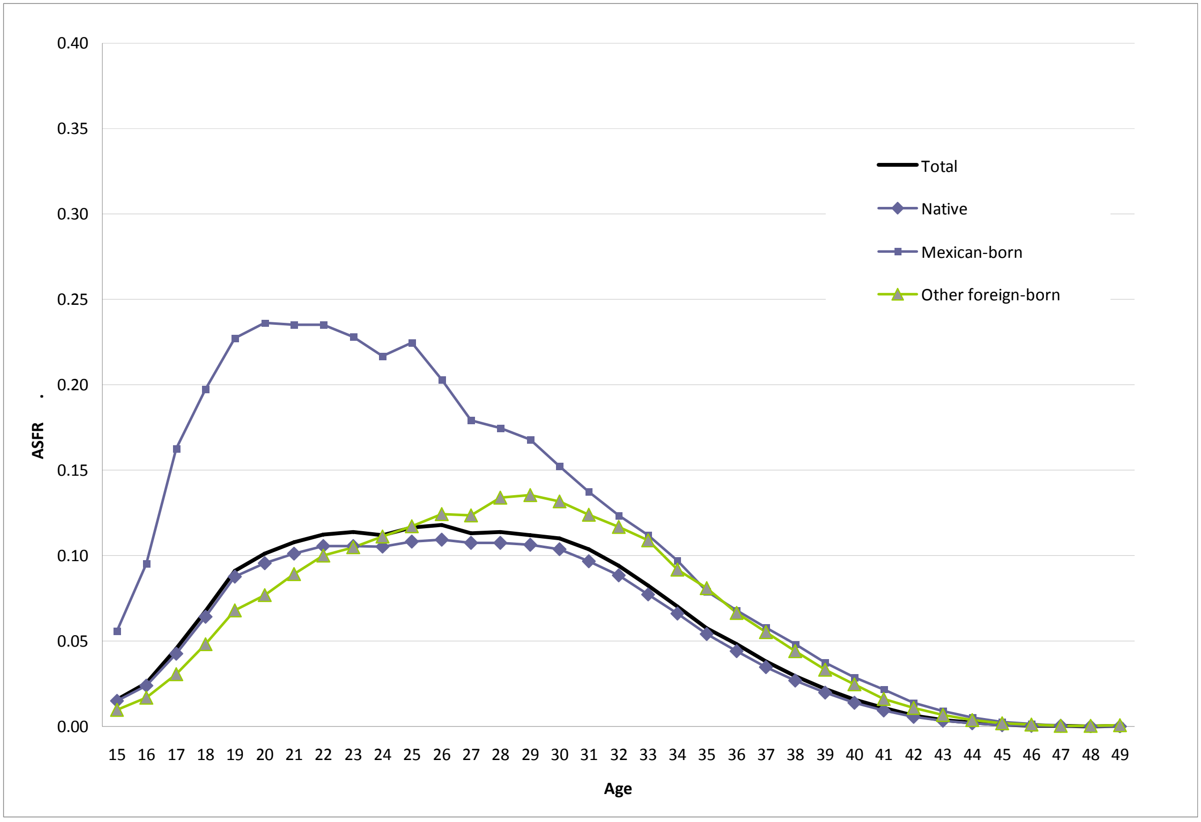

Figure 3-3: Age-specific fertility rate (ASFR) for three components of the U.S. female population in 2000

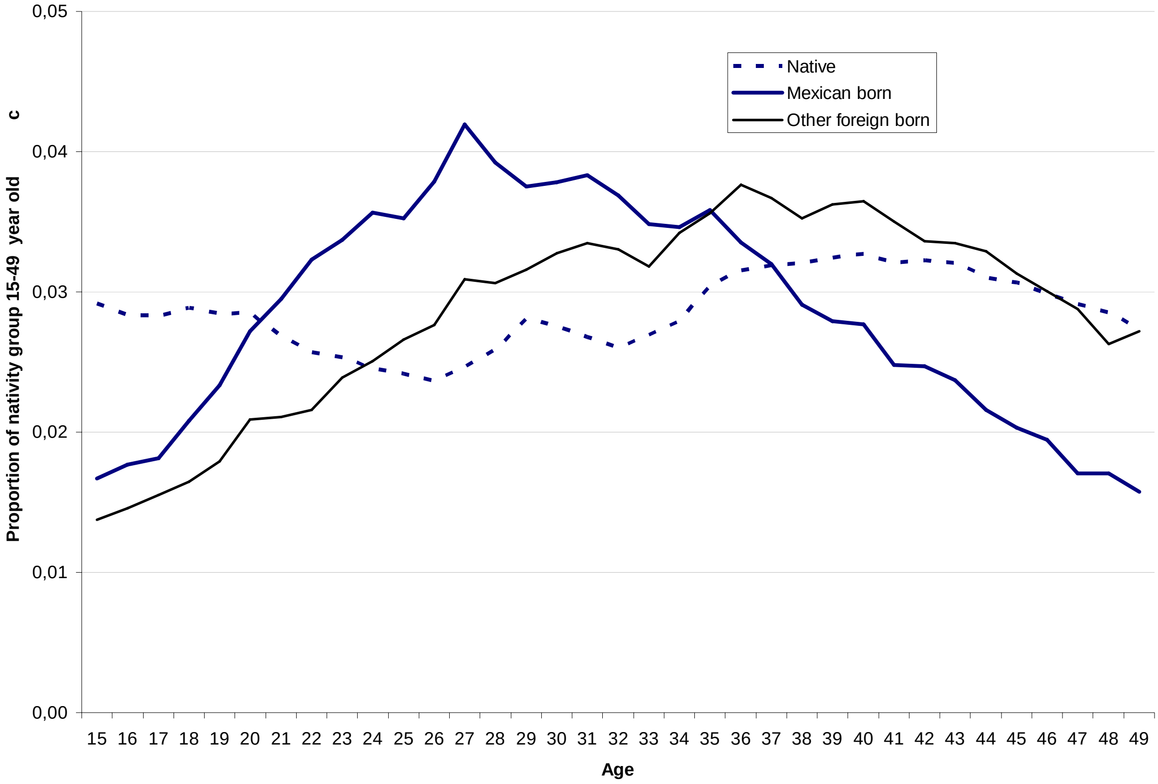

Figure 3-4: Age composition of three nativity groups in 2000

Table 3-1: Total number of births by nativity of mother and corresponding number of females 15–49 years old in the U.S. census in 1990 and 2000

Females 15–49	**Native-born**	**Mexican-born**	**Other foreign**
1990	59,095,017(90.2%)	1,436,417 (2.2%)	4,974,265 (7.6%)
2000	61,657,370 (85.4%)	3,043,682(4.2%)	7,477,533(10.4%)
Births			
1990	3,539,925(85.1%)	242,325(5.8%)	375,962(9.0%)
2000	3,214,558(79.1%)	371,299(9.1%)	477,965(11.8%)

* Row-percentage in parenthesis.

The number of births for the three nativity groups and the number of women aged 15–49 is displayed in Table 3-1. The number of births to native-born women decreased by 9.2% from 1990–2000 while the number of native-born women 15–49 year old increased by 4.3%. This corresponds with a 1.5% reduction in TFR (see Table 3-2) and shifts in the age composition of women in age-groups with lower fertility (Figures 3-2 and 3-4). From 1990–2000, a large increase of immigrant women, especially the Mexican-born, is worth noting. While the number of Mexican-born women age 15–49 more than doubled, the number of births they have in the U.S. increased by 53%, which suggests either reduced fertility, better coverage of this immigrant group in the 2000 census or possibly changes in the age composition within this age interval. In 1990, 90% of the women of reproductive age were US-born, but by the year 2000, the proportion is reduced to 85%. At the same time, births to native-born women decreased from 85% to 79% of all births to resident women in the U.S.

Table 3-2: Decomposed total fertility rates for three components of the female population in 1990 and 2000.

Eq.		1990	Diff. from (3-1) 1990	2000	Diff. from (3-1) 2000
(3-1)	TFR_{us}	2.078	-	2.059	-
(3-5)	TFR_{n}	1.960	0.118	1.931	0.128
(3-6)	TFR_{m}	4.936	-2.858	3.835	-1.776
(3-7)	TFR_{o}	2.486	-0.408	2.208	-0.149
(3-8)	TFR_{n+o}	2.005	0.073	1.971	0.088
(3-9)	TFR_{n+m}	2.040	0.038	2.032	0.027
(3-16)	$TFR_{n+m(cn)+o}$	2.070	0.008	2.050	0.009
(3-17)	$TFR_{n+m+o(cn)}$	2.074	0.004	2.050	0.009
(3-20)	$TFR_{n+m(fn)+o}$	2.004	0.074	1.969	0.091
(3-21)	$TFR_{n+m+o(fn)}$	2.034	0.043	2.022	0.037
(3-22)	$TFR_{n+m(cn)}$	2.031	0.047	2.021	0.038
(3-23)	$TFR_{n+o(cn)}$	2.001	0.077	1.961	0.098
(3-24)	$TFR_{n+m(cn)+o(cn)}$	2.065	0.013	2.040	0.019

Table 3-2 shows the TFRs for the three subgroups of the U.S. population in 1990 and 2000 calculated under various hypothetical situations. The National Center for Health Statistics (NCHS) reports the TFR for the entire female population as 2.081 in 1990 and 2.056 in 2000 (National Center for Health Statistics 2005) [15].

[15] The difference of 0.14–0.15% between the TFR reported in Table 2.1 and the rates reported by the NCHS publication is considerable [(2.081–2.078)/2.081 = 0.14% in 1990]. While values for (2-1) can be adjusted to the NCHS reported value, it is best not to do so, as other values cannot be adjusted accordingly, and thus correcting one value may result in a biased estimate rather than having an estimate with SE. The source of this difference is not entirely clear. It might be a result from differences from authors and the NCHS methods of correcting age-heaping and moving the resident population from April 1 to July 1 for

The difference between TFR values in Eq. (3-5) and Eq. (3-1) in Table 3-2 answers the question on how much first-generation immigrants contribute to the U.S. fertility schedule. In the absence of all immigrants, the TFR rate of U.S. would have been 1.96 in 1990 and 1.93 in 2000.

As argued above, the contribution of immigrants to total fertility can both be expressed in terms of differences in fertility schedule and in terms of differences in age composition. To evaluate the magnitude and source of the contribution of specific groups of the population, such as the Mexican-born, several computational methods are appropriate for different queries. Subtracting Eq. (3-5) from Eq. (3-8), the effect of the Mexican-born resident population on the TFR in the absence of all other foreign-born immigrants is obtained. The size of this contribution is 0.080 (4.1% increase from native TFR) in 1990 and 0.101 (5.2% increase) in 2000. A different approach is to subtract the value of Eq. (3-8) from Eq. (3-1) to see the reduction in TFR for of the entire population when the Mexican population is subtracted from the TFR calculation. This renders a contribution of 0.073 to the TFR (3.6% increase from TFR_{n+o} (3-8)) in 1990 and 0.088 (4.5% increase) in 2000. However, when the difference from (3-9) and (3-5) is divided by

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mid-year estimation. [NCHS most likely uses population counts from the population estimates series rather than the census counts. I believe that the population estimates series differs from census counts in multiple ways, including a somewhat different universe, a different time point (July 1 rather than April 1) and may also be adjusted for enumeration error.] Comparing the population estimates from tabulated PUMS data with age- and sex-specific numbers from the Census website shows a difference in the number of women in the 15–49 age group to be 228,319 (0.3%) in 2000. Looking at the difference by a 5 year age interval, it ranges from a surplus of 150,000 (1.5%) women for ages 15–19 years old to deficit of 214,121 (-1.9%) women aged 35–39 years old. When those 228,319 are distributed by subtracting or adding to single-year age groups, it renders an exact estimated TFR as reported by the NCHS. If the TFR rate is calculated on five year age groups rather than single year ages, the rates become closer to the TFR reported by the NCHS or 2.091 in 1990 and 2.058 in 2000.

(3-5) the Mexican-born population raises the 1990 native-born fertility rate by 4.1% in 1990 and by 5.2% in 2000.

The corresponding contribution for the other foreign-born population increases the TFR of the natives by a level of 0.045 (2.2%) in 1990 and 0.04 (2.1%) in 2000. The other foreign-born contribute 0.038 (1.8%) to the overall TFR in 1990 and 0.027 (1.3%) in 2000 {[(3-9)-(3-1)]/(3-1)} with Eqs. numbers given in parenthesis. By both measures (increase in the native TFR and impact on the overall TFR), the contribution of the Mexican-born residents in the U.S. increased from 1990–2000 at the same time the contribution of other foreign-born decreased.

Equation (3-16) estimates what the TFR would be if the age composition of the Mexican-born was the same as the natives but with their actual estimated ASFR. This hypothetical situation would reduce the overall TFR in 1990 by a level of 0.008 to 2.070 and down by 0.009 to 2.050 in 2000. The age composition of the other-foreign born population renders an effect of almost the same magnitude. The overall TFR would, if the other-foreign born population had same age composition as native-born, be 2.074 in 1990 and 2.050 in 2000.

As argued above, the contribution of immigrant fertility on the overall TFR can be attributed to both a different age composition and a difference in fertility schedule. By subtracting (3-20) from (3-1) for the fertility level effect of the Mexican-born and (3-21) from (3-1) for the other foreign-born population is extracted. Equations (3-22) and (3-23) estimate the TFR if the foreign-born population were given the age composition of the natives in the absence of other foreign-born population and Mexican-born population respectively. This reduces the TFR to 2.031 in 1990 and 2.021 in 2000 with the other foreign-born population absent (and Mexican-born given the age composition of the native-born) and to 2.001 in 1990 and 1.961 in 2000. This suggest that age specific fertility rates of the immigrants has a considerably larger effect than the age composition has. Equation (3-24) shows the TFR that would be observed if both immigrant groups had the age composition of the natives. This shows a small (less than 1%) overall reduction in the TFR in both 1990 and 2000.

. The fertility-rate contribution and age-composition contribution increases the total contribution to more than 100% of the fertility-rate and age-composition contribution due to the interaction effect of -0.009 in 1990 and -0.011 in 2000.

The age-composition effect is the contribution of the age composition of the Mexican-born immigrants given the ASFR differentials between the Mexican-born and the native-born. It should be noted that there is no composition effect possible if the ASFR of the Mexican-born immigrants is not different from the native ASFR. The age-composition effect is thus inclusive in the fertility effect, hence the large interaction effect that also includes a residual component due to the inclusion of other foreign-born fertility in Eq. (3-1).

This interaction effect is affected by the relative sizes of the subgroups, the rate schedule difference, and age distribution differences. If, in the hypothetical situation with no other foreign-born population present and the age-specific fertility for the Mexican-born population is set to that of the natives, the resulting TFR would, by definition, reproduce the native TFR. The effect defined as the difference between Eqs. (3-20) and (3-1) in the case of the three subgroup analysis is, in effect, removing the contribution of the higher Mexican-born age-specific fertility from the overall TFR and, at the same time, in a sense increasing the size or effect of the natives in the overall TFR Eq. (3-1) relative to the other foreign-born population by a level specified by the size of the Mexican-born resident population in each age group.

When we ask what the contribution of the Mexican-born population is to the overall TFR relative to that of the natives, this interaction effect is inevitable, as the Mexican-born population contributes to the overall TFR by their number, by their age distribution difference, and by their rate schedule difference.

To further evaluate the relative contribution of two defined immigrant groups, the schematic display in Figure 3-5 is used for reference.

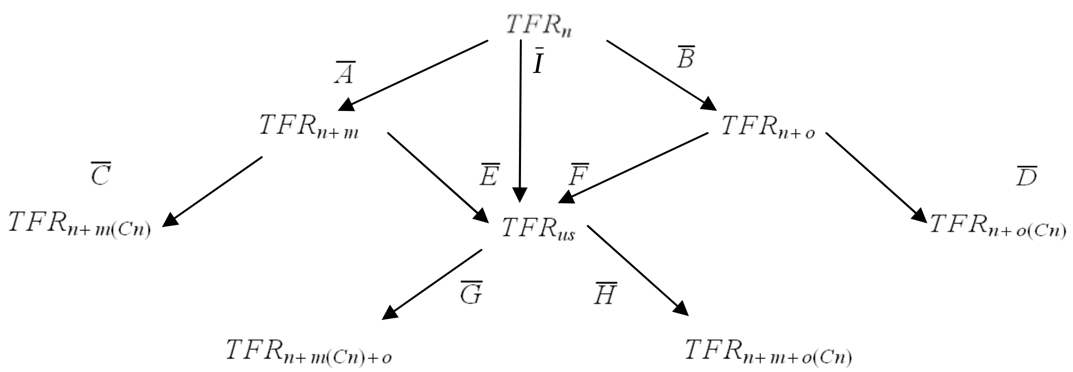

Figure 3-5: Setup of different effect of immigrant women to the U.S. TFR

In Figure 3-5 and Table 3-3 the overall effect of first-generation immigrants on the U.S. TFR is labeled $\bar{I}$, which equals 0.118 TFR units (a 6.02% increase from that of native TFR) in 1990 and 0.128 (6.63%) in 2000. The Mexican immigrants alone add 0.08 to the native TFR in 1990 (4.08%) and 0.101 (5.23%) in 2000, labeled in Figure 3-5 as $\overline{A}$. The corresponding effect of other foreign-born immigrants increase to the native TFR is 0.045 (2.3%) in 1990 and 0.04 (2.07%) in 2000 ($\overline{B}$).The effects of Mexican- and other foreign-born female population sums to more than the total immigrant effect because both effects are estimated independently and are based on the same comparative TFR for the natives only. A substantial part of the effects of both foreign-born groups results from an age composition of the foreign-born that favors age groups with higher fertility schedules than corresponding age groups of the native born but the main contribution of the foreign born effect is a direct effect of higher ASFR's.

Table 3-3: Effect size of immigrants to the U.S. TFR

Eq.	1990	%	2000	%	Proportion of.
(3-9)-(3-5)= $\overline{A}$	0.080	4.08%	0.101	5.23%	(3-5)
(3-8)-(3-5)= $\overline{B}$	0.045	2.30%	0.040	2.07%	(3-5)
(3-9)-(3-22)= $\overline{C}$	0.009	11.25%	0.011	10.89%	$\overline{A}$
(3-8)-(3-23)= $\overline{D}$	0.004	8.89%	0.010	25.00%	$\overline{B}$
(3-1)-(3-9)= $\overline{E}$	0.038	1.83%	0.027	1.31%	(3-1)
(3-1)-(3-8)= $\overline{F}$	0.073	3.51%	0.088	4.27%	(3-1)
(3-1)-(3-16)= $\overline{G}$	0.008	0.38%	0.009	0.44%	(3-1)
(3-1)-(3-17)= $\overline{H}$	0.004	0.19%	0.009	0.44%	(3-1)
(3-5)-(3-1)= $\bar{I}$	0.118	6.02%	0.128	6.63%	(3-5)

Part of the Mexican-born component to the overall U.S. fertility is a result of an age composition that favors the ages of high fertility, ($\overline{C}$). This effect increases the TFR 0.009 (0.41%) in (3-5) or about one ninth of $\overline{A}$ (11.2% in 1990 and 10.9% in 2000). The age composition of other foreign-born women has a smaller effect than in the case for the Mexican-born women. If the age composition of other foreign-born women is changed to such that it matches the natives, the TFR would be reduced by a level of 0.004 from the calculated TFR in (3-8). This effect is a result of relatively fewer other foreign-born women in their teens and early twenties than is observed amongst native-born and those ages have lower age-specific fertility rates (see Figures 3-1 to 3-4) than native-born. By giving the other foreign-born immigrants the age composition of natives but other foreign-born ASFR's, this reduces the effect of the relatively high ASFR of other foreign-born immigrants in their late twenties and early thirties. In Figure 3-5 and Table 3-3, this reduction is labeled $\overline{D}$, and in 1990 was a 0.004 (0.2%) reduction from the TFR of native and other foreign-born combined (Eq. (3-8) and was 0.010 (0.51%) in 2000. The $\overline{E}$ and $\overline{F}$ effects show the change in the U.S. TFR if Mexican-born women ($\overline{F}$) and their births are removed from the calculation of TFR as well as the other foreign-born women and their births ($\overline{E}$). In 1990, the contribution of Mexican-born women to the overall U.S. TFR was 0.073 (3.51%), and in 2000, it was 0.088 (4.27%); corresponding effect of other foreign-born women was 0.038 (1.83%), and in 2000, it was 0.027 (1.31%).

Finally, we examine the effect of age composition differences between Mexican-born women and natives on the overall TFR ($\overline{G}$) as well as the similar effect of age composition of other foreign-born ($\overline{H}$) women. With Mexican-born women given a native age composition, the overall TFR (3-1) was reduced by a level of 0.008 (0.38%) in 1990 and 0.009 (0.44%) in 2000. The age composition of other foreign-born women reduces the level by 0.004 (0.19%) in 1990 and 0.009 (0.44%) in 2000. A cautionary note should be made that the definition of $\overline{G}$ differs from $\overline{C}$ (and $\overline{H}$ from $\overline{D}$) in terms of the reference populations. The $\overline{C}$ and $\overline{D}$ effects are calculated with a substantial part of the total U.S. resident population absent, but $\overline{G}$ and $\overline{H}$ effects are calculated with all nativity and immigration groups present.

Applying Eq. (3-25) to (3-28), selected components of change in the U.S. TFR from 1990–2000 emerge. A change in age composition of the native-born does not have an effect on the native-born TFR but changes the relative composition of the native-born and the foreign-born population in each age group. This compositional change has a very small effect on the overall TFR. If the age composition of the native-born had remained the same, the overall U.S. TFR would have been 2.047 or 0.012 (0.58%) lower than observed in 2000 (Table 3-4). The increase in the Mexican-born population contributed 0.041 (from difference between Eq. (3-21) and (3-1)) births per women from 1990–2000, and the increase in other foreign born only 0.008 (0.39%, Eq. (3-2) and (3-1)). The total increase in all foreign-born women 15–49 year old contribute 0.051 (2.46%) to the TFR in 2000. Combined, the two groups of foreign born population contribute more than the sum of the two groups due to an interaction effect. Eq. (3-29) shows that if the foreign-born fertility rate had not declined from 1990–2000 the large increase in immigration would have increased the overall TFR to 2.143 or by 4%.

Table 3-4: Selected components of change in the U.S. total fertility rate from 1990–2000

Eq.		2000	Difference from (3-1) in 2000	%
(3-25)	$TFR_{n(c90)+m+o}$	2.047	0.012	0.58%
(3-26)	$TFR_{n+m(N90)+o}$	2.018	0.041	1.98%
(3-27)	$TFR_{n+m+o(N90)}$	2.051	0.008	0.39%
(3-28)	$TFR_{n+m(N90)+o(N90)}$	2.008	0.051	2.46%
(3-29)	$TFR_{n+m(f90)+o(f90)}$	2.143	-0.084	-4.08%

As the 1990 Census was found to underestimate the Latino population by 5% (U.S. Department of Commerce 1997) a question arises how the results above would change if the estimate of the Mexican-born population in the Census data were increased by same level. However, estimates of the census undercount are not available by age, sex and country of birth, and thus not possible to correctly adjust the Mexican-born population for the purpose of this paper. One can assume that the undercount for the Mexican-born population is larger than for the broader Latino group. The results presented in Table 3-5 are based on four different population correction scenarios for the Mexican-born population with no changes in the estimated number of births. All the TFR values in table 3-5 are calculated from ASFRs with different level of increase in the size of the Mexican-born population. The ASFRs for the total female population is thus recalculated with 5, 10, 15 and 20% more Mexican-born women that counted by the Census in each age group. Values that by definition are not affected by this correction, such as the TFR for the native-born are not displayed.

As expected, the value of Eq. (3-6) the TFR for the Mexican-born population resident in the U.S. is directly affected by adjustment in the denominator in the ASFRs. Other values are reduced by a far smaller amount as the impact is thinned when the Mexican-born population becomes part of larger group. Even a 20% increase in the Mexican born population affects the overall TFR only by 0.01 children per women. The results in Table 3-5 suggest that the results above are relatively robust to modest changes in the population estimates, but larger corrections would gradually move fertility of the Mexican-born population closer to the fertility of the natives and thus the effect would evaporate.

Table 3-5: Effect on selected TFR from of different level of Mexican-born population correction factor applied uniformly to all ages 15–49 in 2000.

		Level of population correction			
		5%	10%	15%	20%
(3-1)	TFR_{us}	0.003	0.005	0.008	0.010
(3-6)	TFR_{m}	0.235	0.449	0.644	0.823
(3-9)	TFR_{n+m}	0.003	0.005	0.008	0.011
(3-16)	$TFR_{n+m(cn)+o}$	0.002	0.005	0.007	0.009
(3-17)	$TFR_{n+m+o(cn)}$	0.003	0.005	0.008	0.010
(3-20)	$TFR_{n+m(fn)+o}$	0.000	0.000	0.000	0.000
(3-21)	$TFR_{n+m+o(fn)}$	0.003	0.005	0.008	0.010
(3-22)	$TFR_{n+m(cn)}$	0.002	0.005	0.007	0.010
(3-23)	$TFR_{n+o(cn)}$	0.000	0.000	0.000	0.000
(3-24)	$TFR_{n+m(cn)+o(cn)}$	0.003	0.005	0.008	0.010

Summary and conclusions

The ASFR and age composition of native-, Mexican- and other foreign-born women in the U.S. presented in Figure 1-1 to 1-4 show large age differentials in fertility schedules among the two foreign-born groups and the native-born, which combined with age distribution differential has substantial impact on the overall U.S. TFR. The proportionately large number of Mexican-born immigrants in their twenties can be accounted for by a combination of young age structure in Mexico, considerable circular or return migration and finally a considerable increase in the migration stream, with traditional age pattern of migration that peaks close to 20-year-old, in the decades prior to the 2000 census. Constant emigration from a stable population where the migration follows common age pattern would, in the long run, result in a foreign-born population age structure characterized by more evenly distributed population within the childbearing ages excluding ages below the peak age of migration. The age composition of the other-foreign born in the U.S. suggests a more stable immigration stream than observed for the Mexican-born.

The age composition of the two groups of foreign-born population and fertility differentials highlights the importance of nativity specific emigration rates in population projections so age specific fertility rates are applied to proper nativity groups. The changes in size, composition and fertility rates of the three groups defined by nativity sets the stage for addressing the research questions that guides the summary below.

Research question 1

The total contributions of all foreign-born women to the U.S. TFRs in 1990 was 0.118 (6.0%) and in 2000 0.128 (6.6%) with percentages estimated as relative increases to the TFR of the native-born. This effect is considerablegiven the fact that native born constituted 90.2% of women of childbearing age in 1990 and 85.4% in 2000. Fertility differentials between the natives- and foreign-born make a partial contribution to explaining the difference between U.S. in other Western societies such as other OECD countries. While the 6% effect is not huge, it increases the native-born TFR, which is below replacement level, to 2.059, just about the replacement level. The results suggest that 1^{st} generation immigrants are not the dominant explanation to high U.S. fertility rates when it is compared to the lowest-low total fertility rates in number of other countries. The corresponding effect of immigration on U.K. fertility is 8% of the overall TFR of 1.84 (Dunnell 2007) and, for France, 6% of a TFR of 1.98 in 2006 (Héran and Pison 2007). France and U.K have among the highest fertility rates in Europe along with the Nordic countries and Ireland (Population Reference Bureau 2007).

Research question 2

Both in 1990 and 2000 the higher foreign-born ASFR is the main underlying source of the effect of the foreign-born on the TFR. Age composition does however have a noticeable effect. The age composition of the Mexican-born women in childbearing ages accounts for 11% of the Mexican-born effect on the U.S. TFR in both 1990 and

2000. The age composition of the other foreign-born population contributed 8.9% to the other foreign-born effect on TFR in 1990 but increased to 25% in 2000.

Research question 3.

When it comes to explaining the change in TFR from 1990–2000, the first thing to note is that the total fertility rates in 1990 and 2000 are 2.078 and 2.059, respectively, and differ only by a level of 0.019. Consequently, there is little in absolute level to explain. However, the results show considerable change in the nativity specific components that are worthy of attention given that immigration retains the U.S. fertility just at replacement level.

The contribution of all immigrant fertility to the TFR rose from 6.20% in 1990 to 6.63% in 2000 and the contribution of Mexican-born women to the higher U.S. TFR increased from 4.08% in 1990 to 5.23% in 2000, measured as an increase from the native TFR. The corresponding contribution of other foreign-born immigrants decreased from 2.30% in 1990 to 2.07% in 2000. This contribution is observed even though both the Mexican-born and other foreign-born population experienced decreases in fertility. This increase is due to a large increase in the foreign-born population in the decade, in which the number of Mexican-born women in their reproductive age, in the U.S., more than doubled from 1990–2000.

The increased TFR of 0.084 **(**Eq. 3-29) that would have resulted from the increased foreign-born population if it experienced the same ASFR in 2000 as in 1990 is largely offset by a reduction in the foreign-born ASFR that reduces the TFR by 0.051

(Eq. 3-28) that is estimated by holding the ASFR of foreign-born constant from 1990–2000. The ageing of the native female population that results in compositional change in women in childbearing age from 1990–2000 decreases the TFR by a level of 0.012, or slightly over an half a percent point, because of the dominance of the native-born population in each age category.

The immigration effect on TFR estimated in this paper is not large but compared with the number of first generation immigrant women resident in the U.S. it is substantial. In this paper only the effect of first generation immigrants on the U.S. TFR is estimated. The assimilation hypotheses suggest that it takes a few generations for the higher fertility of immigrants to converge to the average native-born fertility schedule, which suggests that second and later generation immigrants may have additional contributions to the currently high U.S. fertility rate.

Research on fertility differentials by generation have showed mixed results. Smith and Edmonston (1997b) report a TFR in 1994 of 3.23 for first generation Hispanic immigrants, 2.63 for second generation Hispanics, and 2.04 for third and later generations. Glusker (2003) however, in her analysis of the June 1986 and 1988 CPS data, finds a different fertility pattern by generation of Mexican-origin women, in which Mexican-born women have a TFR of 3.01, women of Mexican parents experience a TFR of 1.84 but women of Mexican-ancestry (later generations) have a TFR of 2.26.

The main result of this study does not address the bias in population estimates due to Census undercount of specific groups of the population. If the estimated 5% undercount of the Latino population in the 1990 Census (U.S. Department of Commerce 1997) applied equally to all ages of the Mexican-born female population, the estimated

TFR reported in Table 3-2 would be upwardly biased by the same level. However, a correction of this bias for the Mexican-born population would further call for corrected population estimates for other groups. The quality of such bias correction would be unknown and would lead astray reference to the official NCHS TFR on which most international comparison of fertility schedule is based. These one-eigth to one-fourth of percent point changes in the overall TFR in the hypothetical situation with 5 or 10% population correction suggest that the results are robust to moderate correction of the Mexican-born population.

While the current study does not distinguish between the different hypotheses on the migration-fertility link, the results shed light on the nature of the immigrant contribution to the curiously high U.S. fertility rates.

Ignoring the age-composition effect in past research may have been valid in a general discussion of the effect of immigration to U.S. fertility level. While small, composition effects that contribute to 0.9% of overall TFR can have substantial aggregated impact in population projections. Projections that ignore origin-dependence fertility schedules and migration patterns may expose components of the population to incorrect ASFRs that may affect projected annual number of births.

The importance of subgroup-specific rates of vital events has gained increased consideration in recent years. Smith and Edmonston (1997b) incorporated generation specific fertility rates for race/ethnic groups to achieve improved projection accuracy over standard cohort component methods. Also, the U.S. Census Bureau incorporates in their projections age specific net-migration rates for four race/ethnic groups (Day 1996). These age-sex-origin specific projection assumptions take into account the same components that are displayed in Table 3-2. The result of ignoring these components may in some cases result in trivial differences in the size of the total projected population, but taking the components into account contributes to more trustworthy projection with a more accurate description of specified subgroups of the future population.

Similarly, ignoring the age composition of the foreign-born population in the discussion of immigrants' higher ASFR contribution to U.S. fertility level may leave out a small component of the immigrant effect, but knowledge about the size of this effect will focus the discussion on the nature of this effect.

The overall conclusion of this study is that the fertility level of the U.S. remains curiously high even after removing the effect of immigration. The native-born fertility level reported in Table 3-2. is higher than the TFR in most other OECED countries (Population Reference Bureau 2007) with the exception of Turkey, Iceland, Mexico and New Zeeland.

Even though Lesthaeghe and Neidert (2006) find subgroups of the population defined by nativity and region that follow family and fertility demographic trends that are similar to those in western European countries such as the Netherlands, the overall TFR or even the native TFR in the United States is inconsistent with the typical patterns of the second demographic transition.

Whether the local area trends observed by Lesthaeghe and Neidert will surmount the current trend for the entire U.S. population in the coming decades will remain an empirical question for the future. Until then, it is important to understand the components of the current fertility schedule. Increased knowledge of the current fertility schedule is important on its own and can contribute to improved population projections as well as a better understanding of the social structure in which the population resides.

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Appendix B

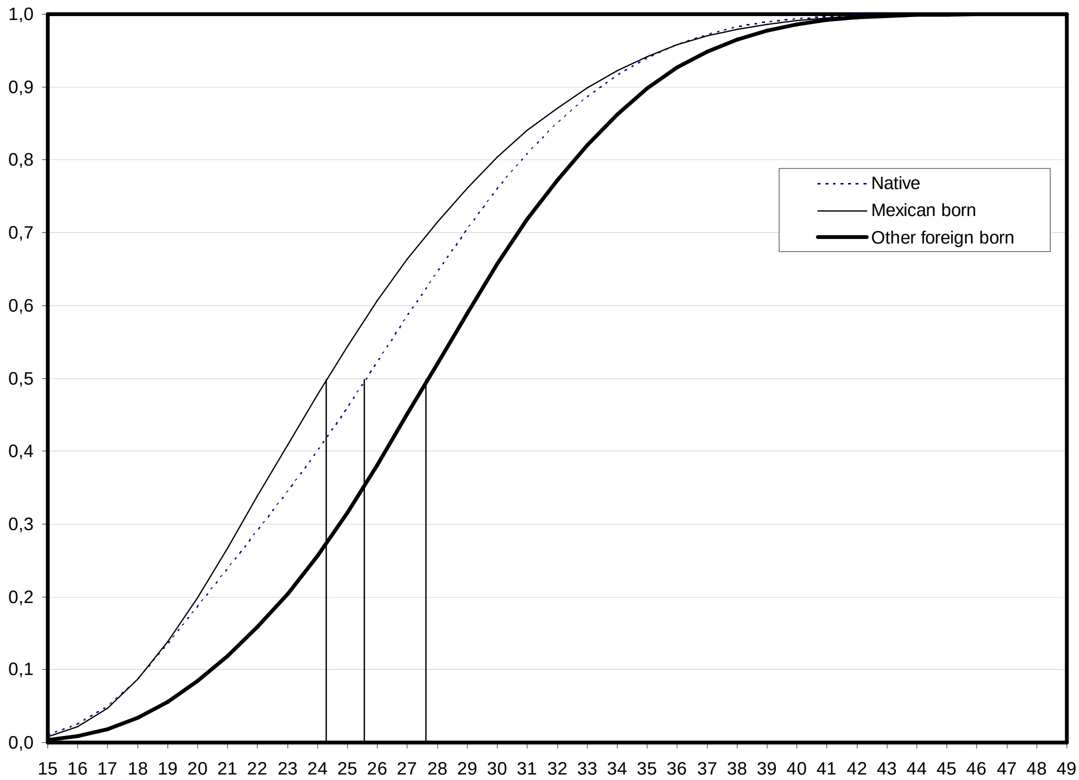

Figure 3-6: Cumulative proportion of birth by age of mother by three nativity groups in 1990.

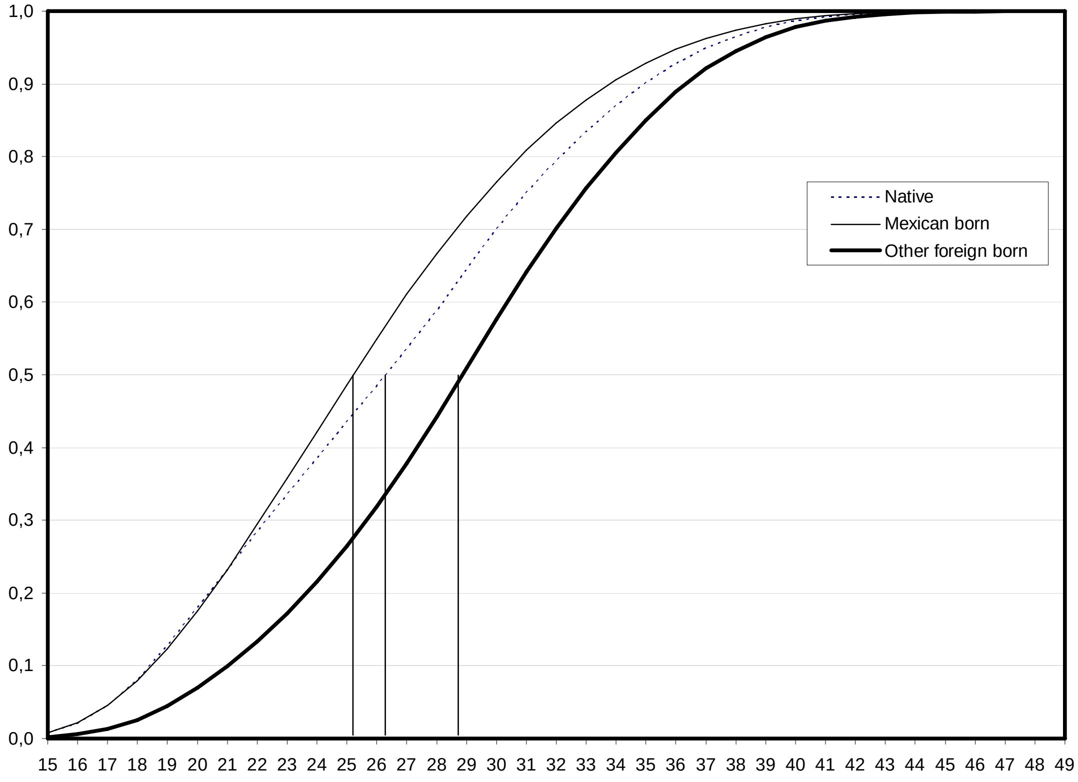

Figure 3-7: Cumulative proportion of birth by age of mother by three nativity groups in 2000.

Table 3-6: ASFRs and TFR for hypothetical subpopulations (A and B) with different set of ASFR under condition of two scenarios with different age composition

Scenario I

Pop	Age	Births	N	ASFR
A	21-30	4	20	0.200
A	31-40	20	200	0.100
A	TFR			3,0

Pop	Age	Births	N	ASFR
B	21-30	8	20	0,400
B	31-40	30	200	0,150
B	TFR			5,5

Pop	Age	Births	N	ASFR
Total	21-30	12	40	0,30
Total	31-40	50	400	0,13
Total	TFR			4,25

Scenario II

Pop	Age	Births	N	ASFR
A	21-30	4	20	0,200
A	31-40	20	200	0,100
A	TFR			3,0

Pop	Age	Births	N	ASFR
B	21-30	80	200	0,400
B	31-40	3	20	0,150
B	TFR			5,5

Pop	Age	Births	N	ASFR
Total	21-30	84	220	0,38
Total	31-40	23	220	0,10
Total	TFR			4,86

Table 3.6 portrays two different scenarios with two equal size population in hypothetical situation where childbearing ages are from 21–40. The first scenario (I) shows the two populations with equal population size and equal age composition. The overall TFR is then a simple average of the TFR for the two subpopulation (3.0+5.5)/2 = 4.25. Under the condition of scenario II, where again the two populations are of equal size (220 persons) but the age composition of population B favors the younger age group where there is larger difference in ASFR. The TFR for the overall population becomes significantly

higher in Scenario II than in Scenario I or 4.86 even though ASFR for the two groups do not differ across scenarios. The age composition of each subpopulation does not affect the subgroups TFRs, but it does affect the overall TFR.

Chapter 4

USING VITAL RATES TO ESTIMATE THE MEXICAN-BORN FEMALE POPULATION

Abstract

A large number of studies have estimated the quality of population estimates from the decennial U.S. Censuses. Various methods have been developed for this task including methods that use registered number of vital events and independent estimates of vital rates to estimate exposure years. The exposure years are compared to Census count estimates to evaluate the Census coverage. This paper explores the usability of fertility rates estimated from sample survey in combination with registered number of births to estimate the Mexican-born population in the U.S. by exploiting the completeness of the birth registration system. The use of mortality rates for the same purpose is further examined. The results show that the intuitively simple and mathematically sound method is unsuitable for population estimates when mortality rates are bias and unsystematic sampling error reduces the accuracy of fertility rates. The results suggest that when researchers explore fertility behavior of subgroups of the population, the question should not only be on how large confidence interval we are willing to accept on the ASFRs, but also how large point estimate and confidence interval we can accept for the population estimates that the fertility rates and registered number of births imply.

Introduction

Interests in the size of the Mexican-born population in the U.S. and growing body of evidence suggesting that a large part of the Mexican-born are not counted in the decennial Censuses have contributed to an extensive research body that has, with various methods, attempted to estimate the size of the unenumarated part of the resident population. This study explores the feasibility if using fertility rates estimated from sample survey data in combination with registered number of births to estimate the number of Mexican-born females in the childbearing ages in the U.S. in 2000 in order to improve the accuracy of current population estimates that are based on the decennial Censuses. The study also uses a method pioneered by Robinson (Robinson 1980) that uses a set of age-specific mortality rates and registered number of deaths to estimate the exposure years of Mexican-female population 15– 44 year old.

The accuracy of the U.S. decennial Census for population estimates is of great political, financial, and scientific importance. The Census count is the basis for determining political representation and distributing federal- and state-level funding, and is the foundation of our knowledge about the size, composition, and distribution of the current, past, and future population. The Census provides information for estimates of denominator of demographic rates, to define a population frame in sample surveys, and is a source for micro-data for demographic, economic, and social research (see review in Himes and Clogg 1992). The utility of Census data is further found in marketing and local area demography. Because of the wide-ranging importance of the Census count, the questions of whether, and then how, to adjust the count for known coverage errors has long been grounds for discussion (Walashek and Swanson 2007).

The U.S. Census has, from the beginning, fallen short of counting part of the population and has counted other parts erroneously or more than once (Brunell 2000; Hogan 1993; Mulry and Spencer 1993; Robinson 2001; Siegel 1974). A number of different sources contribute to Census under- and overcount. When housing units are assumed to be vacant or are overlooked by the Census Bureau, all the inhabitants are consequently missed by the Census count. When people have two or more residences, they may not be counted in any of them. Some people are not counted at all when they have no usual place of residence and others might be unwilling to provide information to the government, for example when their U.S. residence is unauthorized. Language problems and illiteracy further reduce the ability and willingness of some residents to be included in the Census (see review in Puente 1995).

The quality of the Census count is also affected by Census overcount. Overcount takes place when people are counted that should not be counted or when people are counted more than once. People that have two or more residences may be counted in both places. Others that were born or moved after April 1st, the Census day, may be counted erroneously in the Census, as may some who died before the Census day. Temporary visitors are sometimes counted when they should not be. Persons fabricated by Census staff also contribute to the Census overcount.

The net Census undercount, the difference between the true size of the population and the Census count, or equally, the difference between the undercount and the overcount, was estimated at 1.61% in 1990 and 1.18% in 2000 (U.S. Census Bureau

2001), with later revisions to 1.58% in 1990 and 1.15% with in 2000 (Robinson 2002). The net undercount is frequently reported as an overall indicator of the Census accuracy, but the overall error rate (overcount plus undercount) of 1.87% in 2000 is often a more appropriate indicator of the potential consequences of the Census error. Even though the overcount cancels out part of the undercount on the national level, the error rate differs for different social groups (Breiman 1994; U.S. Census Bureau 2001) and by geographical location, which results in unequal allocation of funding across the states. As a result of this error, some states filed lawsuits (Schenker 1993) to force Secretary of Commerce to adjust the 1990 Census count (see review in (Choldin 1994).

Errors in Census coverage have a substantial effect on many levels. If the Census coverage is adjusted, it could possibly reallocate one-to-three seats in the House across the states (Schirm 1991) and increase funding to 40% of the U.S. states and local governments (Murray 1992), in addition to the severe effect it has on vital statistics and knowledge about the size and characteristics of national and local populations.

The importance of an accurate Census count and more generally reliable population estimates, has lead to large number of studies elaborating on methods to estimate Census coverage and on adjustment procedures. The dual system estimators (DSE) and demographic analysis (DA) are the two main methods that are used to evaluate the Census coverage.

The DSE method is based on wildlife capture-recapture stock estimation techniques. The adaptation for human population is based on the compilation of two independent lists of residents in a given geographical area at the same date. The number of people missed by each list is used to calculate the capture probability of members of the population and thus allow inferences about the total unenumerated population (see review of the DSE methodology in Breiman 1994; Mulry and Spencer 1993).

In evaluating the 1990 Census, the Census Bureau conducted the Post-Enumeration Survey (PSE), which is independent of the Census count but with the same defined population and same reference date. The PSE covered 380,000 people in 169,000 households from 5,290 block clusters from a stratified random sample (Hogan 1993).

The DSE approach rests on assumptions such as causal independence, where the inclusion on the Census count is independent of inclusion in the other survey (see review in Mulry and Spencer 1993). The recapture probability assumption can be relaxed and the probability modeled, but the validity of the method continues to rest on the quality of the survey data, the Census coding, and the accuracy of the matching process. Breiman (1994), in an overview of the P-project reports from the Census Bureau, evaluates different sources of error that arise when using the PES with the DSE method. The errors include matching-process mistakes, interviewers fabricating survey and Census respondents, incorrect address coding, computer program error and correlation bias. The undercount estimate is highly sensitive to small errors in the DSE processes. Two 0.5% errors, one in the survey enumeration and one in the matching process, can result in a 50% error in the undercount estimates. Breiman concludes that the “PES data are not reliable enough to give accurate undercount estimates” (p. 461). The Census Bureau used the American Community Survey for the DSE evaluation in 2000 which faces some of the same challenging problems as the PES.

The Demographic Analysis is a well-developed method that has been used by the U.S. Census Bureau and other agencies to evaluate the Census coverage since 1950

(Himes and Clogg 1992; Robinson et al. 1993). This method estimates the population and specified components thereof (e.g. by age, sex, and race) by combining different governmental data sources and vital statistics that are independent of the Census count. The method is based on the fundamental demographic balancing equation where the population at time 2 equals the population at time 1 plus births and immigration in the period from time 1 to time 2 and minus deaths and emigration in the same time period. In the DA, the equation is commonly applied to specific subgroups of the population such as those defined by sex, age, and race. The method as developed by Coale (1955) used information both internal and external to the Census count to evaluate its quality. To use the DA method, both estimates of the base-year population and the components of population changes must be available. The components are estimated either directly from vital statistics registers, such as the birth registration system, or indirectly from population rates and proportions, such as sex and age ratios within and between censuses (see a comprehensive review of the method in Himes and Clogg 1992). These resulting population estimates are then compared to the Census count to make inferences about the Census undercount, both for the total population and for age/sex/race groups and sometimes specifically for the foreign-born population.

The DSE and the DA are two fundamentally different methods to estimate population size and composition. The DSE is a micro-level approach that utilizes information about individuals that are counted, or not counted, in two subsequent population counts. The DA method is, on the other hand, a macro-level approach to estimate the national population by aggregating population totals for specified subgroups of the population from different official data sources. The main advantage of the DA method is that the method uses available data sources that obviate the need to launch expensive data collection projects. The usefulness of the method rests on the quality of the data and how well necessary population characteristics are recorded. A third approach, “minimum reasonable” estimates, has been developed by combining the DSE and DA methodology.

Closely related to the question of the size and characteristics of the undercount in the U.S. Census is a growing body of literature that tackles the question of the size of the unauthorized foreign-born population (Passel 2007; Passel, Van Hook and Bean 2004). The size of the unenumerated Mexican-born population is of special interest due to the size of the Mexican-born population in the U.S. and the size of the U.S.-Mexico border. In addition to incomplete documentation of the volume of foreign-born immigration, the emigration rate and circular flows of the foreign-born population, especially the Mexican-born, are also very imprecisely known, which contributes to the ambiguous status of immigrants that is a major component of uncertainty in estimating immigrant stocks.

The total foreign-born resident population in the U.S. can be divided into three groups for the purpose of demographic estimates: the authorized non-immigrant population, the authorized immigrant population, and the unauthorized foreign-born population.

The foreign-born non-immigrant population consists of those that are admitted for temporary stay in the U.S. and leave when the purpose of their admission is completed. This group consists of students, exchange visitors, refugees, exchange artists, temporary workers and others with temporary legal residence. Recent estimates indicate (Passel, Van Hook and Bean 2004) that there are about 1,047,400 non-immigrants resident in the U.S in the 2000 Census.

The legal status of the foreign-born population is based on both the authorization of their entry and on the authorization of their extended stay in the U.S. The unauthorized foreign-born population may thus have either entered the U.S. legally, but stayed longer than permitted, or may have entered the country illegally. The distinction between legal and illegal entry of the unauthorized foreign-born population is important when apprehension data and other information about border crossings are used to estimate the unauthorized foreign-born population. It is widely believed that a substantial part of the unauthorized population is not enumerated in the decennial U.S. Census, as many of the immigrants are unwilling to provide the authorities with information about their residence, and language barriers may be a contributing factor even taking into account the possibility of a Census form in languages other than English.

A number of innovative methods have been developed to estimate the unenumerated part of the foreign-born population. Van Hook and Bean (1998) identify two main methods in the literature to estimate the unenumerated population. First, a set of methods that estimate the rate of undercount of subgroups of the population by comparing the Census count with independent data such as surveys, school enrollment records, or ethnographic research. This undercount rate is then applied to the enumerated part of the unauthorized population to get estimate of the size of the entire unauthorized population. The second set of methods are those that make independent estimates of the total unauthorized foreign-born population or specific subgroups thereof, with data that are less prone to undercount (Van Hook and Bean 1998).

Included in the second group are methods that use vital rates and number of events to estimate the size of the population at risk. Borjas, Freeman, and Lang (1991) (as cited in Van Hook and Bean 1998) used mortality rates and the number of registered deaths to Mexican-born men and women to estimate the number of Mexican-born missed in the 1980 Census. The mortality rate estimation method was pioneered by Robinson (1980). Van Hook and Bean (1998) elaborate on this approach with varying assumptions about mortality rates of the Mexican-born to estimate how many existed in 1990. Their results suggest that the underenumeration rate for Mexican-born unauthorized migrants is between 15–35% and that the true size of the Mexican-born female population appears to be better represented in the 1990 Census than the Mexican-born male population. They further show that the undercount rate in the Census appears to have shrunk from 1980 to 1990 for the Mexican-born population.

The logic of the using mortality rates to estimate the population size of a specified subgroup by age and sex follows the basic definition of the mortality rate as defined in Eq. (4-1)

$$m(x) = d(x) / N(x) \tag{4-1}$$

where m(x) is the age/sex-specific mortality rate, usually estimated from the age/sex-specific number of deaths d(x) and the age/sex-specific person years, N(x), exposed to the forces of mortality. If mortality rates for a specified subpopulation are available independent of the population estimates, the terms in (4-1) can be reordered to Eq. (4-2)

$$N(x) = d(x) \Big/ m^*(x) \tag{4-2}$$

where the population N(x) is to be estimated from the mortality rate and number of deaths. The superscript * in (4-2) is used to distinguish the mortality rate from that in (4-1), as the rate in (4-2) is estimated from a source independent from the estimated N(x). Eq. (4-2) can then be used to estimate N(x) from age/sex-specific number of deaths.

The age-specific mortality rates are, for example, obtained from another similar population with similar social and economic characteristics and applied to the specified subpopulation where reliable estimates of the age/sex-specific number of deaths exist. Van Hook and Bean (1998) point out that the death registration method is very sensitive to the underlying assumption about the reliability of the death registration, as well as assumptions about the mortality level of the Mexican-born population in the U.S.

The use of vital rates and the number of vital events to estimate population at risk rests on the assumption that estimates of the vital rates are independent of the coverage errors for which the rates and events are intended to adjust. Available vital rates that are available for part of the population may be used to estimate the population to which the rates apply. Age-specific fertility rates can, with a reliable birth registration system, be used to estimate the number of women 15–44 years old in a given population. The National Center for Health Statistics reports age-specific fertility rates for the female population age 15 to 49 years old (Hamilton, Sutton and Ventura 2005). The denominators for these rates in 2000 are derived from the 2000 U.S. Census count (Martin et al. 2005) and the rates are therefore unsuitable to estimate the Census undercount, unless additional pieces of information are brought into the equation.

Fertility rates estimated on sample surveys where the denominators are independent of the Census estimates are well suited for the task of evaluating population estimates. In this research, the age-specific fertility rates calculated from the Current Population Survey are used to estimate part of the Mexican-born female population in the U.S. and compare those estimates to previous estimates. Fertility rates from a sample survey frequently suffer from the known estimation problems, such as insufficient sample size and possible estimation bias due to systematic attrition or survey coverage error.

Methods

The Current Population Survey (CPS), a monthly U.S. household survey that collects information from 133,710 individuals in 64,944 households[16], includes questions on broad set of topics including labor force participation, education and computer and tobacco use. The June Supplement of the CPS includes questions on the fertility and migration history of the respondents. The information on the timing of the last birth is then used to calculate age-specific fertility rates for groups specified by social and demographic characteristics measured in the survey.

The total sample size of the CPS is large by all standards, but when the sample is broken down by age, sex, and country of birth, the size of the confidence intervals for counts, rates, and proportions increases rapidly. In this research, several different methods are used to maximize the utility of information on fertility history and population estimates included in the CPS June Supplement and compare it to the

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[16] Sample size numbers are from the March 2000 Supplement. By 2002, the sample size was increased by about 50%.

population estimates from the Census count tabulated from the public use micro data (Ruggles et al. 2008).

The first approach in this paper is to calculate the fertility rate from the number of women that gave birth in the 12 months prior to the June CPS 2000 survey. The ASFRs, or more precisely the event-exposure ratios, are estimated from the CPS from five-year age groups as defined in Eq. (4-3)

$$f^s(x,\ 5) = B^s(x,\ 5) \big/ N^s(x,\ 5) \tag{4-3}$$

where *f* denotes the fertility rates for women x to x+5 years old, the superscript s indicates that the statistic is estimated from a sample survey. B denotes births, and N stands for the female population from x up to x+5 years old from a sample survey.

To reduce the evident sampling error in the CPS survey data from more than one sample month can be pooled but caution must be taken not to pool months that include the outgoing rotation groups in the CPS that are interviewed eight times over a period of 16 months. Pooling data across time to increase quality of point estimates further rests on the assumption that the property of interest does not change in the time interval data is pooled. If a rate or a proportion changes between the pooled sampling months, a bias may by incorporated into the estimated statistic. The reduction in sampling error is, however, often favored over the risk of including a small bias from pooling data over a short interval.

The second set of age specific fertility rates used for population estimates in this paper is calculated from three pooled CPS June Supplements, in 1998, 2000, and 2002. The NCHS reports a small (0.4%) change in the fertility rate from 1998 to 2002 for the

Mexican-origin population in the U.S. While the estimated fertility rate of the Mexican-origin women may differ from that of the Mexican-born women, the stability of the estimated fertility by the NCHS strengthens the validity of the assumption of constant fertility rates from 1998–2002 for the pooled CPS data. The fertility rate is defined by Eq. (4-4)

$$f^{ps}(x,\ 5) = \frac{B^{98s}(x,\ 5) + B^{00s}(x,\ 5) + B^{02s}(x,\ 5)}{N^{98s}(x,\ 5) + N^{00s}(x,\ 5) + N^{02s}(x,\ 5)} \qquad (4\text{-}4)$$

where the superscript *ps* stands for pooled survey, and superscripts 98, 00, and 02 stand for the survey years 1998, 2000, and 2002.

The third approach to estimate fertility rates for the Mexican-born population is to use open birth-interval data to increase the usability of the fertility history in the CPS data by counting last births from more than just the last year (Schmertmann 1999). The open-interval methodology increases both the number of reported births in the numerator and the number of women-years in the denominator. The method rests on three basic assumptions; first, that there is constant fertility in the open interval; second, that age is the primary characteristic affecting fertility rate of an individual; and third, that “conditional on age and other controls, there is no heterogeneity in fertility risk across individuals” (Schmertmann 1999 p.506). Schmertmann finds that large violation of the model assumptions introduces only a small bias to the estimates. The estimated fertility rate is defined in Eq. 4-5

$$f^{os}(x,\ 5) = B^{os}(x,\ 5) \,/\, N^{os}(x,\ 5) \qquad (4\text{-}5)$$

where the superscript *os* strands for open-interval birth history from the survey sample. The numerator in this fertility event exposure ratio is the observed number of last births in the past five years and the number of age-specific exposure years in the interval. If, for example, the last birth of a 27-year-old woman was four years ago, the woman contributed one birth to the numerator and four person-exposure years to the denominator, one year for each of the 24, 25, 26, and 27 year old. Both the person years and number of events in the fertility rate estimate are centered on the time of last birth; each sampled person can thus contribute from one to five years of life-years exposure to the risk of childbearing depending on the number of years since last birth. The fourth set of ASFR is obtained by combining Eq. 4-4 and Eq. 4-5 with the five-year birth history interval from three June CPSs, in 1998, 2000 and 2002.

In addition to the four sets of ASFR rates defined above, ASFR from Schmertmann, Swicegood, and Bean (2004) are used for population estimates. Schmertmann et al. present an innovative method of using pooled CPS samples to maximize the utility of the fertility information in the supplement. The retrospective fertility histories from the June CPS data are used to reconstruct historical fertility schedules for the Mexican-born population from 1960 to 2000. The good fit of the12-parameter, time-series poison-regression modeled ASFR to fertility rates estimated with natality statistics and official population estimates gives the authors confidence that the method produces accurate fertility rates for specified groups for which published official statistics are not available. The proposed method has, however, not been published in a peer-reviewed journal, which reduces the usability of the method. Their reported

Mexican-born fertility rates are used in this study to provide additional population estimates for the Mexican-born population.

The NCHS publishes data on fertility rates for the Hispanic population in the U.S. Studies do however show that the Mexican origin population experience higher fertility rates than other Hispanic origin population, and that foreign-born Hispanic experience higher fertility than later generation Hispanics (Smith and Edmonston 1997). The rates for the Hispanic origin are, however, useful to for comparison to the other estimates, as fertility rates based on a sample survey include unsystematic sampling errors that may lead astray population estimates.

Two sets of mortality rates are used in combination with the reported number of deaths to Mexican-born women in the U.S. Mortality rates independent of the population estimates for which the rates are intended to adjust are hard to find. Sample surveys rarely have a large enough sample size and a small enough attrition rate to justify the use of panel data to estimate mortality rates of women in their reproductive ages where mortality is relatively low. The choice of mortality rates for estimates of population size have therefore been guided by empirically supported assumptions rather than on direct estimates of the subgroups' mortality rates.

For the purpose of this paper, the total U.S. female mortality rates in 2000 and the female mortality rate in Mexico in same year are used to estimate the number of Mexican-born women in the U.S. The number of deaths by age, sex, and country of birth are found by tabulation of the NCHS cause-of-death public-use data file (National Center for Health Statistics 2000). The life table values for the U.S. and Mexico were collected from the WHO life table for member states database (World Health Organization 2006).

Results

Table 4-1 reports population estimates for the Mexican-born female population resident in the U.S. in 2000 obtained from different data sources and different fertility rate calculations.

The first column includes the population count from the U.S. Census in 2000 from the IPUMs data (Ruggles et al. 2008) that is generally believed to be too low. The second column includes population estimates from the June CPS, where the Mexican-born female population is estimated with the basic CPS weights (US Department of Labor and Bureau of Labor Statistics 2002). The estimates from the CPS counts are 5–23% lower in each five-year age category than the corresponding age group from the Census count. The CPS population should not be significantly different from the Census count, as the sampling weights are created to reproduce the Census count with the exception of a slightly different population universe, where the CPS represents the non-institutional population. The population in the armed forces are included in the CPS but not used for estimates of the unemployment rate (Raley 2002). Both the Census count and CPS estimate show a far larger number of Mexican-born in their early twenties than in their late teens, a pattern that is expected when immigration peaks in the early- or mid-twenties (Rogers and Raymer 1999; Rogers and Castro 1981).

Population estimates from fertility rates

In the presence of a highly accurate birth registration system, the fertility rate methodology for population estimate rests on the accuracy of estimated fertility rates. The results in columns 3–8 in Table 4-1 show a large variation in the estimated number of Mexican-born women depending on the set of ASFR used in the estimation process. The observed number of births to 15–19-year-old Mexican-born women in combination with the estimated fertility rate based on the 5–year birth-history interval pooled across June CPS surveys in 1998, 2000, and 2002 (column 5) shows a population estimate of 808 thousands, which is 2.7 times higher than the estimated population from the Census for this age group. This estimate is based on sample survey rates that have the largest number of person-years. Even with the general consensus that the Census underestimates the size of the foreign-born population; the size of the population suggested by the fertility rates of 15– to 19 year olds presented is too high to suggest a reliable population estimate.

The application of vital rates presented in Eqs. 4-3, 4-4, and 4-5 for population estimates is highly sensitive to small changes in age-specific rates. To examine the sensitivity of the method, a simulation was performed. One Mexican-born 15– to 19-year-old female in the CPS June 2000 survey was selected at a time and assigned to a different country of birth (other than Mexico), thus reducing the denominator by a number indicated by the final weight of the person-record. The number of births is as well reduced by the same quantity if the woman had given birth in the year prior to the survey (Eq. 4-5). Each person in the sample can therefore have a substantial effect on the estimated ASFR. By removing one person at time from the 2000 June CPS and recalculating the estimated fertility rate, the derived population estimate fluctuates with changes in the estimated fertility rate. The largest swing in the estimated population with the removal of one Mexican-born female from the sample is an increase in the level of 105,000 women to a decrease of 11,000 women. This exercise simulates a plausible error in the survey management, where coding errors and fabrication of persons are known to happen.

Sampling error is, however, a major contributor to the accuracy of these estimation methods. Calculations of standard error of proportions (fertility-event exposure ratio) are used to estimate 95% confidence interval for the population estimates based on the fertility rate analysis. The upper and lower confidence intervals for the fertility proportion are calculated on the weighted population proportion but unweighted number of person-years in the sample. The exact confidence interval for proportion is applied from Armitage and Berry (1994). As the number of births are divided by a number smaller than 1, the lower confidence interval for the fertility ratio becomes the higher confidence interval for the population estimate and vice versa.

Table 4-1: Estimates of the 15– to –44-year-old Mexican-born female population in 2000 residents in the U.S. from different sets of fertility rates

	Population count		From fertility rates					
Age	(1) Census	(2) CPS pop. estimates	(3) 5–year int. pooled '98, '00, '02	(4) Single year, pooled '98, '00, ´02	(5) 5–year interval, 2000	(6) Single year 2000	(7) NCHS Mexican Origin	(8) Poison regression estimates
15–19	294,403	225,952	808,447	566,616	713,618	371,721	469,434	499,175
20–24	482,135	393,675	676,674	525,532	734,450	507,607	631,172	537,391
25–29	583,753	511,053	743,641	764,436	637,047	538,709	760,428	585,077
30–34	555,566	478,672	603,650	579,166	594,904	549,306	678,113	584,163
35–39	482,044	406,363	456,683	396,291	462,004	418,116	580,528	458,920
40–44	372,850	353,106	208,876	278,261	295,922	341,211	498,525	242,042

The population estimates in Figure 4-6 summarize clearly the problem with the usage of survey ASFR for population estimates. A potential bias in the fertility rates for the youngest age group results in too-high estimates for this age group. The fertility rates are based on one of a fairly large sample survey where information on up to five years of fertility history is pooled from three surveys. The smallest confidence interval is for the 20–24-year-old, where the range is about 132,000 persons.

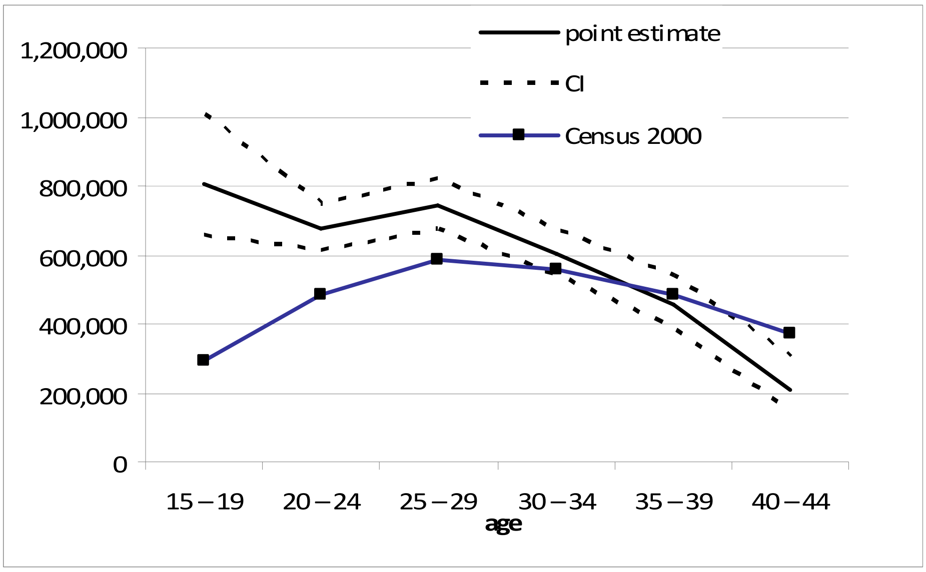

Figure 4-1: Estimated number of Mexican-born females in the U.S. from ASFR based on 5–year birth history, pooled data from the 1998, 2000, and 2002 June CPS Supplements.

The population estimates presented in Figure 4-7 are based on fertility rates which include measure-events and exposure-years included in the estimates presented in Figure 4-6. Consequently, the age patterns of the estimates are similar, but the CI are wider, as the rates in Figure 4-7 are based on a smaller number of person-years. The larger estimates of Mexican-born female population age 15–19-year-olds than of 20–24-year-olds observed both in Figure 4-6 and Figure 4-7 is unrealistic given the known age pattern of migration observed in the literature **(**Rogers and Raymer 1999; Rogers and Castro 1981**).**

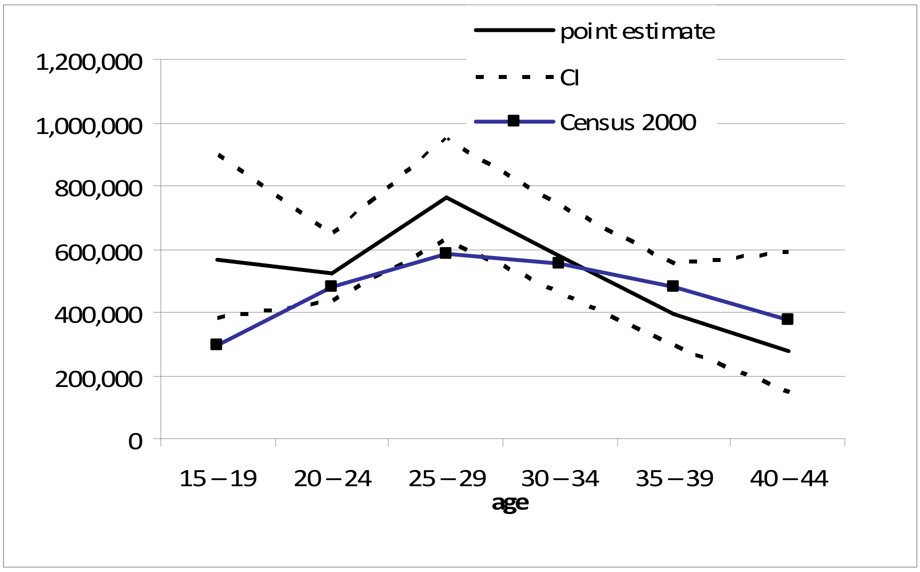

Figure 4-2: Estimated number of Mexican-born females in the U.S. from birth-history last year pooled from 1998, 2000, and 2002**.**

The population estimates presented in Figure 4-3 are based on fertility rates from five year birth history from CPS June 2000 Supplement. The overall age pattern is similar to that estimated in Figure 4-2 except for lower estimate in the youngest age group and

50% larger estimate in the oldest age group. The sample size for the point estimates in Figure 4-3 is about one third of that in Figure 4-1 that results in far larger confidence interval, which is about 500.000 persons wide for the youngest age group.

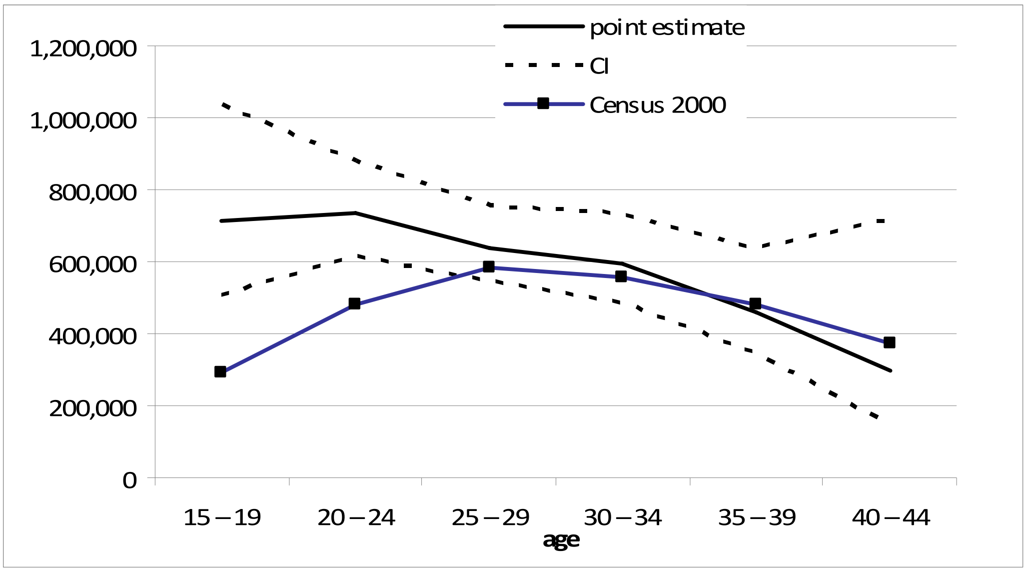

Figure 4-3: Estimated number of Mexican-born females in the U.S. from ASFR. Five-year birth history, CPS June 2000 Supplement.

Figure 4-4 shows a set of population estimates similar to the Census count, but the calculated confidence interval reveals very unstable population estimates. The underlying rates are based on a single survey year with birth history from a single year, which provides the smallest number of person-years for the fertility rates. The largest confidence interval for any set of population estimates presented in Table 4-1 are for the 40–44-year-old age group, for which the lower CI for the fertility rate is very close to 0, and that results in over 2 million 40–44-year-old Mexican-born women. The maximum value in Figure 4-4 is set to 1.2 million for comparability with previous figures. This large population estimate is an obvious shortcoming of the method when the confidence interval reaches zero, which leads to a population approaching infinity.

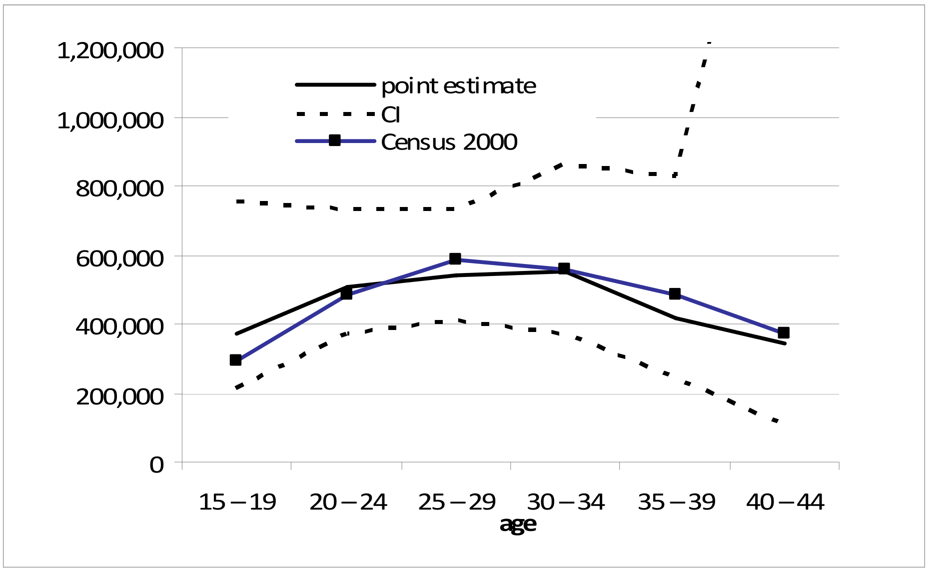

Figure 4-4: Estimated number of Mexican-born females in the U.S. from ASFR. Birth-history last year, CPS June 2000 Supplement.

Population estimates from mortality rates

Columns 3–8 in Table 4-2 show the number of Mexican-born women resident in the U.S. based on the number of deaths from multiple cause-of-death public-use data files (National Center for Health Statistics 2000) from two sets of mortality rates. First from the life table for the U.S. female population and then mortality rates from life table for the Mexican population in 2000 (World Health Organization 2006). If the Mexican immigrants in the U.S. were from a random sample of the Mexican population and randomly allocated to a socio-economic position in the U.S., then one could assume that that the mortality rate for the immigrants were somewhere between the mortality rates experienced in the two countries where the immigrants are exposed to the forces of mortality in their lifetime. Studies do, however, suggest that immigration is a selection process with people, who are, on the average, different from those who do not migrate, with respect to characteristics such as age and educational attainments. The random sample and random allocation assumption thus does not hold, but in the absence of precise mortality rates for the Mexican-born population in the U.S., exploration of the usability of the selected mortality rates is worth the attention.

When the migration status of a substantial part of the Mexican-born population in the U.S. is ambiguous and circular (Bean et al. 2001), the residence status of the death certificate does not necessarily capture the same place of residence that defines population estimates. The population estimates with the mortality rate approach is therefore calculated on three sets of age-specific number of deaths. First, all deaths to

Mexican-born females in the U.S. are used regardless of their resident status (columns 9 and 10). Then the number of deaths by age to Mexican-born women residents in the U.S. (columns 11 and 12) and finally the number of deaths to Mexican born women resident in the U.S. averaged over 1999, 2000 and 2001 in order to reduce effect of annual fluctuation. Table 4-4, 4-5 and 4-6, in the Appendix, show the mortality assumption (age specific number of deaths and mortality rates) for the population estimates presented in Table 4-2.

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Table 4-2: Estimates of the 15–44-year-old Mexican-born female population residents in the U.S. from different sets of mortality rates and number of deaths

	Population count		All Mexican born deaths in U.S.		Mexican born Residents in the U.S. Number of deaths from 2000		Mexican born Residents in the U.S. Average number of deaths from 1999, 2000 and 2001	
Age	(1) Census	(2) CPS pop. estimates	(9) U.S. life table	(10) Mexico life table	(11) U.S. life table	(12) Mexico life table	(13) U.S. life table	(14) Mexico life table
15–19	294,403	225,952	241,026	213,636	205,128	181,818	205,983	182,576
20–24	482,135	393,675	327,660	290,566	289,362	256,604	304,965	270,440
25–29	583,753	511,053	381,132	310,769	362,264	295,385	335,849	273,846
30–34	555,566	478,672	306,757	273,494	262,162	233,735	275,225	245,382
35–39	482,044	406,363	261,947	246,667	245,133	230,833	234,808	221,111
40–44	372,850	353,106	213,295	206,145	185,549	179,330	188,247	181,937

In addition to problems with accurate population estimates for the mortality rate denominator, the numerator may also be biased if the country of birth of the deceased is incorrectly recorded on death certificates. The estimated number of deaths from mortality data may not properly reflect the living condition and forces of mortality that immigrants experience in the U.S. If the immigrant is an unauthorized resident, he or she is likely to be without health insurance coverage, which may lead to return migration to Mexico if the immigrant becomes sick, and thus reduce the number of deaths occurring in the U.S. Sickness may also reduce the probability of migration to the U.S. in the first place. On the other hand, the legal and the social status of unauthorized immigrants may contribute to hazardous living conditions that are worse than for the average U.S. resident. Consequently, some Mexican-born immigrants may experience higher rates of injuries and unhealthy working conditions that could affect their mortality rates.

All sets of mortality event-rates estimation produce five-year population estimates that are considerably smaller than estimates from the Census count. The difference ranges from 18% to 58% depending on age groups and set of mortality assumptions. There is very little difference in the population estimates if we use deaths from 2000 or average over three consecutive years which suggest that annual fluctuation is lower than the estimates from the Census 2000. The mortality analysis approach is clearly not suited for estimating the Mexican-born population in the U.S. when the method produces estimates smaller than those that are known to be too low. Without well-supported selection of proper mortality rates, the mortality analysis does not provide reliable population estimates, as the method is very sensitive to selection of a set of mortality rates (Van

Hook and Bean 1998) and a small error in fertility rate can produce a large error in population estimates.

Discussion

The use of estimated vital rates and registered vital events to calculate person years is intuitively a solid methodology for population estimates. The person year estimates is based on fertility rates equation where two quantities produce the third with simple cross-multiplication. The systematic and random error that affects the estimated fertility rates is directly influencing the population estimates. The calculated confidence interval with the population figures presented in Figures 4-1 to 4-4 are too wide to provide valuable information for suggested corrections of the official population estimates based on Census count.

When dissimilarities between the various population estimates are examined the results do provoke stimulating question on the nature of both the fertility behavior and fertility measurement of Mexican-born women in the U.S.

When the five year birth history is used for to estimate the fertility rates for the 15–19 year old, the resulting population estimates are 2.4 to 2.7 times the Census count, the validity of open interval methodology for fertility estimates under the condition of substantial circular migration. The calculation of the fertility rates takes into account timing of migration to the U.S.[17] but if the migration process is circular and ambiguous, the potentials for overlapping timing of the two events may suggest that retrospective birth history is not suitable for fertility estimates for the migrant population.

The problem with defining dates, duration, and exposure to the risk of childbearing in the U.S. is not only a question of measurement in the Current Population Survey but might be a fundamental question about the nature of the fertility migration pattern of the young Mexican-born female population. If pregnancy in Mexico is followed by a migration and childbearing in the U.S. the migration inflates the fertility rate by increased number of births with less than complete person year of exposure.

Guendelman and Jasis (1992) find, analyzing data from household survey and focus group discussions, that about 10% the respondents crossed the border to give birth in the U.S. in 1982–1987. While the sample size was only 184 15–44-year-old women, the result suggest that this practice occurred in the past but it is impossible to apply this estimated proportion from a specific border-county in the 1980s to the entire nation in 2000.

A tabulation of the Mexican 2000 Census indicates that there are 16,264 0-year old and 20,721 1-year old children that were born in the U.S. but resident in Mexico. Information on the nativity of the mother of those children is not available as the mother-child link is not collected in the Mexican census. A Mexican born woman in the household could have number of different family relationship with the child. If all the 0-year old U.S. born in the Mexican 2000 Census are children born to Mexican born

[17] The year of entry to the U.S. is recorded in set of two, three or four years, such as 1992—1993 or 1996—1998.

mothers, the number accounts for 4.4% of the birth cohort in the U.S. defined by Mexican born mothers.

Rendall and Torr (2008) find by analyzing the U.S. and Mexican Census and U.S. birth registration data, that about 10% of second generation Mexican-American children live in Mexico some part of the school years. The authors suggest that high rate of migration back to the U.S. explains why only about one third of those children spend all their school years in Mexico. While the Mexican census data does permit analysis of the mother-child connection to estimate how many of the mothers migrate to Mexico with their U.S. born children, the proportion of second-generation Mexican-American children that spend part of their school years in Mexico, supports the idea that some part of the high Mexican-born fertility in the U.S. might driven by circular migration associated with fertility intentions. They further find that the high rate of return migration reduces the number of school years second generation Mexican-American live in Mexico.

The ASFR from five year birth history, pooled across three survey years, produce significantly smaller population estimates for the 40–44-year-old Mexican-born female population than the Census count produces. Other estimates in Figure 4-2–4-5 process lower point estimate but with confidence interval that overlaps the Census estimates.

The results from the use of mortality rates to produce population estimates are disappointing but informative. When the application of mortality rates produce population estimates that are significantly below the estimates from the Census count there are in essence only three possible explanations, one that concerns the Census count and two that concern the mortality estimates. The first potential explanation is that the Census overcounts the Mexican-born population. The second is that the estimated number of deaths to the Mexican-born population in the mortality rate method is too low. Finally, the third possibility is that the mortality rate used in the estimation process is too low.

The first of the explanations is very unlikely given the large body of evidence that indicates that the Census undercounts the Mexican born population. A more likely explanation of the low population estimate is the accuracy of the mortality rate. Previous studies have found that Hispanics in the U.S. experience lower adult mortality rates than non-Hispanic whites, even though they have in general lower socioeconomic status (Sorlie, Backlund and Keller 1995). Palloni and Arias (2004) in their evaluation of this so called epidemiological paradox, find that the “salmon-bias effect” is a partial explanation for lower mortality rates for the Mexican-born population. In the presence of circular migration, when people move back and forth across the U.S.-Mexican border, it may be difficult to separate the "healthy-migrant effect" and the "salmon-bias effect"

It is also likely that deaths to the Mexican foreign born are undercounted. While the overall coverage of the death registration system is close to complete, classification error on natality may reduce the estimated number of births to Mexican-born is the U.S. that would result in too low population estimate if the mortality rates are correctly estimated. The increased effort in the 1990s compared to that of the 1980s to apprehend illegal immigrants may result in misreporting of country of birth on death certificates. Family members may try to hide the origin of the deceased and thus their family, by reporting U.S. as the country of birth rather than Mexico. This would result in too few deaths of Mexican-born in the cause of death registry, which could (partially) explain why the current mortality rate population estimates do significantly worse in current study than previous (Van Hook and Bean 1998) application of the method.

In general, the fertility rate estimation seems to work better than the mortality based estimates apart from the large sampling error that produce confident interval too large to provide usable point estimates. The concentration of undocumented immigrants is in the 15–29 year-old-age group is a partial explanation to the large difference between the Census count and fertility rate population estimates. The large difference between the Census count and the ASFR estimation figures in the 15–24 year-old age group can have number of potential explanations. Young adults are in general more likely to be undercounted by the U.S. Census as they tend to be more mobile and less likely to be settled in a permanent residence and therefore less likely to be counted in the Census. It is likely that substantial part of the large number of circular and invisible immigrants reported by Bean et al. (Bean et al. 2001).

The census seems to be doing better counting people older than 30 than it does in counting the younger generations. But prior estimates of the Census count suggest that the Hispanics are underreported in all age groups. The answer to the question about how large population undercount is acceptable depends on the application of the Census data. A correction of the size of the 30–39 year-old Mexican-born population may not result in the reallocation of seats in the United States House of Representatives but could have a significant impact on the reallocation of state level funding to programs to support families and provide children education of acceptable quality.

When researchers estimate the ASFR of specified subgroups of the population the question is frequently how large confidence interval the researchers are willing to accept on the ASFRs. With the availability of the natality data, researcher could make population estimates based on the estimated fertility rate and registered number of births, to evaluate the plausibility of their fertility rates.

The idea of combining survey data with registration system has been explored in different areas. Post stratification is a common example where known characteristics (such as age, sex, race and residence) of the population are used to improve the estimates of prevalence of other characteristics in the population (Levy and Lemeshow 1999). The use of constrains to regression parameter estimates from population information have recently incorporated uncertainty in the population information (Rendall, Handcock and Jonsson Forthcoming).

The current study combines data from survey, census and vital registration systems to provide different population estimates. While the results are disappointing for the purpose of population estimation, the results are informative and point out the importance of maintaining the availability of quality data collection system for researchers and policy makers.

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Appendix C.

Table 4-3: Fertility rates used for population estimates in Table 4.1

(3)* 5–year int. pooled '98, '00, '02	(4) Single year, pooled '98, '00, ´02	(5) 5–year interval, 2000	(6) Single year 2000	(7) NCHS Mexican Origin	(8) Mexican in Mexico
0.055	0.079	0.063	0.120	0.095	0.055
0.163	0.210	0.150	0.217	0.175	0.135
0.148	0.144	0.173	0.204	0.145	0.148
0.115	0.120	0.117	0.126	0.102	0.110
0.063	0.072	0.062	0.068	0.049	0.060
0.029	0.022	0.021	0.018	0.012	0.020

* Column numbers in parenthesis refer to corresponding column numbers in table 4-1.

Table 4-4: Mortality rates used for population estimates in Table 4.2

Age range	U.S.	Mexico
0	0.00663	0.02885
1–4	0.00029	0.00172
5–9	0.00014	0.00026
10–14	0.00016	0.00027
15–19	0.00039	0.00044
20–24	0.00047	0.00053
25–29	0.00053	0.00065
30–34	0.00074	0.00083
35–39	0.00113	0.00120
40–44	0.00173	0.00179
45–49	0.00252	0.00293
50–54	0.00381	0.00483
55–59	0.00608	0.00756
60–64	0.00974	0.01199
65–69	0.01516	0.01814
70–74	0.02341	0.02782
75–79	0.03760	0.04279
80–84	0.06297	0.06570
85–89	0.10424	0.10240
90–94	0.17057	0.16202
95–99	0.27594	0.26028
100+	0.44127	0.42447

Table 4-5: Number of deaths of Mexican-born women resident in the U.S. 1999, 2000 and 2001.

Age	1999	2000	2001	Average
15–19	76	80	85	80
20–24	152	136	142	143
25–29	157	192	185	178
30–34	202	194	215	204
35–39	231	277	288	265
40–44	299	321	357	326
45–49	349	400	418	389

Table 4-6: Number of deaths of Mexican-born women in the U.S. in year 2000 by residence status

Age	Residents	Intrastate Nonresidents	Interstate Nonresidents	Foreign Residents	Total
15–19	56	20	4	9	89
20–24	111	17	8	16	152
25–29	147	38	7	13	205
30–34	158	33	3	17	211
35–39	239	30	8	9	286
40–44	286	28	7	19	340
45–49	340	50	10	9	409

Definition of terms in table 4.6.

Residents: State and County of Occurrence and Residence are the same

Intrastate Nonresidents: State of Occurrence and Residence are the same, but County is different

Interstate: Nonresidents: State of Occurrence and Residence are different, but both are in the U.S.

Chapter 5

Dissertation summary

Sound knowledge about the population size, characteristics and growth, is crucial to population policy, governmental economic planning and welfare reform. When the U.S. Census, the main tool population estimates, is known to have significant systematic coverage error, all available resources should be employed to improve our knowledge about the current and future population dynamics. The foreign-born population resident in the U.S. is known to be particularly under-enumerated in the decennial Censuses. As Mexican-born are by far the largest group of both legal and undocumented immigrants, substantial effort has been made to estimate their number in the U.S., their fertility behavior and their contribution to the future U.S. population.

In the three papers presented in this thesis the completeness of the birth registration system is exploited in an attempt to increase our knowledge about three components of population characteristics; size of the current population, the fertility rate in the current population and the expected number of births in the near future.

In chapter 2 a newly developed method is introduced, the sending country birth cohort (SCBC) model, to improve projection of births to the Mexican-born female population in the U.S. The result of the SCBC model is compared to results of conventional projection methods. When the projection is executed from selected base years to 1999 and compared to the observed number of births, the SCBC performs dramatically better than the conventional projection methods. When projecting with the

SCBC model forward from 1999 and adding estimated cumulative contribution of Mexican immigrant fertility from the 1980s to 2040 the method estimates 36 million births, including 25% to 50% more births after 1995 than are projected using conventional methods. The results suggest that previous official population projections by the Census Bureau have seriously underestimated the contribution of immigrant fertility.

In the third chapter the question on why current and recent U.S. fertility is so high (2.06 in 2000) is addressed by evaluating the contribution of first-generation immigrant fertility on the official estimated U.S. TFR. Simple decomposition is used to extract the effects of Mexican-born and other foreign-born immigrants on the U.S. TFR. The results show that 6% of the U.S. TFR is attributable to a higher ASFR of immigrant women. About 63% of the foreign-born effect in 1990 and 71% in 2000 is attributable to Mexican-born women. The paper in chapter 3 further explores the effect of age composition of the Mexican-born female population in the childbearing ages. When age composition of a subpopulation favors ages with higher ASFRs, the TFR of each subgroup is not affected but the composition can have an impact on the TFR of the overall population. Approximately 11% of the Mexican-born contribution to the high U.S. TFR is due to the age composition of the Mexican-born. The results further shows that the large increase in the number of foreign-born population in the U.S. from 1990–2000 is mostly offset by a reduction in the TFR among both the foreign-born and the native-born population.

The method does not address the contribution of second and later generation Mexican-immigrants that previous research has shown that experience higher TFR than third and later generations (see Table 2-1). Despite this limitation the results provide clear and informative information about the effect of first-generation immigrants on the U.S. high TFR. The chapter touches on the possible effect of Census undercount for the Mexican-born population. But even if the Mexican-born female population resident in the U.S. increased (adjusted) by 20% from the 2000 Census count, uniformly across all age groups, the overall U.S. TFR would be reduced by only 0.01 children per woman, a reduction from 2.059 to 2.049.

Most of the industrial countries observe fertility levels well below replacement level. The results suggest that immigrants contribute to a small or modest part of this high fertility schedule and that a small but noticeable part of this effect is due to age composition of the Mexican-born female population. In the absence of all immigrants, the U.S. TFR would be just below replacement level or 1.93. Researchers can therefore continue to ask why U.S. fertility remains relatively high. The paper contributes to improved understanding of the formal demographic effect of immigration fertility.

The final paper presented in chapter 4 of this thesis tackles the usability of the simple and mathematically sound method that is based on the definition that vital rates equals the number of vital events divided by the person years at risk of experiencing the event. If the age-sex specific rates are known or estimated, independently of a specific population, then registered number of events can be divided by the rate to provide population estimates. This method can hold under 2 conditions. First, those rates are estimated independently of the population. Second, the registered number of events and the vital rates are unbiased. The results suggest that mortality rate method cannot be used for estimating the current Mexican-born female population residence in the U.S. Either the rates or the number of registered events are biased. The application of fertility rates for the same purpose suggest that the ASFR rates based on June supplement of the CPS are estimated with too wide confidence interval to be of use for population estimates. The vital-rate method, which stands on strong mathematical foundation, is broken down by statistics; lack of efficiency and surplus of bias.

When confronting the question on why the rates, especially the mortality rates, are not suitable for this task, a number of potential explanations emerge. One possibility is that the true mortality rates of U.S.-resident Mexican immigrants are lower than the overall U.S. population or the Mexico population. Mexican immigrants may be healthier on average than non-migrants due to selective immigration (i.e., the healthy migrant effect). Also, the "salmon-bias" hypothesis suggests that Hispanic-origin immigrants have lower mortality in the U.S. because sick and dying immigrants are likely to return to their home country. The "salmon-bias-effect" suggests that immigrants in the host country are not less frail than the natives but the vital event takes place and is recorded in the country of birth. Another possibility is that the number of deaths to Mexican immigrants are not adequately recorded in U.S. vital records; some decedents may be erroneously recorded as U.S.-born rather than Mexican-born.

The reverse of the salmon-bias-effect could affect the estimated ASFR. The benefits of giving birth to a child in the U.S. might contribute to the decision and timing of temporary or permanent migration to the U.S.. Union formation, establishment of one's own household and family planning may also coincide and intensify the estimated ASFR when the founding of a new household is combined with a decision to migrate to the U.S. Both the temporary migration for the benefits of U.S. citizenship for the child and the long term migration associated family formation, would inflate the estimated immigrant ASFRs, when measured cross-sectionally in the U.S. but not necessarily if the cohort fertility of the foreign-born population were measured.

The three papers presented above, contribute to the migration science and the general social sciences, by emphasizing the effect that immigration from Mexico has on the U.S. demographic system. The preceding papers have examined the formal demographic effect of immigration and immigrant fertility. When addressing the three main research questions it is clear that the nature of Mexican migration is not completely understood and further research is needed to fully comprehend the nature of the migration processes. When tackling the first research question, the first paper suggests that the future contribution of immigration and immigrant fertility is likely to be much greater than previous projections suggest. This immigration impact is likely to reduce the level of population aging that is inevitable with observed fertility decline in the U.S. population in the past decade. The second paper indicates that the U.S. fertility level remains relatively high, in part because of the large number of foreign-born women in the U.S. and their higher than average fertility rates. This contribution to high fertility rate corresponds with the result from the first paper where both suggest that immigrant fertility is having substantial impact on U.S. future population. In the third paper the question on the use of vital rate to infer about the resident Mexican-born population in the U.S. received poor support. When tackling the question on why the method failed, the need for improved measurement on immigrants' vital rates and on the nature of the Mexico-U.S. migration stream emerged.

Immigration and immigrant fertility maintain a growing U.S. population. Without immigrant fertility the U.S. total fertility rate would be below replacement level that would result in a declining population in the long run in the absence of migration. While rapid population growth is by many considered a problem in less developed countries, too-slow growth and population decline may be consider a problem for more developed countries as large fraction of the economy is dependent on increased demand for produced goods, services and construction. Slow growth and population decline that is experienced with population aging will alter many aspect of the society including the health care needs, the social security system, labor market dynamics and the political processes with changing needs of the voting population.

The three papers are focused on population estimation, projections, estimation on demographic events and demographic rates. The need for improved data and advanced models to capture the migration-fertility link is clearly needed. The first paper provided an example how the lack of accurate data can be circumvented with improved models that is able to provide quality projection of the contribution of immigrant fertility. While the innovative model makes important contribution to predicted contribution of immigrant fertility, the accurate and reliable population estimates are preferred to modeling technique that leaps over important vital processes such as survivorship and migration.

The question on how to improve data quality on population characteristics, vital events and vital rates, has long been of central focus in the formal demographic literature and other social sciences, both by emphasizing more data collection and improved measurement instruments in current data collection projects. The results from the preceding chapters illustrate the need for improved knowledge about the Mexico-U.S. migration dynamics. Longitudinal or retrospective surveys on the migration experience of the Mexican-born population, could contribute to increased knowledge about the nature of the circular nature of Mexican-U.S. migration, but some problems may arise when collecting survey information in order to make inference about the population from the sample statistics.

Modeling the risk of migration across the Mexico-U.S. border on the individual level may help enhance the quality of immigration assumptions in official population projections. The SCBC approach is based on the assumption that cohort size is the key determinant of the number of Mexican-born women that experience childbearing in the U.S. Modeling those rates by taking into account factors such as educational level and marital status, may increase the quality of future population projections for the largest contributing country of international migration to the U.S.

Research that examines in detail the reliability of information on a sample of birth- and death certificates would increase the understanding of demographic processes of immigrants in the U.S. Survey research or analysis of health administrative data is further needed to model how and where the Mexican-born population in the U.S. seeks health service. The level of which Mexican-born immigrants seek medical service across the border can be informative for resolving the epidemiological paradox. This kind of research could help to determine the level of which the “salmon bias effect” and the “healthy migrant” hypothesis, explain the lower mortality rates of Mexican-born in the U.S. than the mortality rate of the native-born.

In addition to the formal demographic contribution of the papers presented in this dissertation, they contribute to more general sociological interest of the importance of population growth processes and population characteristics. Large levels of immigration and high immigrant fertility, not only increase population growth, but also the age structure and the ethnic composition of on the U.S. population that has general social implication on both the macro and micro level.

Large levels of Mexican-born and more generally Hispanic immigration and high Hispanic fertility level will increase ethnic diversity in the U.S. complex social stratification system. Ethnic and race relations will become increasingly more important aspect of social reality and on the field of sociology in the near future. Whether or not this increased ethnic diversity will alter the national identity of the U.S. is not clear but language diversity, labor market dynamics, poverty- and welfare policy will continue to be heavily influenced by the effect of immigration and immigrant fertility in the next decades.

The three papers in this thesis exploit the existence of complete coverage birth registration system in the presence of bad population estimate to tell a story on the demography of migration in the U.S. They provide information about the nature of the current and future U.S. fertility and can be used for improved population projections and thus support policy makers, in decisions on future actions, where population size and composition are of importance. The papers also tell a small, but significant, story about the current and future U.S. immigrant society.

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Professional positions

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Selected publications

Schoen, Robert og Stefán Hrafn Jónsson (2006). “Intergenerational Transfer Implications of Birth Fluctuations” *International Studies in Population* 3. 279–290.

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