

APPENDICES

Appendix 1. Residual Methodology for Estimating the Unauthorized Foreign-born Population

The material presented is an update of the methodology statements previously published as appendices for other articles (Van Hook and Kreisberg 2026; Van Hook and Sheftel 2025). These studies relied on the “2023 Vintage Estimates” that run from 2005 through 2023. The update provided here, referred to as the “2024 Vintage Estimates,” extends the estimates of the unauthorized foreign-born population from 2023 to 2024, the latest available American Community Survey (ACS) data, and refines the methodology in three ways as described below.

Residual Estimates of the Unauthorized Population

For the purposes of developing a residual estimate, we distinguish among three foreign-born groups. The first, *the unauthorized foreign-born population*, U , includes those who entered the country without inspection and those who arrived legally with temporary visas (e.g., student, tourist, temporary worker) but overstayed or otherwise violated the terms of their visas. We include in this group foreign-born people who have received an official, temporary reprieve from deportation but otherwise resemble unauthorized immigrants demographically, for instance: Temporary Protected Status (TPS) recipients, Deferred Action for Childhood Arrival (DACA) participants, and asylum applicants with work authorization. For estimation purposes, we limit the unauthorized to those who arrived in the country in 1982 or later, with the rationale that most immigrants who arrived before 1982 would have legalized because they were eligible for amnesty under the Immigration Reform and Control Act (IRCA) of 1986. This group of post-1982 entrants who are unauthorized cannot be identified directly in administrative records or census data. The second group, *the LPR/naturalized/humanitarian population* (LNH) includes all naturalized citizens; legal permanent residents (LPRs, or “green card” holders); and immigrants with humanitarian statuses such as refugee or asylee who have yet to adjust to LPR status. Like the unauthorized foreign-born, we limit this group to those who arrived in the country in 1982 or later. This group can be estimated using administrative data. Finally, the third group, *all other foreign-born*, includes nonimmigrants admitted lawfully with temporary visas (such as international students, H-1B high-skilled workers, and H-2A agricultural workers) and all foreign-born persons who arrived in the country before 1982. Pre-1982 arrivals can be identified directly in the American Community Survey (ACS), while nonimmigrants can be identified indirectly based on their characteristics in the ACS.

While the unauthorized foreign-born population (U) cannot be estimated directly, the combined unauthorized and LNH populations ($C = U + \text{LNH}$) can be estimated using the ACS by excluding the “other foreign born” (nonimmigrants and pre-1982 arrivals) from tabulations of the total foreign-born population. Additionally, the number of LNH foreign born can be estimated using administrative data (LNH). Therefore, after certain adjustments are made, the unauthorized foreign-born population can be estimated by subtraction ($U = C - \text{LNH}$).

To do this we proceed in 4 steps. First, we use the ACS (Ruggles et al. 2024) to estimate the combined unauthorized and LNH populations (C), disaggregated by sex (s), region or country of birth (r), birth cohort (c), year of entry (y), and year (t) for all persons of foreign parentage born outside of the United States or outlying areas except those in the third “other foreign-born” group,

which is dropped from the sample. We rely on code developed by Julia Gelatt at the Migration Policy Institute to identify nonimmigrants in the ACS. This group includes noncitizens whose occupations, immigration histories, and family/household characteristics are congruent with the eligibility criteria for specific nonimmigrant visa categories¹. Totals of nonimmigrants identified in the ACS are comparable with administrative data from DHS.

The second step involves smoothing the ACS population estimates to account for heaping in reported year of entry every ten years (i.e., around 1990, 2000, and 2010), to ensure continuity in entry and birth cohorts over time, and to reduce the incidence of negative population estimates.

The third step involves estimating the LNH foreign-born population who arrived in the country in 1982 or later. To do so, we use compiled administrative data on the number of legal admissions or entrants for each year since 1982, disaggregated by sex (s), region or country of birth (r), birth cohort (c), year of entry (y), and year of admission (a). We add to these data an estimate of the number of lawfully present refugees, asylees, and other humanitarian entrants who have not yet adjusted to LPR status, similarly disaggregated. We project each admission cohort forward from year of admission (a) to the current year (t), to yield a stock estimate of the LNH population:

$$LNH_{srcyat} = A_{srcya} - \sum_{i=a}^t (D_{srcyi} + E_{srcyi}) \quad (1)$$

where A is the number of LNH admissions or entrants in year a, D is the annual number of deaths, and E is the annual number of emigrants. D and E are derived from a set of assumed mortality (m) and emigration (g) rates among the LNH foreign born multiplied by the size in year i of the cohort that was admitted in year a.²

In the fourth step, the LNH population is subtracted from the combined unauthorized and LNH populations to yield an estimate of the unauthorized immigrant population. These estimates are disaggregated by sex (s), region or country of birth (r), birth cohort (c), year of entry (y), and year (t). We adjust the estimates for the extent that the ACS underrepresents both the LNH (e_{LNH}) and unauthorized foreign-born populations (e_u). The underrepresentation of groups in the ACS is referred to as “coverage error”, whereby coverage error = (Population – ACS Estimate)/(Population). We describe the source of our coverage error estimates in the next section. We apply these estimates to the components of the residual estimate as shown in equation 2:

$$U_{srcyt} = \frac{C_{srcyt} - LNH_{srcyt}(1 - e_{LNH})}{1 - e_u} \quad (2)$$

¹ Nonimmigrants can be identified in the ACS and other survey data with some precision. They include noncitizens whose occupations, immigration histories, and family/household characteristics are congruent with the eligibility criteria for specific nonimmigrant visa categories. For example, international students (F-1 visa holders) can be identified from age of arrival to the United States, full-time school enrollment, and lack of full-time employment. H-2A workers can be identified on the basis of years in the country, country of birth (nearly all are Mexican-born), and agricultural employment, while H-1B high-skilled workers can be identified from their educational attainment, years in the country, and employment in certain occupations such as information technology workers, engineers, researchers, and doctors and surgeons.

The LNH population (LNH_{srcyt}) is derived from administrative records and therefore unaffected by coverage error. However, the combined unauthorized and LNH population (C_{srcyt}) is derived from ACS data and could be too low due to coverage error. Before subtracting the LNH population from the combined population, we adjust the LNH population downward (by multiplying by $1 - e_{LNH}$) to reflect the number represented in the ACS. As a result, the numerator of equation 2 is the unauthorized population *represented in the ACS*, which is finally adjusted upward by dividing by $1 - e_u$ to yield the total unauthorized population.

Coverage Error

The residual method relies on coverage-error estimates for both the unauthorized and LNH foreign-born populations, in that higher levels of coverage error of either population would lead to a higher estimate of the unauthorized population. In the ACS and similar nationwide surveys, coverage error occurs when people are missed because they fail to respond to survey takers; respond but provide insufficient or inaccurate information about their demographic characteristics (in this case, their place of birth and citizenship); or because they live in nonresidential or unconventional locations. Coverage error could be particularly high among unauthorized immigrants because they may be more difficult to locate (e.g., they live in agricultural worker barracks or crowded multi-family housing units), or they may attempt to avoid detection due to fear of government authorities.

Most prior research on the coverage error for unauthorized immigrants has focused on Mexicans, the largest single national-origin group among them. In general, this research compares the population counted in the U.S. Census or ACS with an independent estimate of the same population derived or inferred from non-census data sources, such as birth or death registrations, independent surveys, ethnographic studies of neighborhoods with large shares of unauthorized immigrants and estimates of Mexicans living in the U.S. derived from Mexican census data.

Evaluations of the rate of coverage error for the Mexican unauthorized immigrant population fell in the range of 15% to 35% in 1990 (de la Puente 1992; U.S. General Accounting Office 1993), and remained in this range until the middle of the 2000–2009 decade (Genoni et al. 2012; Hill and Wong 2005). Warren’s recent analysis (Warren 2020) supports these findings. He examined the decline in cohort sizes (after accounting for mortality) between the 1990 and 2000 Mexican censuses and found that about 5.5 million people left Mexico during the 1990s. The 2000 U.S. Census counted 4.5 million such individuals, implying a coverage error rate of 18% for 2000.

Based on their analyses of U.S. death records and Mexican census data, Van Hook and colleagues (Van Hook et al. 2014) found that coverage error declined during the latter half of the 2000–decade. Declining coverage error was apparently associated with substantial reductions in shorter-term unauthorized-immigrant laborers during the Great Recession (particularly in the hard-hit sectors of construction and services)—a group that is likely to be harder to count than longer term, more settled unauthorized immigrants. By 2010, coverage error rates for the unauthorized Mexican-born population were estimated to be below eight percent. These estimates are somewhat lower than the coverage error assumptions made by DHS (10%) and Pew (13%) in the past, although Pew now assumes similarly low levels of coverage error. Van Hook et al. (2021) updated Van Hook and colleagues’ (2014) estimates of coverage error with the latest available Mexican census data and

U.S. death records at that time and found evidence of further declines in coverage error among women but small increases among men between 2010 and 2017.

Finally, we found that coverage error appears to have increased since 2020 due to increases in harder-to-count groups: recently-arrived immigrants and Central Americans. Because these new estimates are unpublished to date, we review them in detail here.

We first deduced the level of coverage error among newly-arrived immigrants (which we define here as those in the country for less than 5 years) by examining changes in the size of immigrant entry cohorts. We provide an example in Figure A1. The red line shows the number of Central American immigrants who arrived in the U.S. in 2019 at ages 20–39. This cohort appears to increase with each year spent in the country. It is important to recognize that this is impossible; cohorts cannot grow over time. They can only decline as people leave the country or die. The cohort was probably undercounted in the ACS. In 2020, for example, the cohort observed in the ACS was only 59% of its expected size, implying a coverage error of roughly 41%. We calculate the coverage error rate as the number missing from the ACS as a share of the expected or actual number in the population: $(\text{Expected} - \text{Observed in ACS}) / \text{Expected}$. We conducted this analysis on all newly-arrived cohorts and show the results for the 2015–2019 entry cohorts by country or region of birth in Table A1. Coverage error for the 2019 arrival cohort ranged from 12% among Mexicans to 24% among Central Americans. Our analysis further suggests that coverage error among new arrivals has risen somewhat over the last five years, from 15% for the 2015 arrival cohort to 18% for the 2019 arrival cohort. Additionally, the share of unauthorized immigrants who were new arrivals increased dramatically in recent years, especially among the groups with the highest rates of coverage error. For example, among South Americans, the percentage of new arrivals increased from 32% to 52% between 2020 and 2024. With more new arrivals, even a moderate level of coverage error for new arrival cohorts leads to a bigger undercount in the total unauthorized immigrant population.

The limitation of the year-of-entry method is that it estimates coverage error for new arrivals *relative to longer-term residents* with at least five years of U.S. residence. If longer-term residents are also undercounted, then it is likely that coverage error among new arrivals is even greater than the estimates shown in Table A1. For this reason, we used an additional method based on birth records that is more sensitive to coverage error among more settled immigrants (i.e., those with U.S.-born children).

Namely, we compared the number of registered births to foreign-born mothers (accumulated over the previous five years) with the corresponding numbers of U.S.-born children ages 0–4 of foreign-born mothers in the ACS. Nearly 100% of births are registered in the United States, so birth registration data can serve as an accurate barometer of the population of mothers and young children across multiple national origin groups (Johnson 2022; O’Hare 2014). For example, U.S. vital statistics indicate that there were about 4.0 million infants born to foreign-born mothers in the five-year period from 2020 to 2024. This figure excludes children who would not have appeared in the ACS because they died or emigrated. This is about 16% more than the number of such children in the 2024 ACS.

Table A3 shows the estimates of coverage error in the five-year 2024 ACS (broken out by calendar year) by country or region of birth. Results indicate particularly high levels of coverage error

among Central Americans, and rising levels of coverage error among both Mexicans and Central Americans. Note that even U.S.-born white children are undercounted in the ACS, but at a much lower rate than the foreign-born. To account for the well-documented challenges of counting children in the ACS among all groups, we adjusted the estimates by subtracting the U.S.-born white coverage error rate from all foreign-born rates (lower panel of Table A3).

As a final step, we combined the coverage error estimates generated from the year-of-entry and birth registration methods to develop a single set of coverage error rates for the unauthorized population from 2021–2024. First, we converted the estimates shown in Tables A1 and A3, which pertain to all immigrants, to estimates for the unauthorized. That is, we assumed that legal immigrants have a flat coverage error rate of 1.5% (following DHS’s assumption) and then calculated what the rate for unauthorized immigrants would be if the remaining error were concentrated among them. Second, we assigned newly-arrived immigrants the coverage error estimate generated by the year-of-entry method; all remaining unauthorized immigrants were given our pre-2021 coverage error estimate based on the research described above (see Van Hook et al, 2021). Third, we increased the coverage error among unauthorized immigrants ages 0-44 to align with the birth registration coverage error estimates, if the birth registration estimate was higher. The final coverage error estimates are shown in Table A4.

Emigration

Unfortunately, official government statistics on emigration from the United States have not been published since 1956. Therefore, out of necessity, foreign-born emigration has been estimated with a variety of indirect demographic methods.

The U.S. Census Bureau estimates net emigration using a residual method (not to be confused with the residual method for estimating the unauthorized foreign born). This method compares the size of foreign-born cohorts between two decennial censuses or surveys after adjusting for mortality, yielding estimates of emigration among the entire foreign-born population. Residual-based estimates of the annual foreign-born emigration rate tend to fall between 1% and 1.2% (Ahmed and Robinson 1994; Mulder et al. 2003; Warren and Peck 1980): Warren and Peck 1980: 1.2%; Ahmed and Robinson 1994: 1.2%; and Mulder et al. 2003: 0.9%). In the most recent estimates, Leach and Jensen (M. Leach and Jensen 2013) tracked the size of immigrant entry cohorts across adjacent years of the ACS. They found higher annual rates of emigration for recently arrived immigrants: 0.6% for all immigrants, 1.3% among those in the country less than 10 years, and 0.4% for longer-term residents. Leach (Mark Leach 2017) later revised these estimates upward to 0.8%, 1.8%, and 0.5%, respectively.

Other researchers have used linked administrative records to estimate emigration levels and rates among LPRs and naturalized citizens (Duleep 1994; Jasso and Rosenzweig 1982). More recently, Schwabish (Schwabish 2011) estimated emigration among immigrants in the SSA earnings file (which tracks individuals even if they leave the United States), finding higher rates of emigration than residual estimates (1.3% overall and 2.3% in the first decade of U.S. residence). Nevertheless, his estimates are valuable because they provide detailed information about variation in emigration by demographic characteristics, such as age, sex, country of birth, and duration of U.S. residence.

Our residual estimates require estimates of emigration for the LNH foreign born population broken down by demographic characteristics. We used a prediction equation provided by Schwabish to obtain information about variations in emigration rates by age, sex, duration of residence. We then adjusted Schwabish's estimates to account for annual levels and trends in emigration, based on the trends seen in annual residual estimates by country or region of birth from 2000–2024, which were generated using Leach's (2017) methodology.

Mortality

Most groups that produce residual estimates assume that the LNH population has the same age- and sex-specific mortality rates as the U.S. population. But given the well-documented mortality advantage of immigrants (Markides and Gerst 2011; Markides and Rote 2015), we adjust the U.S. mortality rates downward. The adjustments were based on an analysis of the 1997–2008 National Health Interview Survey (Blewett et al. 2019), whereby we estimate proportional hazard Cox models predicting the hazard of dying as a function of region of birth (Latino, Asian, and other foreign-born versus U.S.-born), by sex. We then used the estimated hazard ratios to adjust the mortality rates for the United States (Berkeley Mortality Database), thus obtaining sex-, age-, and year-specific rates for Latino, Asian, and other immigrants.

2024 Vintage Updates

When producing the 2024 Vintage estimates, we updated our 2023 Vintage methodology in three ways, each of which increased the estimated size of the unauthorized foreign-born population above the level if we had used the 2023 Vintage methodology.

First, we relied on the five-year 2024 ACS files for the 2020–2024 population estimates of the foreign-born population (C and LNH) rather than the single-year ACS files. Note that we broke up the five-year files by calendar year, so we were still able to produce single-year estimates from 2020 through 2024. We selected the five-year ACS rather than the single-year ACS because the five-year ACS incorporates the Census Bureau's updated population weights for 2020–2024 that rely on its updated (i.e., much higher) 2024 vintage population estimates of foreign-born inflows¹⁸.

Second, we adjusted our methodology for smoothing the ACS population estimates. As noted earlier, we smooth the estimates within entry and birth cohorts by taking a moving average of cohort sizes over time. When the population size is more-or-less steady over time as was the case for much of the 2010-decade, this method yields stabler estimates of the cohort size with less noise, effectively “borrowing strength” from the cohort in adjacent years. However, if the population is growing as it did during the early 2020s, the smoothed population estimates for the later data points of the series will be too low. The reason is that the smoothing algorithm averages the most recent years (with the highest population estimates) with earlier years (with lower population estimates). To address this problem, we project the population for three years beyond the end point of the data series (from 2025 to 2027) before applying the smoothing algorithm. This new method is neutral about the future size of the population in that it assumes that the foreign-born population size remains the same size in future years. It applies current mortality and emigration rates and assumes that all deaths and departures are replaced by new arrivals.

Third, we refined our estimates of the number of lawfully present refugees, asylees, and other humanitarian entrants who have not yet adjusted to LPR status. These estimates are a component of the LNH population. For the 2023 Vintage, we counted entrants who arrived in 2015 or later, meaning that those who arrived before 2015 but did not adjust as of 2023 would be treated as unauthorized immigrants. We also counted special humanitarian entrants (from Cuba, Haiti, and those arriving on Special Immigrant Visas, or SIVs) as legal. For the 2024 Vintage, we made two changes. First, we counted refugee and asylee entrants who arrived in 2001 or later as opposed to 2015 or later. The reason we made this change is that, although refugees and asylees are strongly encouraged to apply for adjustment within a year of arrival, they are considered legally present in the United States even if they do not adjust their status. Second, we now treat all Cuban entrants who arrived before 2017 as legal, but those arriving in 2017 as all other groups. This is congruent with changes in how Cubans were treated starting in 2017 when the Obama administration ended the "wet foot, dry foot" policy in a modification of the Cuban Adjustment Act. Further, we no longer make special provisions for Haitians or SIVs, as these groups are not granted full legal status unless they adjust to LPR status. Altogether, these changes increased our 2024 estimates of the unauthorized population by about 167,000, with most of the increases occurring for immigrants from "rest of Asia" (primarily Afghanistan and Iraq; 90,000), Cuba (16,000), and Haiti (8,000).

A Note about Citizenship Data

We do not rely on self-reported information about citizenship to produce estimates of the unauthorized foreign-born population due to the well-documented unreliability of this information (Brown et al. 2019). Nevertheless, among the foreign-born who are not estimated to be unauthorized, we do produce estimates of the numbers of non-citizens and naturalized citizens. The estimated number of naturalized citizens is the number who self-report in the ACS as naturalized, excluding those who did not answer the question but were imputed to be naturalized by the census bureau, and excluding those who have not lived in the country long enough to be eligible for naturalization (i.e., five years for most people, and three years for those with a U.S. citizen spouse).

Appendix 1 References

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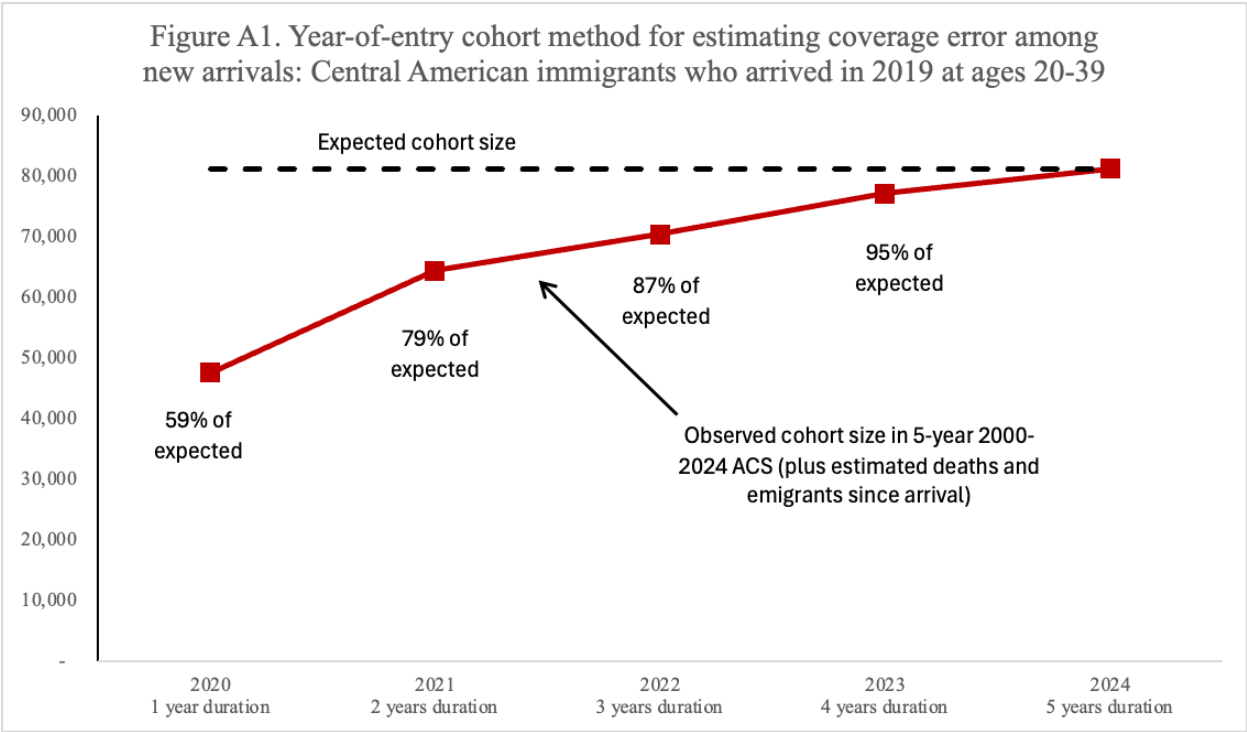


Table A1. Estimated coverage error based on year-of-entry method in 5-year 2024 ACS for new arrivals and share of new arrivals by country or region of birth,

<i>Coverage error for new arrivals (duration <5) by entry cohort</i>					
	2015	2016	2017	2018	2019
Mexico	9%	8%	10%	12%	12%
Central America	21%	20%	22%	24%	24%
Caribbean	18%	17%	20%	21%	21%
South America	17%	16%	18%	20%	20%
Asia	12%	11%	14%	15%	15%
Europe, Canada, and Oceania	11%	10%	13%	14%	14%
Africa	13%	12%	14%	16%	16%
All foreign-born	15%	14%	17%	18%	18%

<i>% of new arrivals (duration <5) among unauthorized population by ACS year</i>					
	2020	2021	2022	2023	2024
Mexico	6%	8%	10%	12%	14%
Central America	24%	29%	31%	32%	29%
Caribbean	11%	17%	27%	37%	52%
South America	32%	37%	43%	48%	52%
Asia	7%	7%	8%	8%	10%
Europe, Canada, and Oceania	10%	11%	16%	20%	25%
Africa	21%	23%	21%	21%	27%
All foreign-born	13%	17%	21%	24%	26%

Table A2. Birth registration method for estimating coverage error among all immigrants in the ACS

	U.S.-born children of FB mothers, born in five-year time period		% missing children in ACS
	Expected, based on vital statistics ¹	Observed in ACS ² , end of time	
2009 – 2013	4,425,745	3,912,374	12%
2010 – 2014	4,377,432	3,791,511	13%
2011 – 2015	4,367,000	3,863,203	12%
2012 – 2016	4,360,283	3,767,906	14%
2013 – 2017	4,345,292	3,743,970	14%
2014 – 2018	4,308,243	3,737,186	13%
2015 – 2019	4,216,790	3,553,172	16%
2016 – 2020	4,113,889	3,528,974	14%
2017 – 2021	4,010,989	3,504,775	13%
2018 – 2022	3,975,484	3,458,240	13%
2019 – 2023	3,980,130	3,314,630	17%
2020 – 2024	4,025,969	3,375,230	16%

¹births to foreign-born mothers minus estimated deaths (based on U.S. infant/child mortality rates) and emigrants (1% per year)

²2013–2019 single-year ACS; 2020–2024 5-year ACS

Table A3. Coverage error detected by birth registration method among children born to immigrant and U.S.-born mothers

	ACS ¹ Year				
	2020	2021	2022	2023	2024
Unadjusted estimates					
<i>Place or region of birth of birth mother</i>					
Mexico	8%	7%	11%	17%	17%
Central America	28%	30%	29%	35%	32%
Caribbean	14%	12%	12%	14%	16%
South America	14%	14%	14%	16%	19%
Other world regions	14%	10%	9%	11%	9%
All foreign-born	14%	12%	12%	16%	15%
U.S.-born white	6%	6%	5%	4%	3%
Adjusted estimates (discounting the level of coverage error among children of U.S.-born white mothers)					
<i>Place or region of birth of birth mother</i>					
Mexico	2%	2%	6%	13%	14%
Central America	22%	24%	23%	31%	29%
Caribbean	8%	7%	7%	11%	13%
South America	8%	8%	9%	13%	16%
Other world regions	8%	5%	3%	7%	7%
All foreign-born	8%	6%	7%	12%	12%

¹2020–2024 5-year ACS

Table A4. Final estimated coverage error among the unauthorized foreign-born in the ACS¹

	Mexico	Central America	Caribbean	South America	Asia	Europe, Canada, Oceania	Africa	All
2005	21%	20%	20%	21%	16%	16%	16%	20%
2006	21%	21%	20%	21%	16%	16%	17%	20%
2007	21%	21%	20%	22%	16%	16%	17%	20%
2008	14%	14%	12%	14%	10%	10%	11%	13%
2009	10%	11%	9%	10%	8%	8%	8%	10%
2010	8%	9%	7%	8%	6%	6%	6%	8%
2011	8%	9%	6%	7%	6%	6%	6%	8%
2012	8%	9%	6%	7%	6%	6%	6%	8%
2013	8%	9%	6%	7%	6%	6%	6%	8%
2014	8%	9%	7%	8%	6%	6%	6%	8%
2015	8%	9%	7%	8%	6%	6%	6%	7%
2016	8%	9%	7%	8%	6%	5%	6%	7%
2017	8%	9%	8%	9%	6%	6%	7%	8%
2018	8%	9%	8%	9%	6%	6%	7%	8%
2019	8%	9%	8%	9%	6%	6%	8%	8%
2020	8%	19%	8%	11%	6%	6%	8%	10%
2021	9%	28%	10%	14%	6%	6%	9%	13%
2022	10%	33%	12%	16%	7%	7%	10%	16%
2023	13%	38%	16%	19%	8%	9%	13%	20%
2024	14%	40%	23%	23%	9%	12%	16%	22%

¹2013–2019 single-year ACS; 2020–2024 5-year ACS