Demographic Inputs for Utah's Long-Term Baseline and Scenario Planning Projections

June 2023

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Table of Contents

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Introduction

This document presents inputs and methods that produced the demographic components of change for the Vintage 2021 Kem C. Gardner Policy Institute's Utah Demographic and Economic Model (UDEM).[1] Details include geographic variations within the state, age and gender patterns, and special types of migration related to retirement, missionaries, students, and other special populations. The document also reports how the limited 2020 decennial census data were combined with other resources and models to inform the process.

UDEM produces low, baseline, and high scenarios of Utah's resident population through 2060 as part of the Long-Term Planning Projection products. This document serves as a supplement to the basic UDEM methodology already published. The assumptions and inputs provided in this document provide additional insights and transparency into the UDEM process.

Key Indicators

- ***TFR* - ** Total Fertility Rate. The number of children the average woman might expect to have throughout her life.
- ***LEB* - ** Life expectancy at birth. The number of years the average newborn is expected to live.
- ***Total Employment* - ** The total number of filled jobs.

Other Important Concepts

- ***Per-capita rate* - ** The number of demographic events divided by the number of people at risk for the event (e.g., number of births divided by number of women aged 10 through 50).
- ***Age-specific rate* - ** A per-capita rate for one age group. The numerator and denominator are both restricted to that age.
- ***Age schedule* - ** A series of age-specific rates covering a larger age range (for example, all the female age-specific mortality rates for ages 0 through 100).

UDEM Overview

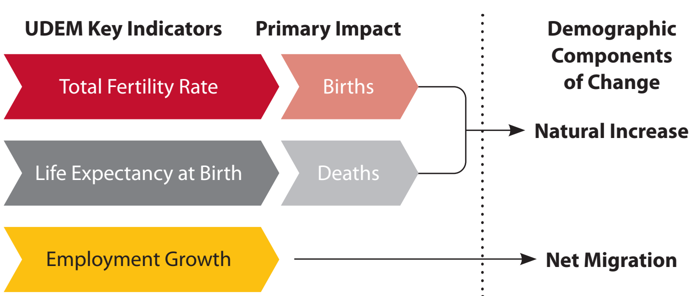
Key Indicators

UDEM projects the three demographic components of change: births, deaths, and net migration. Each year, natural increase (the excess of births over deaths) and net migration (the excess of in over out migrants) can increase or decrease a population. These components combine to form the demographic balancing equation upon which projection models are built.

In UDEM, three key indicators drive the components of change: total fertility rate (TFR), life expectancy at birth (LEB), and total employment. Figure 1 overviews how the three indicators translate to inputs, the combination of which results in the components of change each year.

Table 1 summarizes these indicators at the state level for low, baseline, and high projection scenarios. Data for 2019 (prior to the COVID-19 pandemic) are also included for reference.

Figure 1: UDEM Projection Key Indicators



Source: Kem C. Gardner Policy Institute

Table 1: State-level Scenario Assumptions Overview

Year/Scenario	Total Fertility Rate	Life Expectancy		Employment	
		Female	Male	Jobs *(thousands)*	Average Annual Percentage Growth Rate
2019 Estimate	1.98	81.8	78.1	2,130	-
2060 Low	1.74	85.4	81.3	2,820	0.70%
2060 Baseline	1.78	87.3	84.2	3,450	1.20%
2060 High	1.86	89.2	87.1	4,100	1.60%

Source: Kem C. Gardner Policy Institute

Process Overview

UDEM is a modified cohort-component projection model custom-designed for Utah's unique demographic characteristics. First, natural increase is calculated using rates derived from projected LEB and TFR. The population is then aged one year to produce the "survived-and-aged" population. Finally, migration is used to balance the discrepancy between the labor supply (determined by the survived-and-aged population) and demand (determined by economic modeling).

Projected fertility rates, life expectancy, and employment differ between counties and multi-county regions within the state. To address these variations, UDEM uses layers of detail to translate each indicator into rates of birth, death, or migration that are patterned by age and sex. Employment is the main, but not only, driver of migration in UDEM. Missionaries, retirees, and other special populations influence migration in varied ways throughout the state.

The UDEM method follows a general pattern. The key indicators are projected first, and the detail is added later through various models and assumptions. Finally, this process must be repeated three times: once each for the (1) baseline, (2) low, and (3) high scenarios.

Detailed Inputs and Assumptions

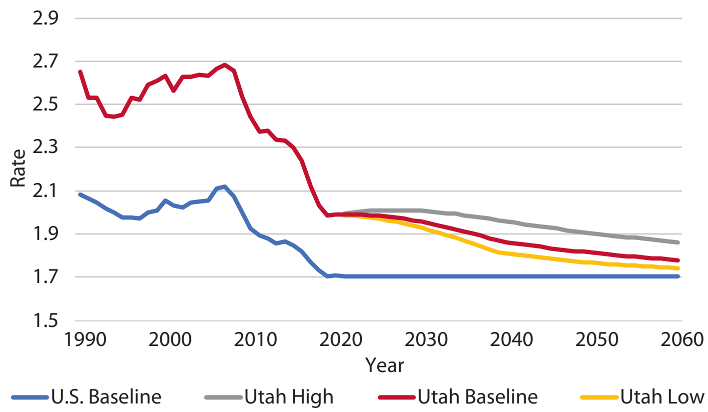
Births

The total fertility rate (TFR) is the number of children the average woman might expect to have throughout her life. UDEM projects Utah's TFR in relation to the U.S. Census Bureau's "middle", or baseline, projections.[2] First, we model how Utah's TFR compares to the U.S. historically, and then use different assumptions to extrapolate that trend forward to create the three scenarios. The TFR is calculated for counties and multi-county regions by holding the ratio of the region's TFR to Utah's constant over time. To create age-specific fertility rates (ASFRs), we combine the changing TFRs with a constant age shape. Key data sources included the U.S. Census Bureau, Utah Department of Health, and the National Center for Health Statistics.

State Results

For both the U.S. and Utah, the TFR dropped precipitously since 2007. Prior to 2002, Utah's TFR roughly paralleled the nation at a higher level. Since then, the rates have been converging.[3] The rate of convergence picked up after 2007 (Utah's most recent fertility peak), and then increased from 2017-2019. This iteration of UDEM assumes Utah's TFR will continue converging towards the nation's TFR at a constant rate (see Appendix). Figure 2 shows the projected state-level baseline, high, and low TFRs.

Figure 2: Historical and Projected U.S. and Utah Total Fertility Rate, 1990-2060



Sources: Kem C. Gardner Policy Institute, U.S. Census Bureau, National Center for Health Statistics.

Scenario Assumptions

- **Baseline -** Uses the full TFR data for 2002-2019.
- **High -** Assumes the most rapid declines for 2017-2019 were temporary outliers and fits data for 2002-2016, producing a slower rate of convergence.
- **Low -** Has a quicker rate of convergence using data for 2007-2019.

The first projected year for the Census Bureau's TFR was 2016, whereas the UDEM TFR began in 2019. The Census Bureau's overall U.S. TFRs are constant throughout their projection horizon. First, we updated the Census Bureau projections using the most recently available historical data (to 2019) and then held that TFR constant as a reference point for our projections. To capture near-term variations, we merged the short-term with the trend over a 20-year period using a weighted-average approach.

Geography

TFR estimates were produced for five counties: Salt Lake, Utah, Davis, Weber, and Washington. All five counties featured large enough populations to produce reliable estimates and unique data patterns that warranted separate treatment. For the remaining 24 counties, TFR estimates were projected for every economic or other multi-county region. At each time point, the 2019 ratio of the geography's TFR to the state is maintained. Table 2 reports TFR data for Utah.

Multi-county Regions

This document details several multi-county regions. Many of Utah's county populations are too small to obtain reliable estimates of demographic metrics, especially when detailed by age and sex. This necessitates combining counties into multi-county regions. Decisions were made based upon the purpose, data availability, observed data patterns, and expert local knowledge. We revisit these groups as part of the process for each new iteration of future projections, since Utah is always changing.

While the 2017 projections were done at two levels: state and counties, the 2021 projections also included an intermediate geography called an "economic region". More information on the economic regions can be found in the Net Migration discussion below. Projections are generally done top-down, meaning the larger level is projected first, then then smaller region is projected, and components of change are statistically controlled to match the total.

When projecting individual metrics for a region or county, we applied the finest level of detail available. For example, we could estimate reliable birth age schedules for Salt Lake County but not Iron County; therefore, we projected Salt Lake County using its own rate schedule, but Iron County using the Southwest Economic Region's schedule.

Table 2: Total Fertility Rates for Utah Regions, 2019 and 2060

Year		2019	2060		
Region / Scenario	**Ratio to State**	**Historical**	**Low**	**Baseline**	**High**
State Of Utah	1.00	1.98	1.74	1.78	1.86
Uintah Basin Economic Region	1.22	2.43	2.13	2.17	2.28
West Central Economic Region	1.06	2.11	1.85	1.89	1.98
Southwest Economic Region	1.03	2.04	1.79	1.83	1.92
Southeast Economic Region	0.97	1.93	1.69	1.73	1.81
Greater Salt Lake Economic Region	0.99	1.97	1.73	1.77	1.85
East Central Economic Region	0.93	1.84	1.61	1.65	1.72
Utah County	1.18	2.35	2.06	2.11	2.21
Rich/Wasatch Counties	1.10	2.19	1.93	1.97	2.06
Cache/Morgan Counties	1.10	2.18	1.92	1.96	2.05
Box Elder/Tooele/Juab Counties	1.10	2.18	1.91	1.95	2.04
Davis County	1.07	2.12	1.86	1.90	1.99
Washington County	1.03	2.04	1.79	1.83	1.92
Weber County	0.96	1.91	1.67	1.71	1.79
Salt Lake County	0.90	1.79	1.57	1.61	1.68
Daggett/Grand/San Juan/Summit Counties	0.88	1.75	1.54	1.57	1.64

Source: Kem C. Gardner Policy Institute

Age Schedules

Figure 3 shows the smooth age-specific fertility rates (ASFRs) developed and used for the state in UDEM. For ASFRs, only women are included in the denominator. ASFRs for each single-year age group are summed to produce the state's TFR, represented by the area underneath each curve in Figure 3. The peak childbearing age for the state occurs a little before age 30 in both 2019 and 2060. See the Appendix for further details.

Deaths

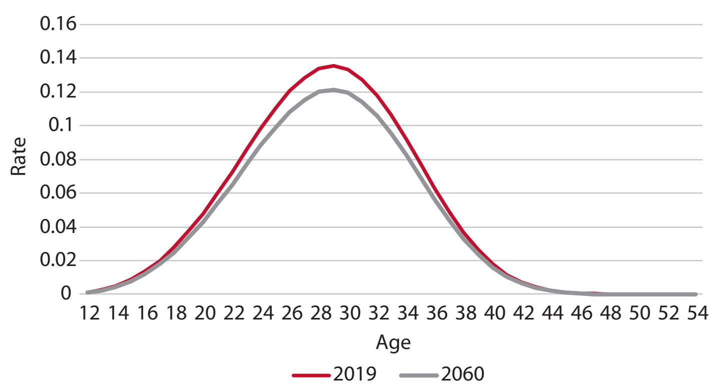
Life expectancy at birth (LEB) is the number of years the average newborn is expected to live. The general UDEM approach is identical to the TFR method: the LEB is projected in relation to the Census Bureau's middle scenario. Consistent with best practices, these estimates are produced separately for males and females. Multi-county region values were determined by 2019 ratios to the state and a smoothed age schedule was used for the age-specific mortality rates (ASMR). Key data sources included the U.S. Census Bureau, Utah Department of Health, National Center for Health Statistics, and USA Mortality Database.

State Results

Utah has long had a higher LEB for males and females than the nation. In 1990, the Utah and U.S. LEB began converging at roughly constant rates for both men and women. LEB has converged faster for women and is now virtually identical to the nation.[4]

Figures 4 and 5 present state-level LEB for each sex and scenario. For the baseline scenario, the LEB gap (Utah – U.S.) is projected to converge but not cross. The female LEB is always higher than the male, which is nearly universal in human populations. Despite some recent setbacks, LEB is expected to continue rising.[5]

Figure 3: Utah State Age-specific Fertility Rates, 2019 and 2060



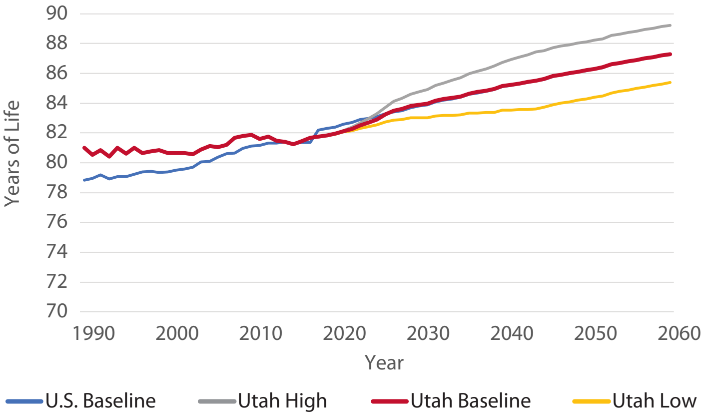
Source: Kem C. Gardner Policy Institute

To capture near-term patterns for Utah, we merged the short-term to the trend over a 10-year period using a weighted average between the last observed LEB and the projected trend. The Census Bureau's series does not do this, resulting in the jump between 2016 and 2017. There is no short-term adjustment for COVID-19. We made this decision due to the uncertainty of COVID-19's future impacts on death rates.

Scenario Assumptions

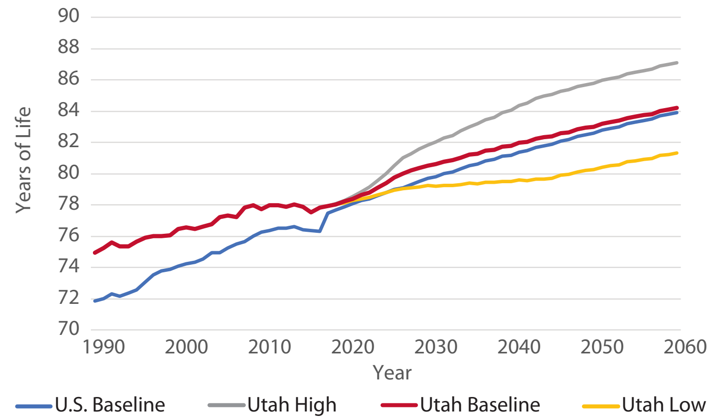
- **Baseline –** Convergence continues at a constant rate for both males and females.
- **High –** The LEB difference will return to its 1990 level by 2045. This will occur by the same amount annually beginning in 2017 (linear change).
- **Low –** The mirror image of the high scenario, symmetrical around the baseline scenario.

Figure 4: Female Historical and Projected Life Expectancy at Birth for the U.S. and Utah, 1990-2060



Sources: Kem C. Gardner Policy Institute, U.S. Census Bureau, USA Mortality Database.

Figure 5: Male Historical and Projected Life Expectancy at Birth for the U.S and Utah, 1990-2060



Sources: Kem C. Gardner Policy Institute, U.S. Census Bureau, USA Mortality Database.

Geography

Some economic regions were combined: (1) Southeast and Uintah Basin, (2) West Central and East Central. Six counties had their own LEB estimates: Salt Lake, Utah, Davis, Weber, Cache, and Washington. LEB county groupings were different than those used in the fertility rates. All other counties used rates from their larger regions. Table 3 summarizes the life expectancy data.

Age Schedules

Age-specific mortality rates (ASMRs) can be roughly interpreted as the probability someone of a given age dies during a certain year. Figures 6 and 7 show the smooth ASMRs developed and used in UDEM for the state-level projections. Rates are highest at the end of life, and then in infancy. In the middle of life, there is a slight hump which generally relates to accidental deaths, especially for males, and also maternal mortality for females. Unlike TFR, it is difficult to explain LEB in relation to its rates, but the methods are well-documented.[6] See the Appendix for more details.

Net Migration

As discussed above, there are four types of migration included in UDEM: (1) employment-related, (2) retirement, (3) missionary, and (4) migration for special populations such as students. Most of the net migration is employment-related.

Employment

The difference between projected employment and the employed working-age population determines the number of labor migrants. Employment is the main driver of adult and child migration. Children are assumed to migrate with these adults, calculated by the child dependency ratio. Complete details are in the full UDEM documentation. After an initial UDEM model run, additional employment is modeled for the construction, retail trade, and healthcare industries, because they depend highly on the new migrants.

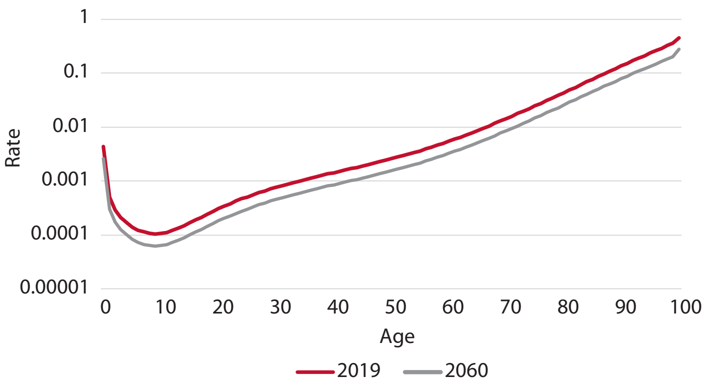
The Gardner Institute Industry Trends Model (GITM) uses the Bureau of Economic Analysis (BEA) concept for industry insights to project total employment.[7] Regional Economics Models,

Table 3: Life Expectancy at Birth for Utah Regions, 2019 and 2060

Region	Female					Male				
	Ratio to State	2019 Historical	2060			Ratio to State	2019 Historical	2060		
			Low	Baseline	High			Low	Baseline	High
State Of Utah	1.00	81.8	85.4	87.3	89.2	1.00	78.1	81.3	84.2	87.1
Southwest Economic Region	1.01	82.9	86.5	88.5	90.4	1.01	79.0	82.3	85.2	88.1
Greater Salt Lake Economic Region	1.00	81.8	85.4	87.3	89.2	1.00	78.1	81.4	84.2	87.1
Southeast / Uintah Basin Economic Regions	0.98	80.4	83.9	85.8	87.7	0.97	75.6	78.8	81.5	84.3
East Central / West Central Economic Regions	0.98	80.2	83.6	85.5	87.4	0.97	75.7	78.9	81.7	84.5
Washington County	1.02	83.9	87.5	89.5	91.5	1.02	79.6	82.9	85.8	88.8
Cache County	1.02	83.7	87.4	89.3	91.3	1.03	80.5	83.8	86.8	89.8
Utah County	1.01	82.4	85.9	87.9	89.8	1.01	79.1	82.4	85.3	88.2
Davis County	1.00	82.2	85.7	87.6	89.6	1.02	79.3	82.6	85.6	88.5
Salt Lake County	1.00	81.5	85.1	87.0	88.9	0.99	77.4	80.7	83.5	86.4
Weber County	0.99	80.9	84.4	86.3	88.2	0.98	76.8	80.0	82.8	85.6

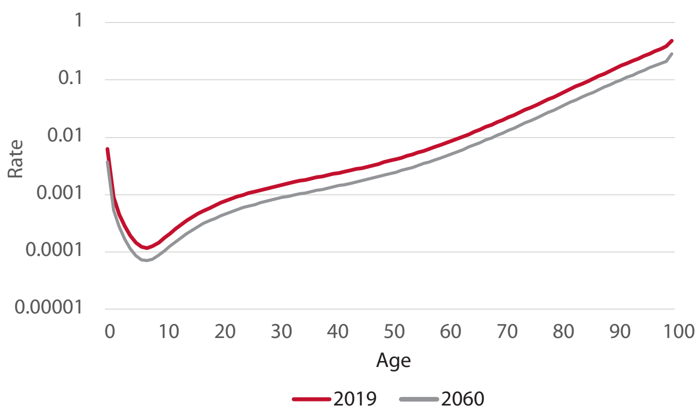
Sources: Kem C. Gardner Policy Institute, USA Mortality Database

Figure 6: Age-specific Mortality Rates for Utah Females, 2019 and 2060



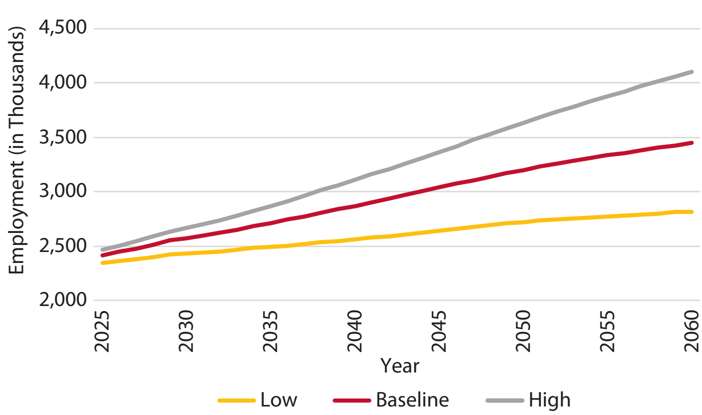
Source: Kem C. Gardner Policy Institute.

Figure 7: Age-specific Mortality Rates for Utah Males, 2019 and 2060



Source: Kem C. Gardner Policy Institute.

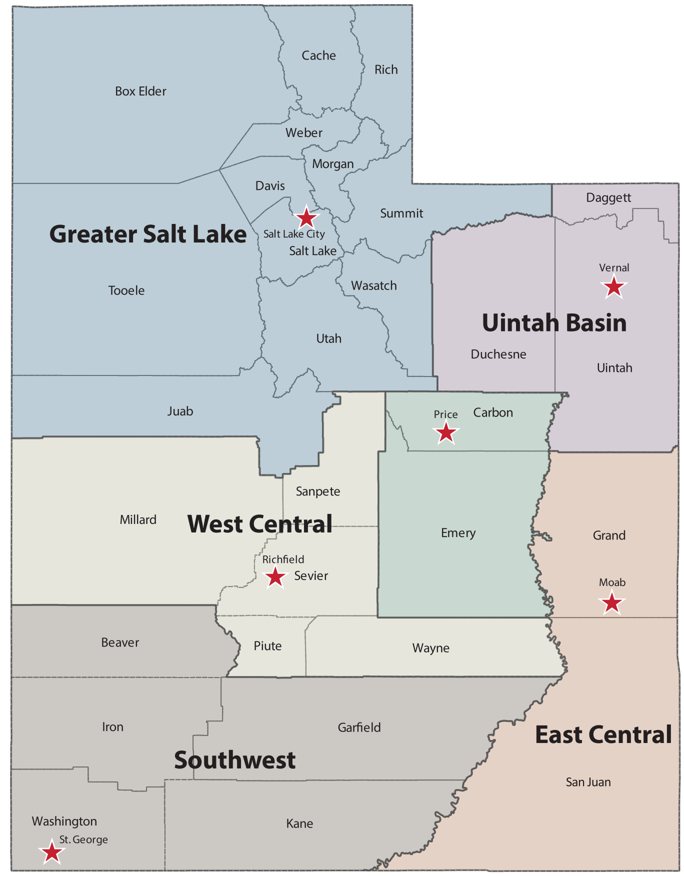
Figure 8: Total Employment in Utah by Scenario, 2025-2060



Source: Kem C. Gardner Policy Institute.

Inc. (REMI) software allocates the state's industry distribution among the counties in accordance with GITM totals and includes assumptions on special scenarios. The methodology for employment projections, as well as how they are integrated with demographics to produce migration, are published in the full GITM and UDEM documentations. Figure 8 shows the time path for total state employment in the three scenarios.

Figure 9: Utah's Economic Regions



Source: Kem C. Gardner Policy Institute

Table 4: Modeled Employment (in Thousands) for Utah Regions, 2019 and 2060

Region / Scenario	2019 Region	2060 Low	2060 Baseline	2060 High
State of Utah	2,130	2,820	3,450	4,100
Greater Salt Lake Economic Region	1,880	2,510	3,050	3,610
Southwest Economic Region	147	207	281	353
West Central Economic Region	35.8	36.6	44.4	52.7
Uintah Basin Economic Region	30.9	31.1	37.7	46.8
East Central Economic Region	16.5	14.6	17.2	22.2
Southeast Economic Region	15.2	16.1	19.1	22.3

Source: Kem C. Gardner Policy Institute, Bureau of Economic Analysis

Geography

The Gardner Institute economic regions provide the sub-state geographic framing for employment projections. These regions, created in 2020, reflect multi-county areas with close connections in commuting and other economic relationships.[8] Figure 9 and Table 4 provide a map of the regions and an overview of total employment projections.

The GITM employment projections utilize relational stochastic time series models. Predicted percentiles were used for scenarios.

Figure 10: Initial Target Net Migration Rates, Utah and Large Counties

Source: Kem C. Gardner Policy Institute

Scenario Assumptions

- **Baseline –** 50th percentile (median).
- **High –** 75th percentile.
- **Low –** 25th percentile.

Labor Migration – Geography and Age Schedules

Five counties received their own net migration schedules: Salt Lake, Utah, Davis, Weber, and Washington. Smoothed schedules for these counties and the state are in Figure 10. The remaining 23 counties were grouped into four typologies: aging, ring, rural, and rural-school counties (see Figure 11).[9]

To project future labor migration, the modeled migrants and their children must be assigned a sex and age. UDEM distributes migrants evenly between males and females, so detailed focus was placed on age schedules. Each age schedule serves as an initial series of values that are uniformly shifted up or down to match the projected number of net migrants. Since net migration data from 2000-2010 were the most reliable at the time of projection, those rate data provided a foundation which we smoothed using cubic splines.[10]

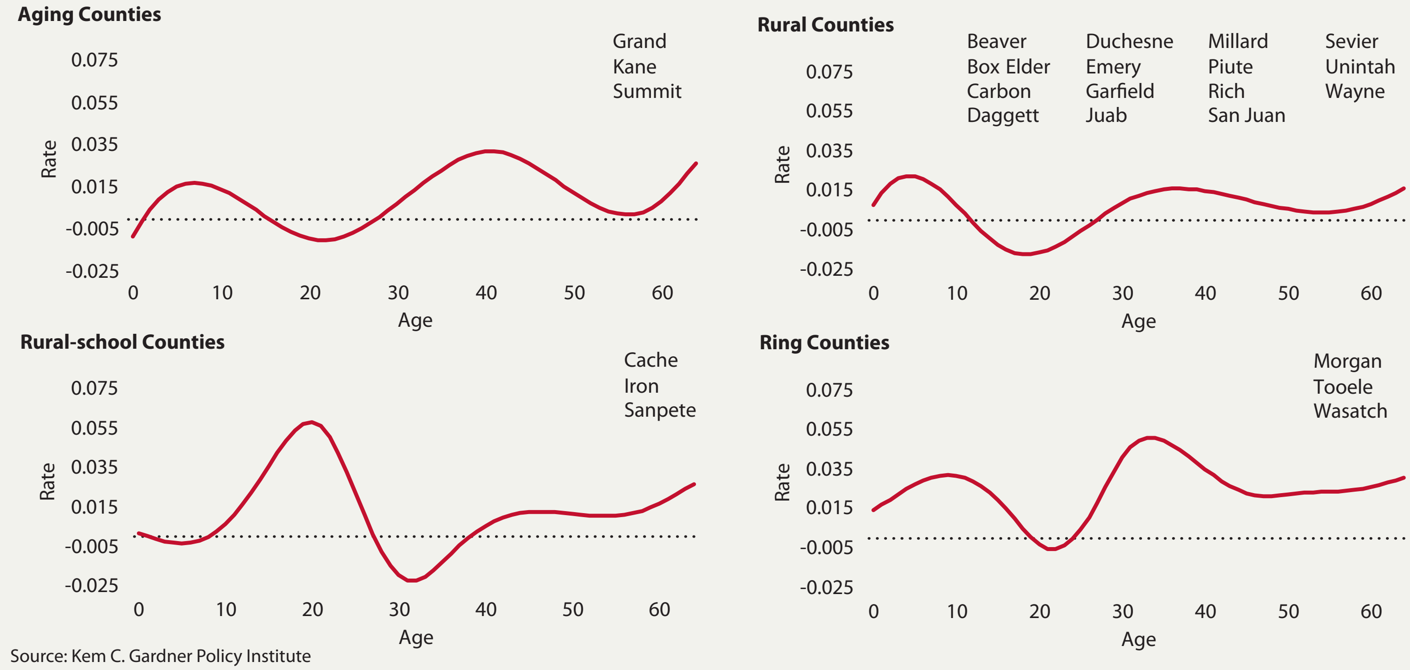
Retirement Migration

The combination of the aged (65 years and older) dependency ratio with labor migration determines total retirement net migration. That migration is then distributed across selected counties. Retirement net migration consists of in and out migrants. Utah is a net in-migration state for retirees (more people enter than leave the state). Among the counties, Salt Lake County is unique in that it assumes negative retirement net migration, meaning more migrants leave than enter. Some counties receive zero retirement net migrants. The distribution of migrants within the "net-in" counties appears in Table 5. The detailed methods for this procedure are in the full UDEM documentation.

Missionary Migration

Each year, a significant share of 18 to 22-year-olds temporarily exit the state to serve missions for the Church of Jesus Christ of Latter-day Saints, returning 18 months to two years later, depending upon their gender. Excluding missionary migration would bias our college-age projections. Figure 12 shows target modeled net migration rates for young adult males and females. Due to data uncertainty, all geographic levels and time points use the same rates.

Figure 11: Initial Target Net Migration Rates, County Groupings



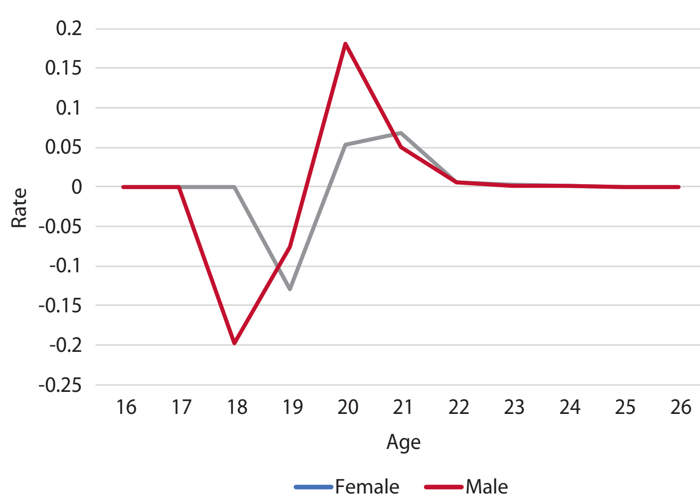
Source: Kem C. Gardner Policy Institute

Table 5: Target Allocation Shares for Utah's Retirement "Net-in" Migrants

Economic Regions	
Greater Salt Lake	52.6%
Southwest	43.2%
West Central	4.3%
Counties	
Washington	35.8%
Utah	27.9%
Davis	10.1%
Iron	5.2%
Cache	4.7%
Weber	4.2%
Tooele	2.9%
Sanpete	2.2%
Box Elder	2.0%
Wasatch	1.9%
Sevier	1.9%
Kane	1.0%

Source: Kem C. Gardner Policy Institute

Figure 12: Modeled Missionary Age-specific Net Migration Rates for Utah



Source: Kem C. Gardner Policy Institute.

Other Migration and Special Populations

Special populations are populations that would not be present if some institution (physical or cultural) did not exist. They typically do not follow population dynamics captured by the standard cohort-component projection method. Failure to account for special populations can bias population projections, especially for small areas such as counties.[11]

Unfortunately, the limited 2020 decennial census release did not provide adequate data for modeling special populations. Therefore, we used 2010 data from two populations: (1) group quarters measured at the 2010 decennial census; and (2) higher-education student populations for that same year. These counts were aggregated to produce age-sex special population counts that are held constant over time, with net migration being estimated as a residual.

Table 6 summarizes special population types by county. To keep the modeling manageable, we only consider populations that are substantially large or could significantly affect the county's sex and age structure.

Table 6: Summary of Utah Special Population Designations by County

County	Group Quarters					Student
	Correctional	Juvenile	Military	Other Institutional	Other Non-Institutional	
Cache	-	-	-	-	-	Utah State University
Carbon	-	-	-	-	-	Utah State University - Eastern
Davis	-	-	Yes	-	Yes	-
Garfield	Yes	Male	-	-	-	-
Iron	-	-	-	-	-	Southern Utah University
Kane	-	-	-	Yes	-	-
Piute	-	Male	-	-	-	-
Salt Lake	Yes	-	-	-	-	University of Utah
Sanpete	Yes	Yes	-	-	Yes	Snow College
Utah	-	-	-	-	Yes	Brigham Young University, Utah Valley University
Washington	-	Yes	-	-	-	Utah Tech University
Weber	-	-	-	-	-	Weber State University

Notes: Under group quarters, a "yes" means both sexes, whereas "male" means males only. A hyphen "-" means no special populations in that group. Student populations include males and females, and institutions are listed.
Source: Kem C. Gardner Policy Institute

2020 Census Data Adjustments

The UDEM projections rely upon high-quality decennial census data for county, sex, and single-year age groups. However, due to the COVID-19 pandemic and other administrative issues, the Census Bureau delayed delivery of the 2020 decennial census, which did not meet the timelines needed for the January 2022 release of the Gardner Institute's Utah Long-Term Planning Projections. To address this, we combined previous data sources with the new 2020 census information to create an adjusted starting population.

Initial data estimates for July 1, 2020, were produced by running the UDEM model from 2010-2020, with external controls for the demographic components of change provided by the Utah Population Committee (UPC), to produce a population age and sex distribution.[12] The 2020 Decennial Census Public Law Redistricting Data (PL 94-171) file[13] provided two new pieces of information: (1) the total population for each county, and (2) how many of those people were under/over age 18. We assumed the UPC-controlled age distributions (conditional on whether someone was under/over 18) were correct and multiplied those by the new information in the PL file.

We then assumed a linear interpolation for each age/sex/county group between 2010 and 2020 to produce new intercensal single-year of age and sex population estimates. Using these as inputs, we also recalibrated the UDEM model parameters before projecting to 2060.

Appendix

Convergence at a Constant Rate

We denote the difference of Utah TFR minus U.S. TFR as g(t). Assumed convergence of TFRs at a constant rate uses an exponential decay model:

$$g(t) = g(0)e^{rt} \tag{1}$$

where r<0 is the constant rate of change and t is time (year). It is fit to the historical data by taking logs, running a simple OLS regression model, and then predicting future values. A projected Utah TFR is then obtained from estimated parameters and the already-projected TFR_{US} by

$$TFR(t) = e^{\ln g(0)+rt} + TFR_{US}(t). \tag{2}$$

The same model is used for LEB.

Age-specific Fertility Rate Model

After exploring several methods, we found that a simple proportionate change in ASFRs was not only less resource-intensive, but tended to produce results with better face validity. Also, sensitivity tests showed that compared to the TFR, the shape of ASFRs had little impact on UDEM projection results. If *x* is age, the model is

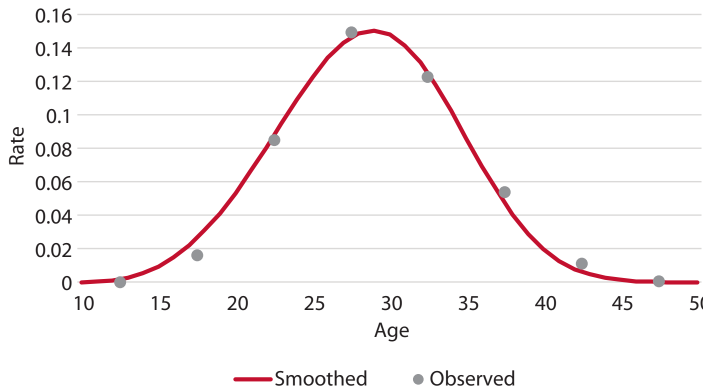
$$ASFR(x,t) = TFR(t) \times f_{WEI}(x;\Theta), \tag{3}$$

where

$$f_{WEI}(x;\Theta) = \left(\frac{a}{\sigma}\right)\left(\frac{x}{\sigma}\right)^{a-1} e^{-\left(\frac{x}{\sigma}\right)} \tag{3a}$$

The function f_{WEI} is a Weibull probability density function unique to each geography. TFR(t) provides the time-varying fertility level, and f_{WEI} the time-invariant age shape. Using a parametric shape also had the added benefit of smoothing the data from five-year to the required single-year age groups. The following figure shows an example fit using maximum likelihood methods.

Appendix Figure 1: Observed and Smoothed Utah State Age-specific Fertility Rates, 2014-2018



Source: Kem C. Gardner Policy Institute.

Age-specific Mortality Rate Model

LEB is a nonlinear function of ASMRs. For each geography, we used computational methods to solve for a proportionality constant *λ(t)* such that

$$LEB(t) = e_0\big(\lambda(t)q(x)\big), \tag{4}$$

where e_0 is a standard iterative function that produces life expectancy from the *q(x)* death probabilities. Similar to TFR, one term provides the time-varying level while the other provides the time-invariant age shape.

We estimated each geography's initial age schedule of rates by fitting the following model to observed ASMRs:

$$q(x) = k_1 f_1(x;\Theta_1) + k_2 f_2(x;\Theta_2) + k_3 F_3(x;\Theta_3), \tag{5}$$

where

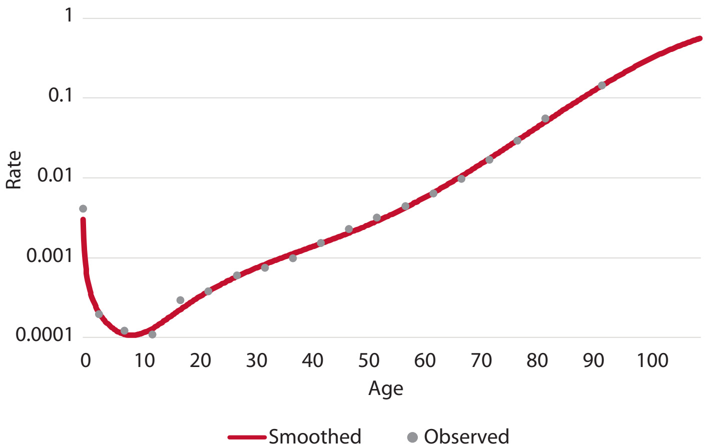
$$f_1(x;\Theta_1) = f_{GAM}(x;a,\sigma) = \frac{1}{\sigma^a \Gamma(a)} x^{a-1} e^{-\left(\frac{x}{\sigma}\right)} \tag{5a}$$

$$f_2(x;\Theta_2) = f_{LN}(x;\mu,\sigma) = \frac{1}{\sigma x \sqrt{2\pi}} e^{-\left(\frac{(\ln(x)-\mu)^2}{2\sigma^2}\right)} \tag{5b}$$

$$F_3(x;\Theta_3) = F_{LOG}(x;\mu,\sigma) = \frac{1}{1+e^{-\left(\frac{(x-\mu)}{\sigma}\right)}}, \tag{5c}$$

Here, f_{GAM} is a gamma probability density function, f_{LN} a log-normal density function, and F_{LOG} a logistic cumulative distribution function. These three hazard functions provide the time-invariant shapes of the infant/childhood, accidental/midlife, and senescent components of the age schedule, whereas the three *k(t)* parameters provide their respective

Appendix Figure 2: Observed and Smoothed Utah Female Age-specific Mortality Rates, 2008-2012



Source: Kem C. Gardner Policy Institute.

time-varying levels. This model is conceptually similar to a proportional hazards Heligman-Pollard model,[14] but uses more familiar distribution functions already provided in base R statistical software[15]. Data were fit using maximum likelihood methods, with an additional constraint that female death rates always be lower than male for a given geography and year.

Appendix Figure 2 illustrates the model fit for Utah Females. The rates extrapolated to age 120 are then top-coded at 100 using the estimated life expectancy at that age.

We justified the proportionality assumption using similar logic to the ASFRs.

Endnotes

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