California's uncertain population future

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Introduction
This appendix provides a technical description of our probabilistic population forecast for the state of California. The unique feature of our forecast is that it attempts to quantify our uncertainty about the future. Rather than issue a single forecast or a set of scenarios, we report the results of 10,000 possible futures. Each forecast is based on a unique combination of assumptions about the future trajectories of fertility, mortality, and migration, both domestic and international. These trajectories are selected based on the level, trend, and variability we have observed in the historical time series for these events. The key assumption underlying our approach is that the best guide to our uncertainty about the future is the variability we have observed in the past. The probabilistic forecast method is discussed in detail in Lee and Tuljapurkar (2000) with application to the United States. (http://demog.berkeley.edu/~rlee/papers/leetulja2b.pdf) This paper applies this methodology to a state-level forecast. The major difference in this state-level approach is that migration is stochastically forecast.

Forecast method
Each forecast begins in the year 2000 with the age/sex distribution of the California population as enumerated in the US Census. The standard cohort-component method is used to forecast the population. The forecast proceeds by single year. Each birth cohort is aged one year with population lost through deaths and out-migration from the state and population added through in-migration to the state. Each year a new birth cohort is forecast by apply fertility rates to the female population. The forecast ends in the year 2050.

Below I briefly summarize the 10 inputs to the forecast model: 6 are shared by all 10,000 forecasts and 4 are unique to each forecast. In the sections that follow, I discuss these in detail.

All 10,000 population forecasts use these same inputs:

1. The *age/sex distribution of the starting population* is based upon the Census 2000 enumeration for the state of California.
2. The *shape of the age distribution of births per woman* is based upon age-specific data from the United States for the period 1917-1996.
3. The *age shape of the decline in mortality rates* is based upon application of the Lee-Carter mortality estimation to historical data for the United States (1950-2000).
4. The *shape of the age/sex distribution for net domestic California migration* is based upon data from the March Current Population Survey (1996-2001).
5. The *shape of the age/sex distribution for international immigrants* to the United States is based upon data from the March Current Population Survey (1996-2001).
6. The *national trajectory of the level of international immigrants* admitted to the United States is based on the forecast by the U.S. Census Bureau in their Middle Series Projection. (Hollmann, Mulder, and Kallan, 2000).

Each population forecast requires a unique forecast of the following 4 trajectories for the years 2001 to 2050.

1. The annual level of fertility as measured by *the total fertility rate* (TFR) based on time-series analysis for the period 1917-1996 for the United States.

2. The rate of mortality declined as defined by *the k(t) mortality index* of the Lee-Carter model applied to the US.
3. The *net domestic migration rate* based on time-series analysis of California for the period 1963 to 2000.
4. The *proportion of international migrants* who intend to reside in California based on time-series analysis for the period 1970 to 2000.

Population undercount

Our forecast starts with the age/sex distribution of the state of California as enumerated in the 2000 Census. In 1990, the Census Bureau estimated that about 2.7% of the state's population was not counted in the Census. Although the Bureau also estimated the undercount for the 2000 Census, it determined that its methodology was flawed and as of August 2002 had not released the data. Therefore, California's Department of Finance has filed a Freedom of Information Act request asking the Census Bureau to release of the population counts for California adjusted for Census undercount. This would be the best source of information for an adjusted count.

As an alternative, I believe it would be useful to develop a partial adjustment of state Census counts using the Demographic Analysis method utilizing state data on recent births. A major concern of the state is the undercount of children since school enrollment forecasts depend on such estimates. Based on Post-Enumeration Survey data from the 1990 Census, children accounted for 40% of the undercount in California. So a partial adjustment just for children would go a long way in correcting for the total undercount. It was estimated that the 1990 Census missed 4.3% of California children (higher than the national average of 3.2%). These rates also varied dramatically by race/ethnicity.
http://www.census.gov/dmd/www/pdf/understate.pdf

Using data on births and estimates of mortality and immigration for 1996-2000, I have derived estimates of undercount in the 2000 Census for ages 0 to 3, nationally and in California. As seen in Table 1, it appears that nearly 7% of infants were not counted in the 2000 Census in California.

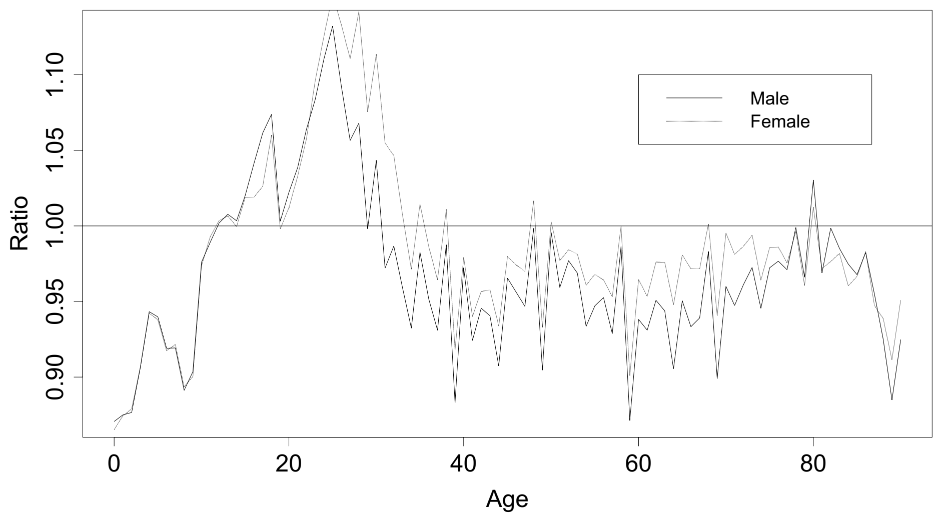
Table 1. Author's estimate of the net undercount for children under age 4 in the 2000 Census.

Age	United States	California
0	4.3%	6.7%
1	3.1%	5.8%
2	3.2%	5.8%
3	2.2%	4.9%

In 1998, California's Department of Finance issued a long-run population forecast for the state by county and ethnicity. (State of California, Department of Finance, *County Population Projections with Age, Sex and Race/Ethnic Detail.* Sacramento, California, December 1998.
http://www.dof.ca.gov/HTML/DEMOGRAP/Proj_age.htm). The DOF estimate for July 2000 can be compared to the Census April 2000 enumeration. Differences could be the result of errors in either source. As noted before, we expect the Census Bureau to have underestimated the population. DOF estimates from 1998 are also subject to errors. The DOF forecast begins with the 1990 Census as adjusted for undercount. DOF must then rely on 8 years of estimates of births, deaths, and migration and 2 years of forecasts to derive its 2000 population estimate. I believe the birth series is very accurate and hence DOF projections for the population under age 10 can be considered reliable. Migration has been highly volatile over the decade. In addition, past analyses using different methodologies and different data sources have led to large discrepancies in the estimate of migration. For these reasons, we might expect the DOF projections for ages over 10 to be less reliable. Figure 1 plots the ratio of the Census enumeration to the DOF population estimate for the year 2000. A very strong age pattern is evident. I believe the best explanation of the pattern is that the Census has substantially undercounted children in California, while DOF has

underestimated the number of adults in their late 20s. (Since this age group moves so much, Census overcounts are also a plausible explanation).

Figure 1. Ratio of Census 2000 to DOF projection.



More research on the issue of undercount is certainly needed. For present purposes, I use the Census enumeration for the starting population for the forecasts.

Fertility

Officially, California's TFR stood at 2.26 births per woman in 2000, while the overall US rate was 2.13 in 2000. http://www.dhs.cahwnet.gov/hisp/chs/OHIR/vssdata/2000data/00Ch2Excel/2_12_2000.xls

Yet if we use the recent Census Bureau counts as denominators along with birth counts for the state we find a TFR of 2.15, essentially identical to the national average. Table 2 shows the calculations. The Census enumeration found 12% more women aged 25-29 than the DOF forecast and it is this larger denominator that leads to a lower estimate of the fertility rate. For present purposes, I assume the California TFR for 2000 was 2.15 (about 5% lower than the official estimate).

Table 2. Author's estimates of age-specific fertility rates for California in 2000 based on Census enumeration.

Age group	Births In 2000	DOF population projection for July 2000	Age-specific fertility rates	Census 2000 population enumeration	Age-specific fertility rates	Ratio of census enumeration to DOF estimate
15-19	56,268	1,151,617	48.86	1,179,262	47.71	1.02
20-24	122,591	1,068,238	114.76	1,135,758	107.94	1.06
25-29	139,668	1,099,056	127.08	1,232,096	113.36	1.12
30-34	127,502	1,255,930	101.52	1,303,166	97.84	1.04
35-39	68,685	1,416,478	48.49	1,384,450	49.61	0.98
40-44	16,571	1,392,521	11.9	1,328,397	12.47	0.95
Total	531,285	7,383,839	2.26	7,563,129	2.15	1.02

Source: Author's calculations based on: State of California, Department of Finance, Demographic Research Unit, *Actual and Projected Births by County, 1970-2010, with Births by Age of Mother and Fertility Rates*. Sacramento, California, August 2001. http://www.dof.ca.gov/HTML/DEMOGRAP/01Births.htm

Note that for further research on the issue of undercount, one could examine age-specific fertility rates by race/ethnicity. Checking these for internal consistency as well as comparing them to alternative sources (June CPS) could aid in estimating the undercount of the female population. Of course, differences in racial classifications in vital statistics and in the census would complicate matters.

In previous work, Lee (1993) developed a time series model for U.S. fertility. For this project, we use the time-series parameters from that U.S. model to forecast the TFR for California beginning with California's starting TFR of 2.15. I implement a mean constrained forecast with the mean TFR set to 1.95, the long-run TFR in the Census Bureau's middle forecast. This insures that the average TFR calculated over all scenarios will converge to 1.95. Figure 2 displays the historical TFR for California. For the forecasts, I show 3 of the 10,000 sample paths against the probability deciles defined by the forecast. The probability is 10% that the TFR will fall within the darkest band and 90% that it will fall in any shaded area. These probabilities refer to the chance that the TFR in any year will fall within the bounds. Figure 3 calculates the cumulative average TFR over the forecast interval. Here we see that the probability deciles are much less wide; that is, while the TFR can reach extreme values in any one year, it is unlikely to remain at these extremes over the course of the projection. The dashed line shows the average fertility levels assumed by the DOF in their 1998 forecast with the TFR gradually rising from 2.4 in 1995 to 2.7 in 2040. Over the short-run this has proven to be too high. Based on our analysis, we would classify this as an unlikely long-run outcome – only about 10% of our simulations show long-run fertility as high as the DOF's assumption.

Figure 2: Total Fertility Rate

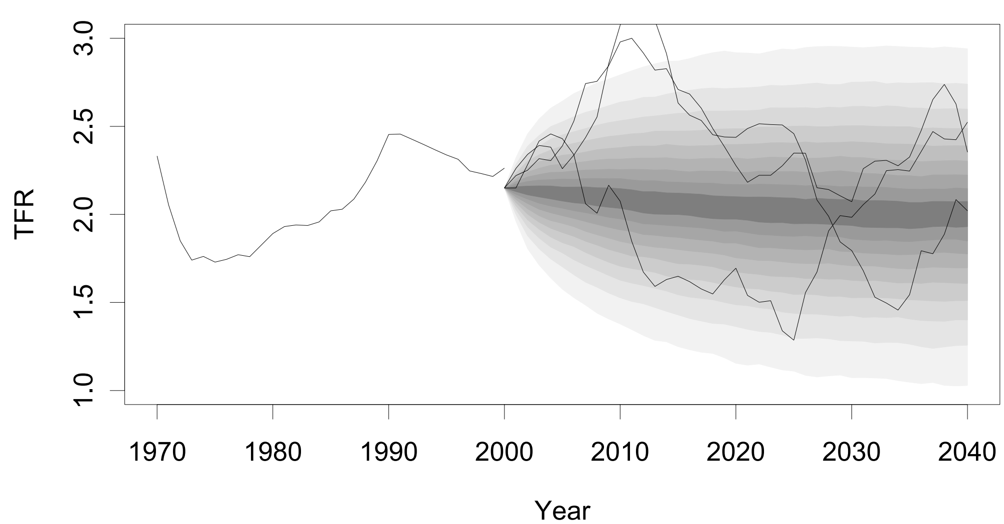
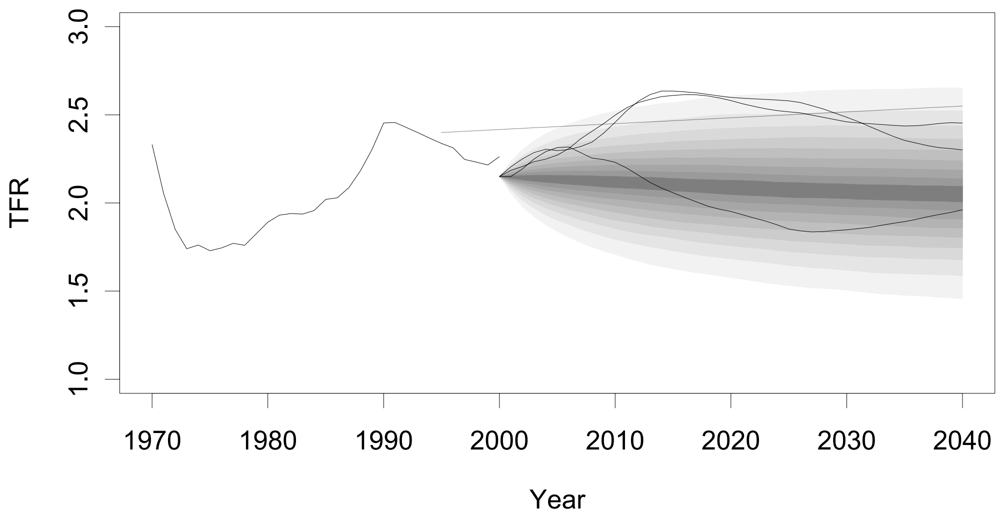


Figure 3: Average of Total Fertility Rate since year 2000



The DOF projection was based on the assumption that fertility is strongly linked to ethnicity and that large increases in the Hispanic population would offset modest decline in Hispanic fertility leading to an increase in California's TFR over the projection period reaching 2.7 in 2040. While the Hispanic population is certain to increase, the DOF's assumption that Hispanic fertility would decline only modestly is very much in doubt. Hans Johnson and Laura Hill have recently completed a monograph on this subject which finds considerable evidence that Hispanic fertility in California has been declining from its peak of 3.5 children per woman in 1991, having reached 2.8 in 1998. In addition, they present evidence for a substantial decline in fertility between foreign and US-born Hispanics. (Hans Johnson and Laura Hill, *Understanding the Future of California's Fertility: The Role of Immigrant*, PPIC, April 2002. http://www.ppic.org/publications/PPIC158/ppic158.abstract.html).

Furthermore as Lee (2001) noted, fertility levels in the sending regions for U.S. immigrants are falling quickly and projections of the future fertility of U.S. immigrants should be reduced accordingly. In this regard I note that Mexico, the major sending region for immigrants to California, has recently been forecast to reach replacement level fertility of 2.1 births per woman in 2005. (Rodolfo Tuirán, Virgilio Partida, Elena Zúñiga and Octavio Mojarro, "Fertility In Mexico: Recent Trends And Forecasts" Paper presented at the Expert Group Meeting On Completing The Fertility Transition, Population Division, United Nations, New York, 11-14 March 2002. http://www.un.org/esa/population/publications/completingfertility/TUIRAN-PARTIDApaper.PDF).

Mortality

Mortality rates by age and sex are forecast by using the Lee-Carter technique applied to U.S. data (see Lee (2000) for a recent discussion of the model). Across most ages, Californians experience lower death rates than other Americans. On average, the life expectancy of California residents in 1999 was 2 years greater than the US average as seen in Table 3.

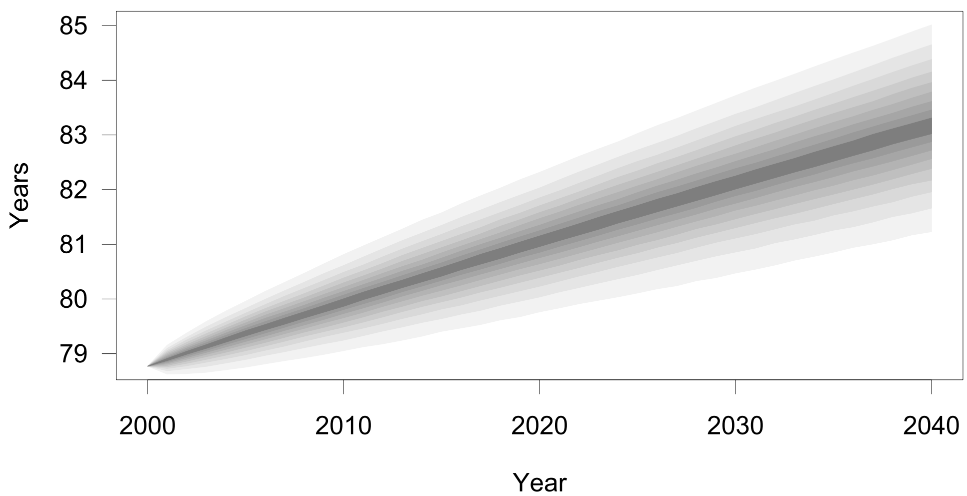
Table 3. Life expectancy at birth, 1999.

	Male	Female
California	76.3	81.0
United States	73.9	79.4
Difference	+2.4	+1.6

Sources: Ficenec, Sandy (2001). *Abridged life tables for California, 1997-1999.* Data summary No. DS01-12001. California Department of Health Services. Center for Health Statistics.
http://www.dhs.cahwnet.gov/hisp/chs/OHIR/Publication/OtherReports/LifeTables9799.pdf
And Hoyert DL, Arias E, Smith BL, Murphy SL, Kochanek KD. (2001). *Deaths: Final Data for 1999*. National vital statistics reports; vol 49 no 8. Hyattsville, Maryland: National Center for Health Statistics.
http://www.cdc.gov/nchs/releases/01facts/99mortality.htm

Mortality rates are forecast separately for each sex: using a common k(t) mortality trajectory with starting values defined by US sex-specific mortality rates adjusted to California levels as defined by the 1999 e(0) values. (Year 2000 k(t) values are derived by adding one year of drift to the 1999 k(t) estimates). Figure 4 plots our California e(0) forecast for sexes-combined.

Fig. 4: Probability Deciles for Sexes-combined Life Expectancy



Note that in an earlier version of this model, I assumed that the “California advantage” in e(0) would disappear over the next 40 years. I had modeled this by assuming a linear decline in the advantage as measured by the difference in year 1999 k(t) values between the California and the US. This proved to be unsatisfactory since it resulted in a dramatic slowdown in the rate of mortality decline in California.

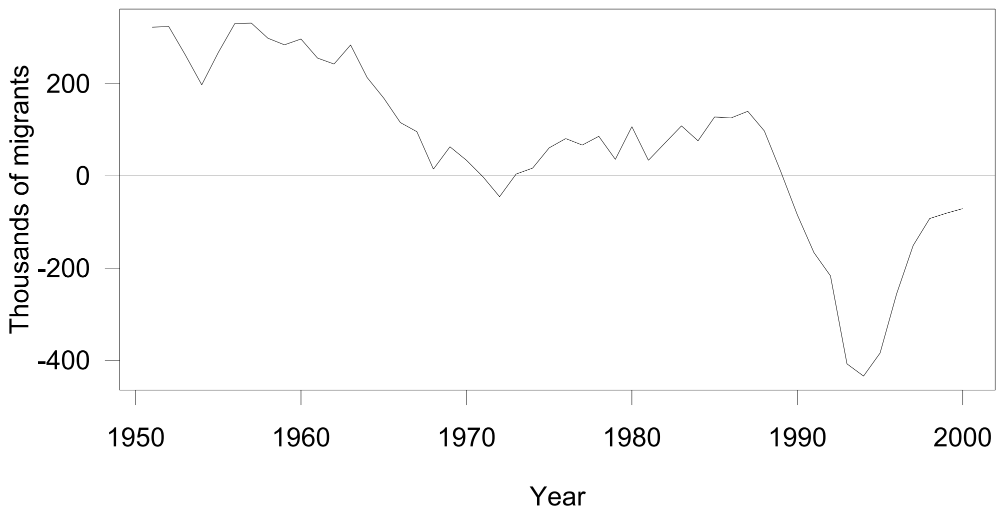
Net Domestic Immigration

Were the data available, I would model the domestic out-migration flow separately from the domestic in-migration flow. (US Census Bureau’s state estimates are based on such a model developed by Edward Frees, “Forecasting State-to-State Migration,” *Journal of Business and Economic Statistics*, Vol 10, No. 2, April 1992). Lacking a long time-series of this data, I instead model the domestic net migration rate.

Hans Johnson of PPIC provided me with the net migration data for California from 1950-1999. He derived these estimates from a variety of sources. The most recent years were taken from the US Census Bureau. I updated his data with the Census Bureau’s year 2000 figures. Figure 5 shows the number of net domestic immigrants. I believe Johnson’s data to be the most reliable time series available. As he notes in his report, there are considerable discrepancies among the sources of migration data. (Hans Johnson, “Movin’

Out: Domestic Migration to and from California in the 1990s," *California Counts*, Vol. 2 No 1, August 2000. http://www.ppic.org/publications/CalCounts4/calcounts4.pdf). DOF and Census Bureau continue to show large annual differences: for the period April 1, 2000 to July 1, 2001 the US Census Bureau reports a net outflow of domestic migrants from California of about 88,000 (or about 71,000 on an annual basis). The Department of Finance estimates a net inflow of 185,000 migrants over the same period. Hence, these 2 agencies differ in their annual estimate by about ¼ million people. http://www.dof.ca.gov/HTML/DEMOGRAP/E-2press.doc

Fig. 5: Net domestic immigrants



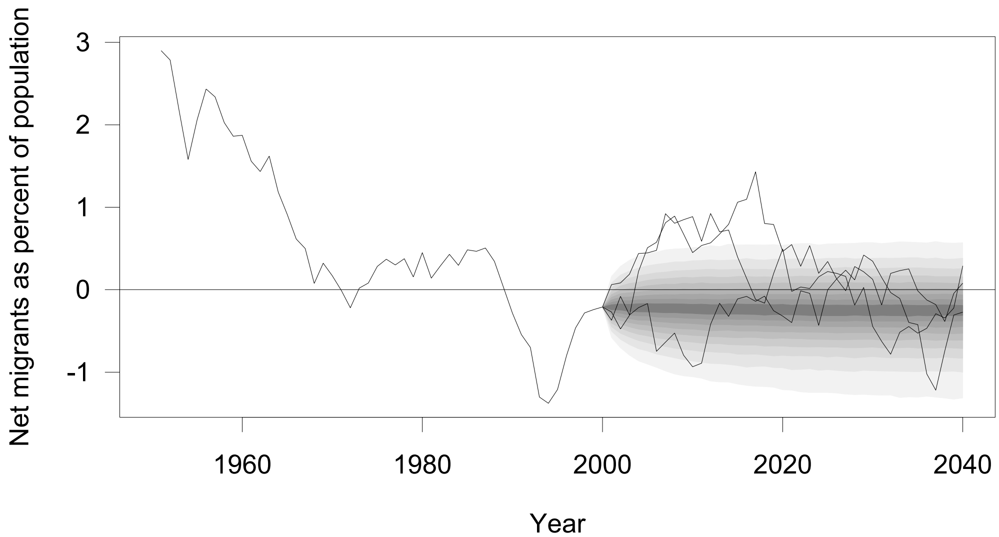
Looking at Figure 5, it is clear that there are 2 distinct periods: an early period characterized by a high but declining net immigration rate and a later period characterized by variable net immigration. Therefore, I tested for a distinct break in the time-series and found that an ar(1) model for the period 1963-2000 provided the best fit. The parameter estimates for the 1963-2000 model are quite similar to those for the period 1950-2000 with a dummy variable for the early period 1950-1962. I fit the ar(1) model using least squares:

$$Y(t) = -.0037 + 0.8429 * Y(t-1)$$
$$\qquad (.0004) \quad (0.0591)$$

Adjusted R-squared: 0.849
Residual standard error: .0022

I simulate 10,000 trajectories of future net domestic immigration rates based on these coefficient values. Figure 6 shows the historical values for the net domestic migration rate as well as the median and 95% probability intervals for the forecast rates. I have also graphed 3 of the 10,000 sample paths.

Fig. 6: Net domestic migration rate



To derive an estimate of the total number of net migrants, the net migration rate is multiplied by the resident population in the current period. This total is then distributed by age and sex according to a fixed age/sex distribution which was derived from the March Current Population Survey. I combined the March surveys for the years 1996-2001. I then estimated the age/sex distribution of those who moved from California to another state and of those who moved into California from another state. According to the CPS data, on average 493,000 Californians moved to another state, while 375,000 residents of other states moved to California for a net loss to other states of 118,000 Californians per year. This loss was more than offset by the annual addition of 242,000 immigrants from abroad.

Figure 7 shows the age distribution of these 3 flows. The age patterns are smoothed using a 3 year moving average. Figure 8 re-draws the age distributions so that they sum to 100%. Overall, the 3 migrant groups show broadly similar age patterns. International immigrants tend to be more concentrated in the age group 15-34 relative to the other groups. While 14% of Californians leaving the state were young children aged 1-6, only 9% of domestic immigrants and 10% of international immigrants to California were young children. Despite these differences, I have simply averaged the domestic in-migration and domestic out-migration age/sex distributions in order to form a net domestic immigration profile.

Fig 7: Age profile of migrants to and from California, 1996-2001

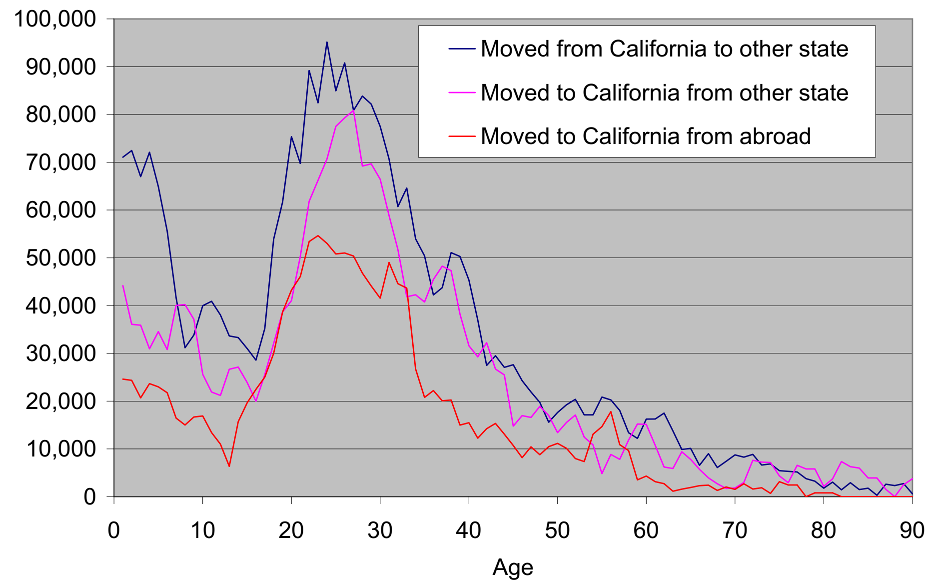
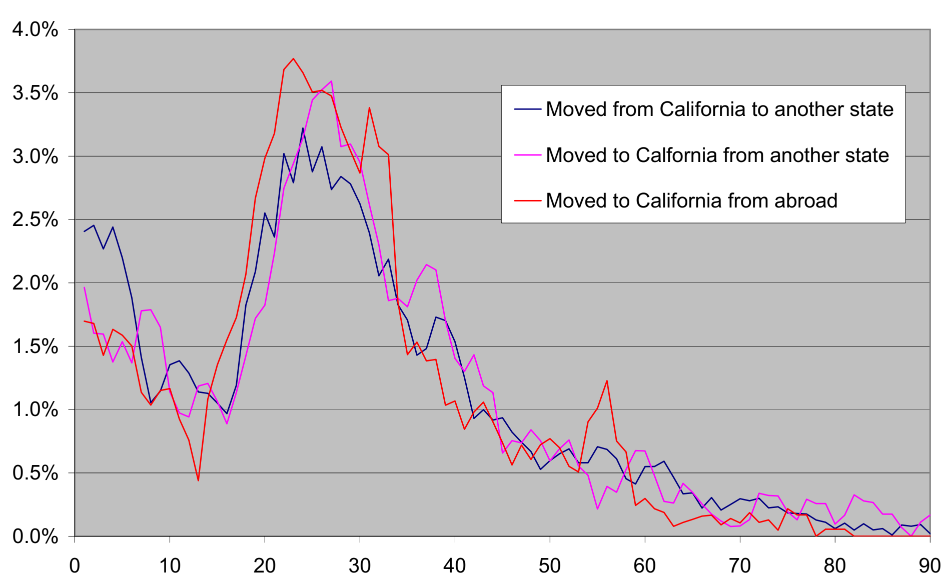


Fig 8. Age distribution of migrants (Each sums to 100%).



In future work, we may want to model net migration as a function of the difference between California and national unemployment rates (and additionally include the impact of international migration).

International Immigration

The Census Bureau provides a forecast of national net immigration. Net international immigration to California is forecast by multiplying the Middle Series forecast of national net immigration by our forecast of the percent of immigrants intending to reside in California. That is, we do not model emigration, nor do we model legal migration separately from illegal migration.

The Bureau currently forecast emigration of legal residents using age/sex profiles of rates of emigration. If I were projecting the California population by foreign-born, I would also use this method.

The Bureau's forecast of net national immigration also includes an estimate of the undocumented/illegal immigrants. The Bureau assumes that the level is unchanged over the course of the forecast using the same assumption as the 1990's base series: 225,000 per year. (Day, Jennifer Cheeseman, Population Projections of the United States by Age, Sex, Race, and Hispanic Origin: 1995 to 2050, U.S. Bureau of the Census, Current Population Reports, P25- 1130, U.S. Government Printing Office, Washington, DC, 1996 http://www.census.gov/prod/1/pop/p25-1130/p251130d.pdf).

There is a large amount of uncertainty about the past levels of illegal immigration as well as future trends. The previous Census population projection used a figure of 100,000 per year for their low scenario and 350,000 per year for their high. For 1994, Census Bureau issued a working paper outlining an illustrative range of illegal immigration by state. For California, the high estimate was 1.784 million illegal immigrants and the low estimate was 1.321 million. The difference between the high and low estimates was about equally divided between uncertainty about the level of national illegal immigrants (3.5 to 4.0 million) and uncertainty about where these immigrants reside (37.3% to 41.6% in California). In this analysis, I will consider only uncertainty about where immigrants reside.

Rather than rely on current legislated limits for immigration, the Census Bureau attempted to derive immigration forecasts based upon increases in labor market demand in the US brought about by population aging. No distinction is made in their modeling between illegal and legal immigrants in response to this demand. For our purposes, we will simple use the Middle Forecast of net immigrants (which lumps both legal and illegal immigrants together).

Our forecast is based on time-series analysis of the proportion of legal immigrants intending to reside in California. The 1965 amendments to the Immigration and Naturalization Act represented a fundamental shift in U.S. immigration policy: ending the national-origins quota system which had restricted immigration from Asia, implementing limits to Western Hemisphere immigration, and making family reunification a central policy focus. By the 1970s, there was a dramatic shift in the sending regions with large increases for Asia and large reduction from Europe. For this reason, I fit the model to data from 1970 to 2000. I find an ar(1) model of the proportion provides the best fit of the data.

$$Z(t) = \underset{(.0004)}{-.0037} + \underset{(0.0591)}{0.8429} * Z(t-1)$$

Adjusted R-squared: 0.849
Residual standard error: .0022

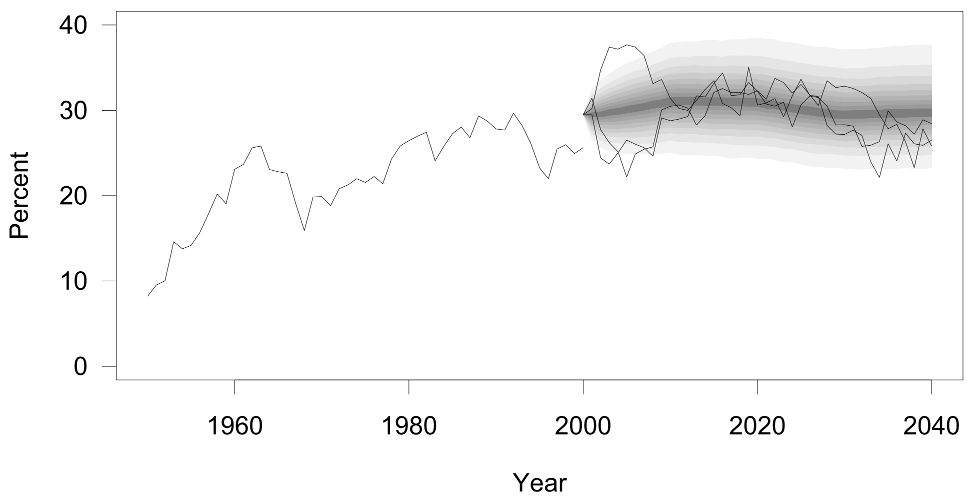
I apply an adjustment factor to the forecast to reflect the fact that illegal immigrants (whom we are treating together with legal immigrants) are proportionately more likely to reside in California. According to INS data from the mid-1990s, 43% of illegal immigrants reside in California. During this same period, about 25% of legal immigrants intended to reside in California. Therefore, the adjustment factor is set based on the formula:

> 43% * annual illegal immigrants + 25% * annual legal immigrants = z% * annual immigrants;
> adjustment factor = z% / 25%

The forecast for illegal, legal, and total immigrants are taken from the Census Bureau's middle forecast.

Figure 9 shows the historical series of the proportion of legal immigrants who intended to reside in California as well as the forecast for the proportion of total immigrants (legal and illegal) who are forecast to reside in California.

Fig. 9: Percent of US immigrants intending to reside in California



We model international migration separately from net domestic migration on the assumption that international migration is not correlated with net domestic migration. In future work, we should examine cross-correlation of these time series. In addition, we might attempt to model immigration based on country of origin data as well as considering a stochastic model of national immigration.

Results

I generated 10,000 population forecasts for California. Figure 10 shows the probability deciles for the total population of California. The probability is 10% that the population will fall within the darkest shaded region and 90% that it will fall within any shaded region. Also included in the figure are point estimates from other forecasts. (For a detailed discussion of these forecasts see Hans Johnson, "How Many Californians? A Review of Population Projections for the State." *California Counts*, Vol. 1, No. 1, October 1999. http://www.ppic.org/publications/CalCounts1/calcounts1.pdf) These forecasts generally fall within our 90% probability intervals. Most lie in the upper limits of our probability ranges, indicating they tend to represent high-growth scenarios.

Fig. 10: California Population Probability Deciles

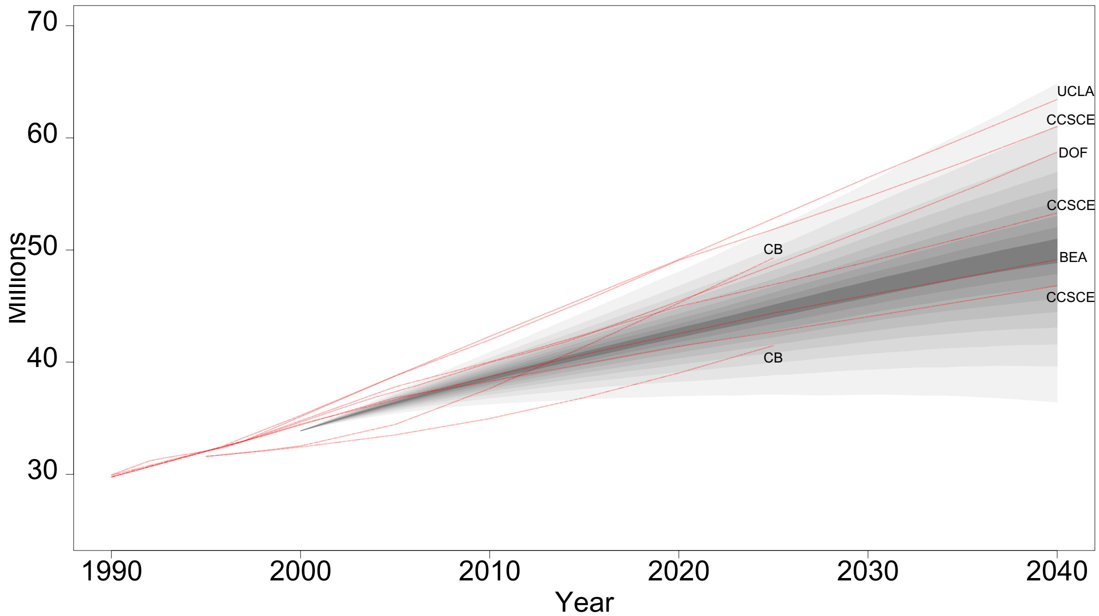
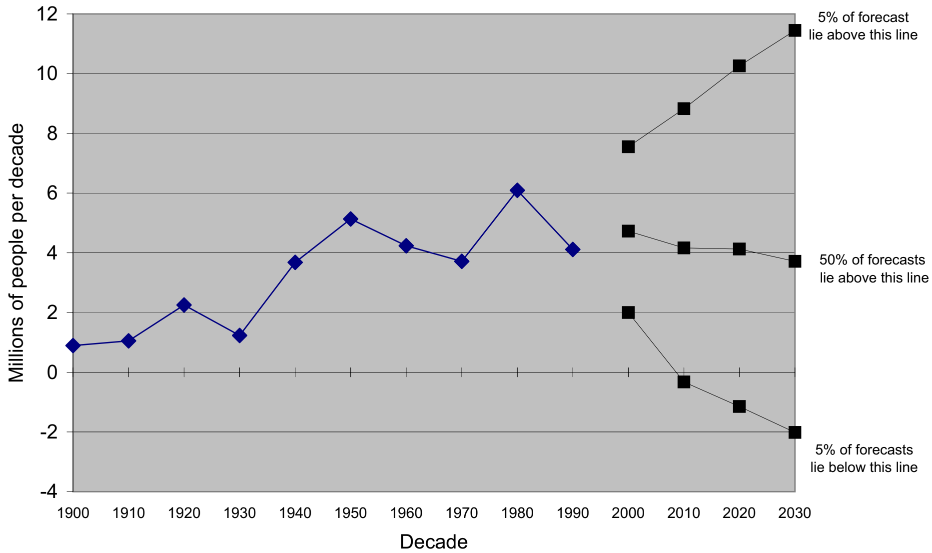


Figure 11 shows net population increase by decade. The state grew by more than 6 million people in the peak decade of the 1980s. The 1990s represented a sharp decline to 4 million people – on par with the net increases of the 1940s, 1950s, 1960s, and 1970s. Most of our forecasts show continued decline as seen in the median forecast. However, there is a wide band of uncertainty around the median which grows over time. For the decade 2030-2040, about 5 % of our forecasts show a net increase of more than 11 millions people and another 5% show a net decline of more than 3 million. Table 4 below summarizes the probabilities associated with various levels of net population change by decade.

Table 4. Net change in population per decade.

Percent of forecasts showing:	2000s	2010s	2020s	2030s
Population decline over the decade	0.1%	3.4%	6.1%	10.7%
Increase fewer than 2 million	2.5%	17.0%	21.2%	28.5%
Increase fewer than 4 million	30.3%	47.2%	48.2%	53.4%
Increase greater than 6 million	18.4%	20.9%	25.1%	25.2%

Fig. 11: Population increase by decade



There are several ages marking life transitions which are of particular interest: births, age 5 (entry into kindergarten), age 18 (entry into college), and age 65 (entry into retirement). Figures 12 –15 document the probability deciles for these select ages. The effect of the 2000 Census undercount is evident in the jump in counts as the birth cohort of 2000 (derived from Vital Statistics data, not Census enumeration) reaches age5 and age 18.

Fig. 12: Probability Deciles for Births

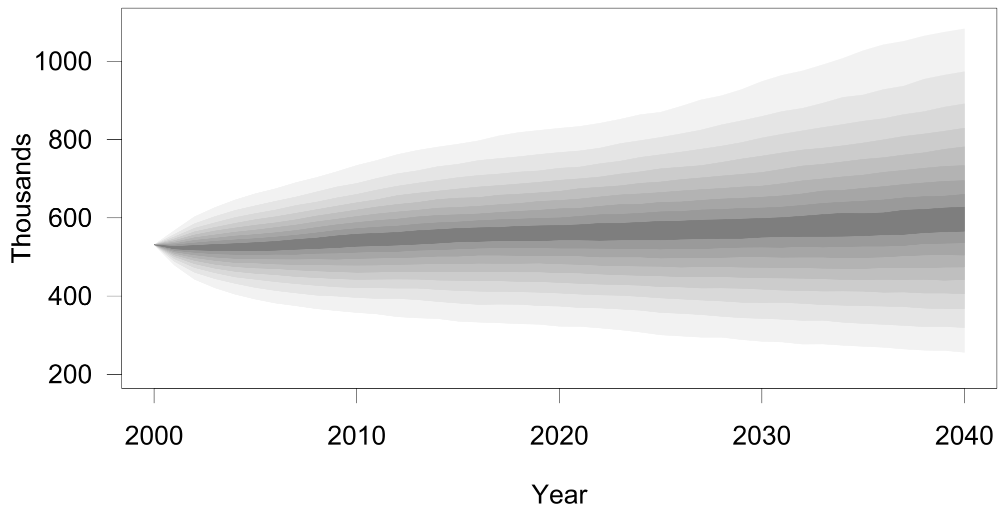


Fig. 13: Probability Deciles for Five year olds

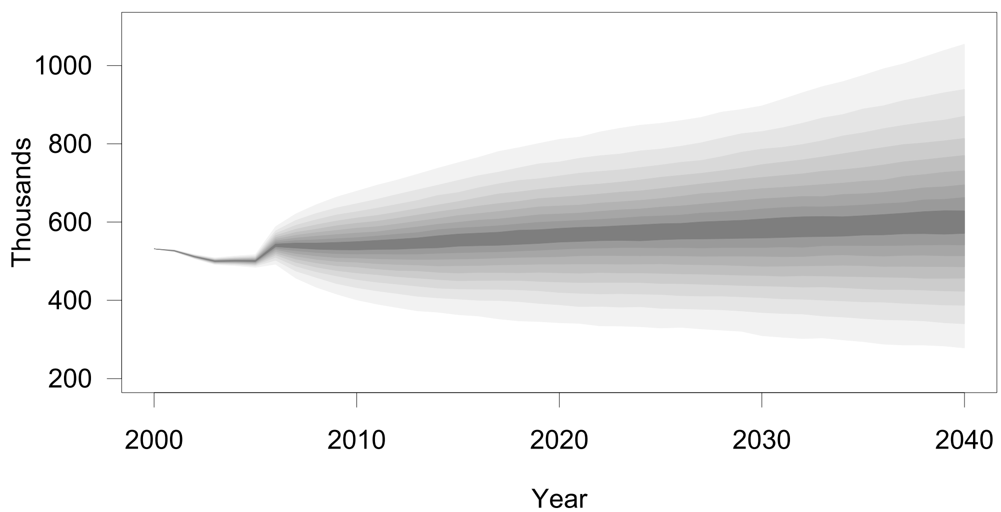


Fig. 14: Probability Deciles for Eighteen year olds

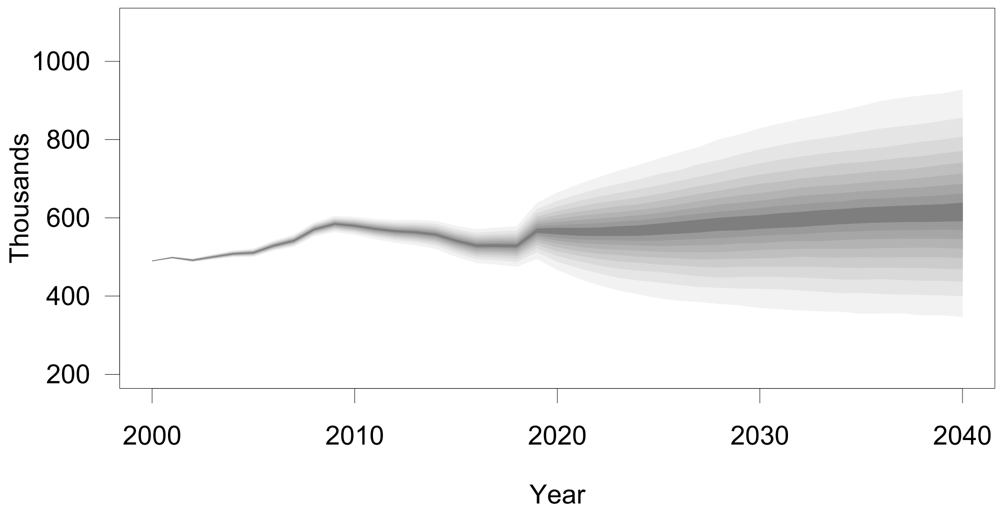
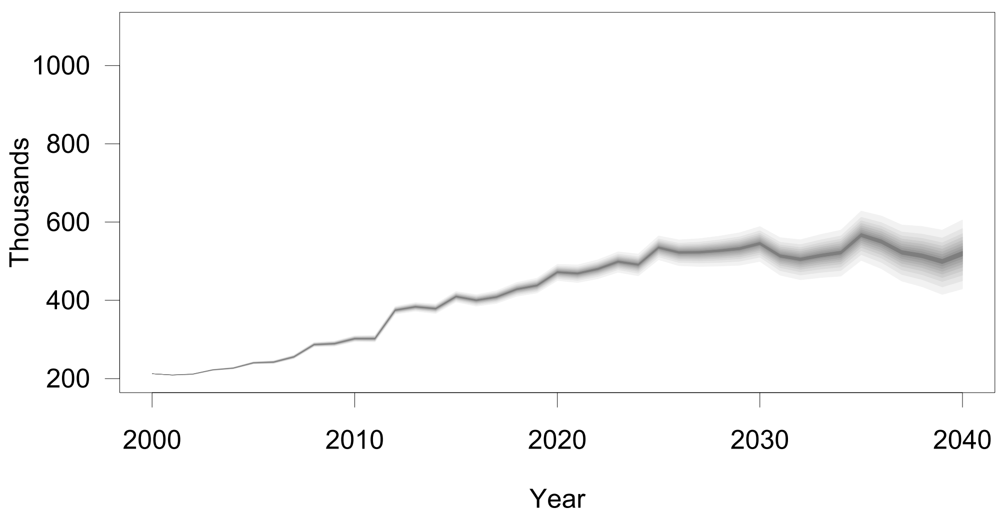


Fig. 15: Probability Deciles for Sixty-five year olds



More generally, we can see the process of population aging reflected in changes in the broad age groups: 0-19, 20-64, 65+, and 85+. These are shown in figures 16 – 19.

Fig. 16: Probability Deciles for Ages 0-19

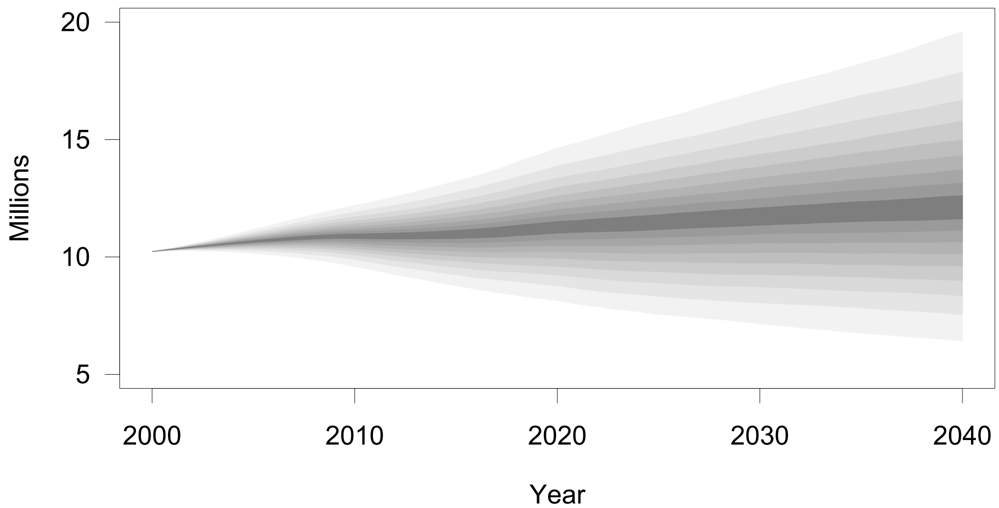


Fig. 17: Probability Deciles for Ages 20-64

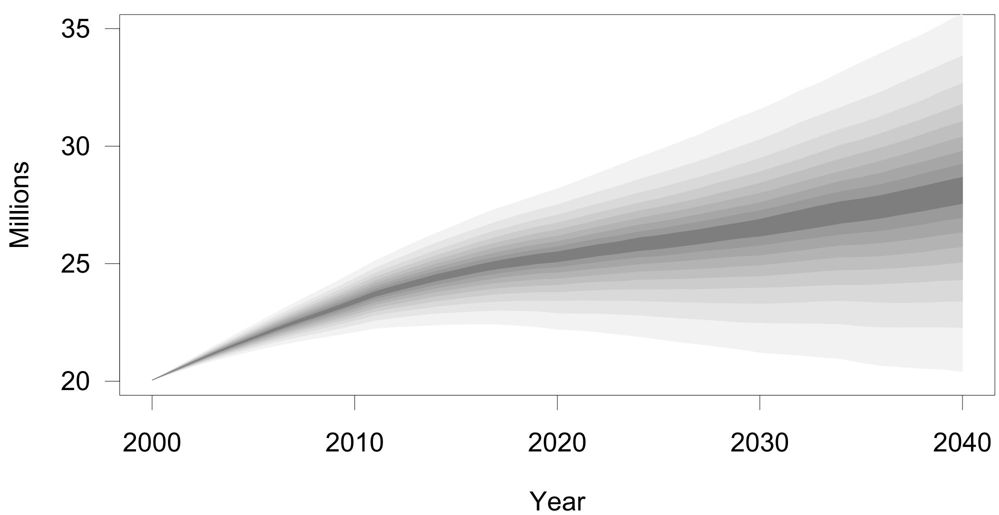


Fig. 18: Probability Deciles for Ages 65 and over

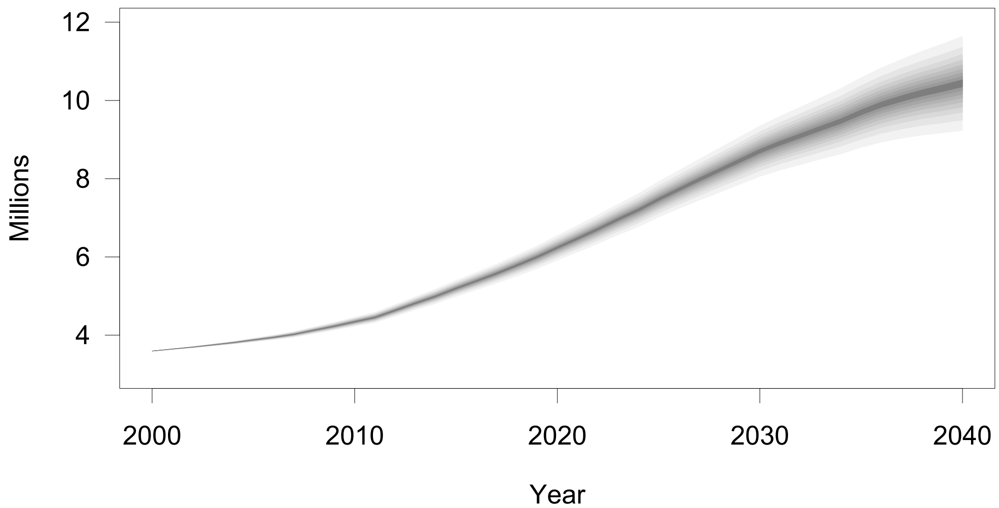
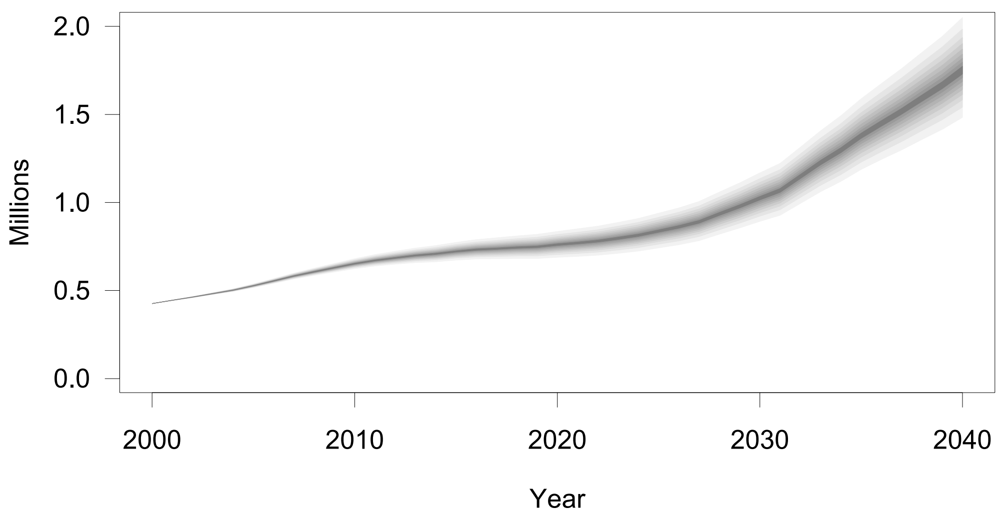


Fig. 19: Probability Deciles for Ages 85 and over



In general, net taxes are paid by the working age population (20-64) and net benefits are drawn by the young (0-19) and older (65+) populations. As crude measures of the potential transfer burden, we can compute the old-age dependency ratio, the young-age dependency ratio, and the total dependency ratio. The increase in the old age dependency ratio is seen to be a near certainty (Fig 20). Little change is forecast over the next decade, but this is followed by dramatic increases. Turning to the young-age dependency we find considerable range of uncertainty. The median forecast shows a drop in this ratio, indicating an easing of the educational tax burden in the state (Fig 21). Combining the 2 together, we see that the total dependency ratio is relatively constant (Fig 22).

Fig. 20: Probability Deciles for Old-age dependency ratio

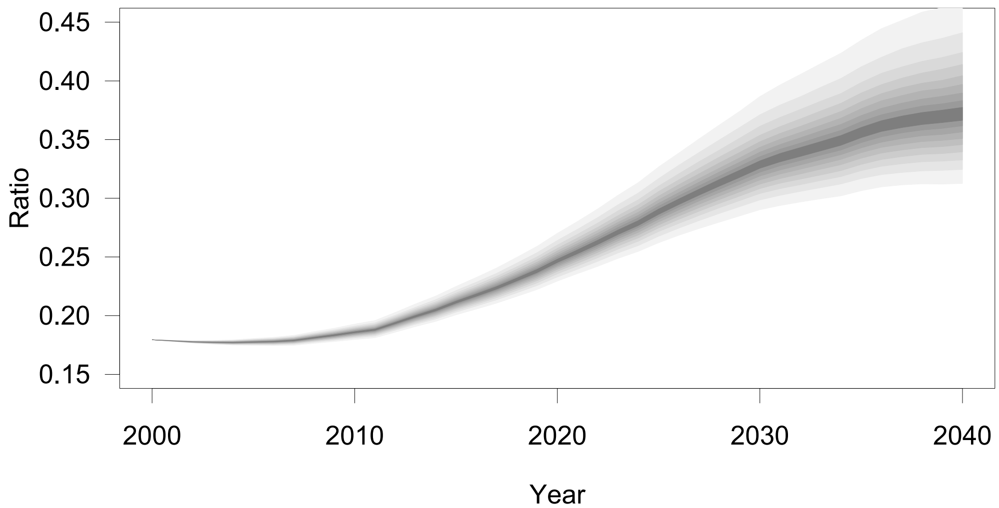


Fig. 21: Probability Deciles for Young-age dependency ratio

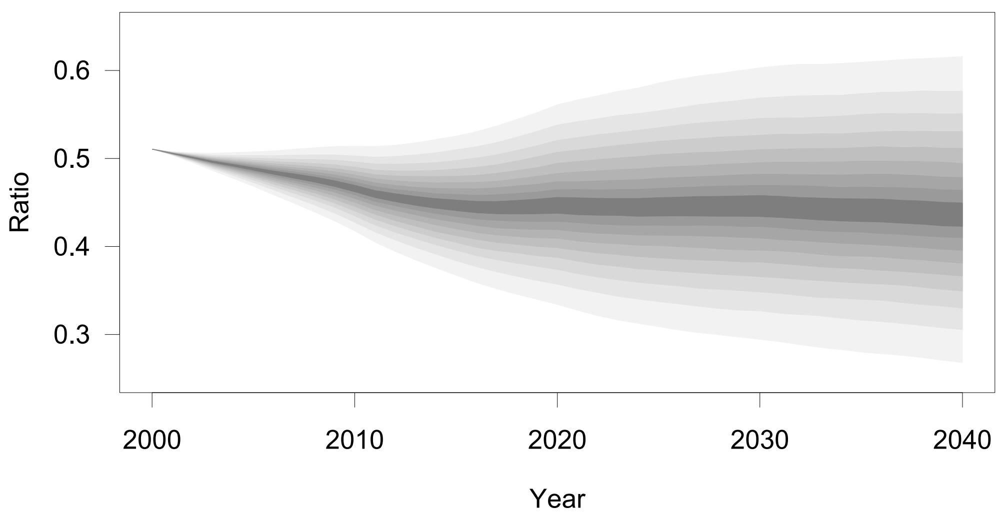
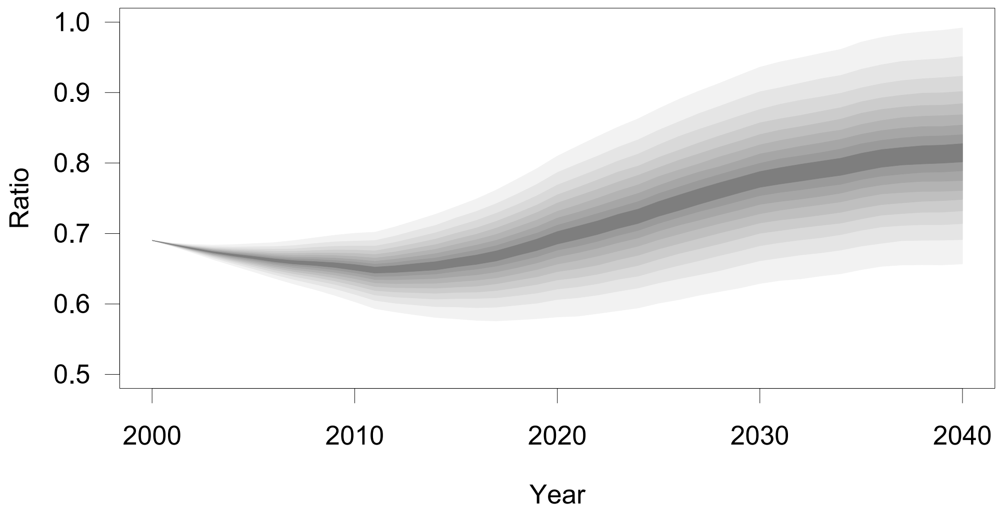
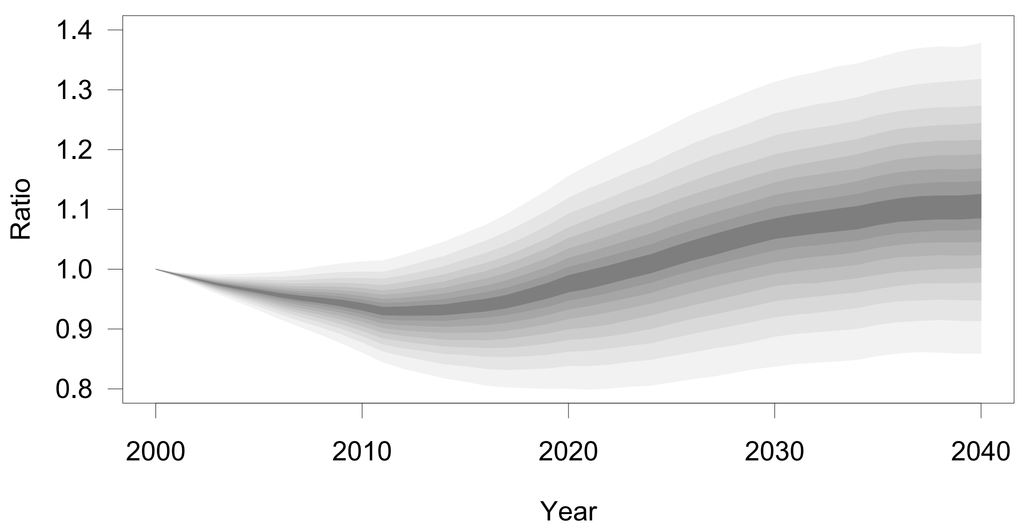


Fig. 22: Probability Deciles for Total dependency ratio



The total dependency ratio is not a good measure of the fiscal impacts of changes in the state's demography since it does not differentiate between children and the elderly. Children are generally more costly to the state than elderly. Assuming that children are about 40% more costly, I have calculated the economic dependency ratio shown in Figure 23. It is evident that changes in the state's demography over the next 10-15 years are likely to modestly ease tax burdens in the state – on the order of a 5-8% tax cut. After 2020 or so, demographic change becomes increasingly likely to raise state taxes. Of course, this exercise ignores the effects of changes in program use and costs over time which will be the subject of Chapter Two of the main report.

Fig. 23: Probability Deciles for Economic dependency ratio



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