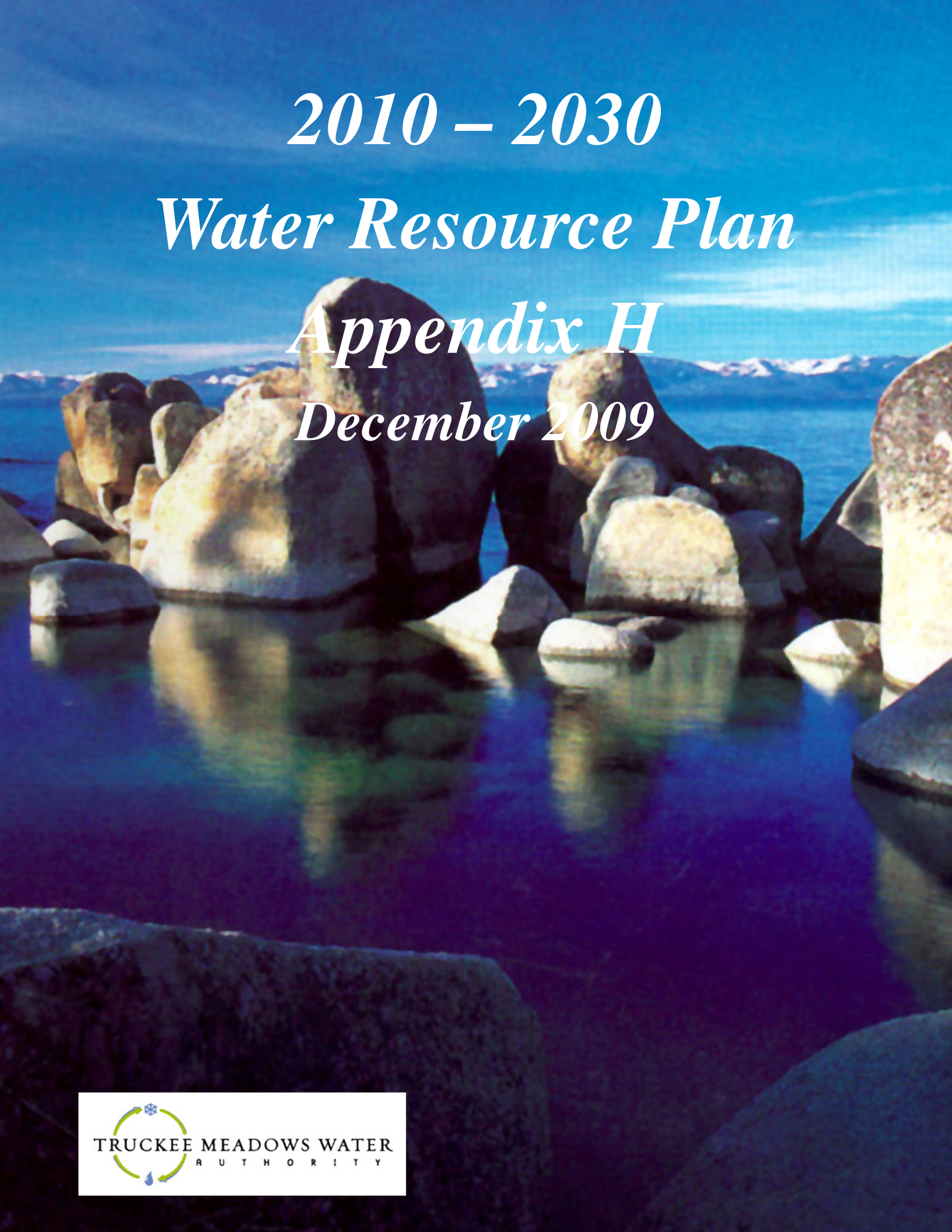

2010 – 2030
Water Resource Plan
Appendix H
December 2009

TRUCKEE MEADOWS WATER AUTHORITY

Appendix H:
Washoe County Population Projections

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Memorandum

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TO: File

FROM: **Shawn Stoddard, Ph.D. Senior Resource Economist**

DATE: August 3, 2009

SUBJ: TPEM Series No. 1: Washoe County Population Projection 2009 to 2050

Findings

- State Demographer reports 2008 population as 423,833 persons.
- Current economic conditions are unprecedented and are thus not easily modeled by traditional population/employment models.
- Washoe County population from 1950 to 2008 is well modeled by a logistic curve.
- Population projection using logistic curve is statistically similar to State Demographer's 2008 population projection for Washoe County.
- Population projections for 2010 to 2030:

Year	Population	Year	Population
2010	440,081	2021	519,876
2011	448,038	2022	526,185
2012	455,872	2023	532,324
2013	463,577	2024	538,291
2014	471,146	2025	544,088
2015	478,572	2026	549,713
2016	485,851	2027	555,166
2017	492,977	2028	560,450
2018	499,946	2029	565,564
2019	506,754	2030	570,511
2020	513,398		

- Logistic curve model can and should be updated annually.

Discussion

To date TMWA has developed two population/employment models, TMWA Population Employment Models, TPEM 2002 and TPEM 2006. TPEM 2002 model projected total population as a function of employment in various economic sectors and projected employment in various sectors as a function of employment and population. This model resulted in increasing population and employment indefinitely through time (i.e. no resource or economic constraints). This model was then constrained by extrapolating land use patterns and utilization rates thus limiting the growth in population to rate that new dwelling units were currently being constructed. The 2002 model had the benefit of detailed employment data by sector from 1969

to 2000, the 2000 census population data, and detailed land use. In 2002 it was a reasonable expectation that future land utilization rates and patterns will be similar to past patterns.

TPEM 2006 was a reconstruction of the logic used in the 2002 model. However, the modeling effort was plagued by difficulties caused by changes in the way the U.S. government reports labor statistics. In 2001 there was a change in the industrial classification system from SIC codes (Standard Industry Classification) to NAICS codes (North America Industry Classification System). This resulted in a break in the time series for all employment data, making time series analysis difficult at best and data series short for any meaningful analysis. BLS (Bureau of Labor Statistics) published a limited amount of reconstructed employment data for the years 1990 to 2001 that allowed for the development of a population/employment model that was based only on population and total employment for Washoe County. Thus, the 2006 model had less detail and information than the 2002 model but used the same logic for the land use analysis. While the 2006 model performed well, it was based on limited data and was very time consuming to develop and only provided limited information.

This memorandum, the first in a series, relating to the development of TPEM 2009 describes the analysis and projection total population for Washoe County. This total population will serve as a key data input for estimating and projecting residential dwelling units and total employment as required for future water demand projections.

Much of the technical discussion on population projection methods is taken either in part or in whole from "*State and Local Population Projection – Methodology and Analysis*" by Stanley K. Smith, Jeff Tayman, and David A. Swanson, published 2001 Kluwer Academic / Plenum Publisher.

Population Analysis Process

There are many different methods of projecting populations. These models range from the simple with minimum data requirement to the very complex with large complex data requirements. The State Demographer uses the Regional Economics Model, Inc. (REMI) model which is a very complex data model that produces very detailed outputs in excess of TMWA's planning needs. The State Demographer last published population projections in October 2008 using the REMI model and data from 2007.

The goal of this analysis is to develop a population projection that captures the most current population trends, considers the natural constraints on growth, has value when compared with other current and recent population projections, and can be easily updated on an annual basis.

Since the 2008 Demographer's projection is the most current projection published and is based on a full economic model, it will serve as a comparison / baseline projection. For a new / updated projection to be useful it should meet these requirements:

1. Project a long-run model of population, i.e. beyond year 2030.
2. Use data that is part of a very long time series, and is not likely to change in the near future e.g., Census and Demographer's certified annual population estimates.
3. Produce a projection that is statistically comparable to results produced by more complicated structural models.

4. Produce results that reasonably include or project current regional economic and population expectation.

The logistic curve model (LCM) used for projecting population in this report was selected based on the results from a model evaluation, testing, and comparison process documented in Appendix A: Population Projection Notes. The LCM described below meets all of the selection criteria defined. LCMs are generally used for long-term population projections, thus this model is able to project population beyond the year 2030. The model is estimated using 59 years of Washoe County population from 1950 to 2008. The resulting model contains the Demographer's projection with-in the 95% confidence interval. Last, the model projections are reasonable given current economic conditions.

Logistic Curve Model

Population for Washoe County is defined as:

$$Pop_t = \alpha / \left(1 + \beta 1 * e^{-\beta 2 * t}\right) + calib$$

Where t is time, Pop_t is population in time t, α is population ceiling, $\beta 1$ and $\beta 2$ are shape parameters, and *calib* is an adjustment factor so the population modeled in 2008 will equal the observed population.

Estimation results:

$$Pop_t = 676{,}985 / \left(1 + 12.93262 * e^{-0.0513267 * t}\right) + calib$$

Where t is time in years starting at $t = 1$ for 1950 and *calib* = 7,464 is an adjustment to make the projection equal observed population in 2008. The $R^2 = 0.9997$ shows that this model is a very good fit to the historic data.

This model is restricted to the lower 95% confidence boundary to capture the current effect of the current economic downturn. The estimation process for selecting the lower boundary requires some explanation. Three models are estimated using the population data. First, an unrestricted model (Model 1) that estimates α, $\beta 1$, and $\beta 2$ for the population data. Model 1 provides an unrestricted estimate of the population ceiling α as 731,313 persons with a 95% confidence interval of 676,985 and 785,641 persons. Second two restricted models are estimated, Model 2, restricts α to 676,985 persons, providing the lower 95% confidence boundary. Model 3, restricts α to 785,641 persons providing the upper 95% confidence boundary. The full estimation results are reported in Appendix A.

Figure 1, provides a graphical comparison of the three models with the historic population from 1950 to 2008. As can be seen all three models plot well with the historic population. All three models fit the data equally well as judge by the R^2 =0.9997 for all models.

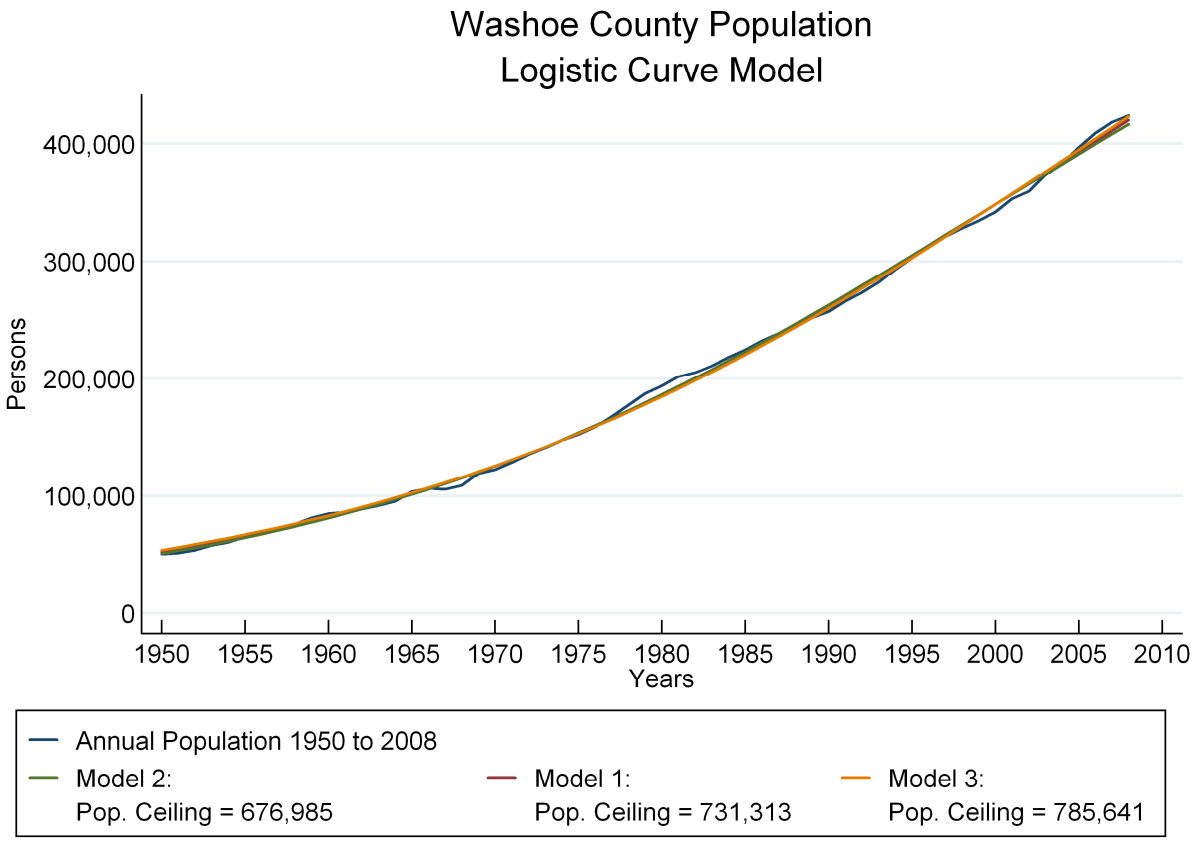

Figure 1: Logistic curves and historic population for Washoe County.

Figure 2, shows the three LCMs calibrated to 2008 estimated population. Through the year 2015 all projections are essentially the same and can be used for planning. However, Model 2 is preferred as the economy is still in period of decline and this has the effect of slowing population growth. Through the year 2020 the Demographer's projection tracks very well with Model 1 and then trends towards Model 2. On this basis Models 1 and 2 are favored for projecting population.

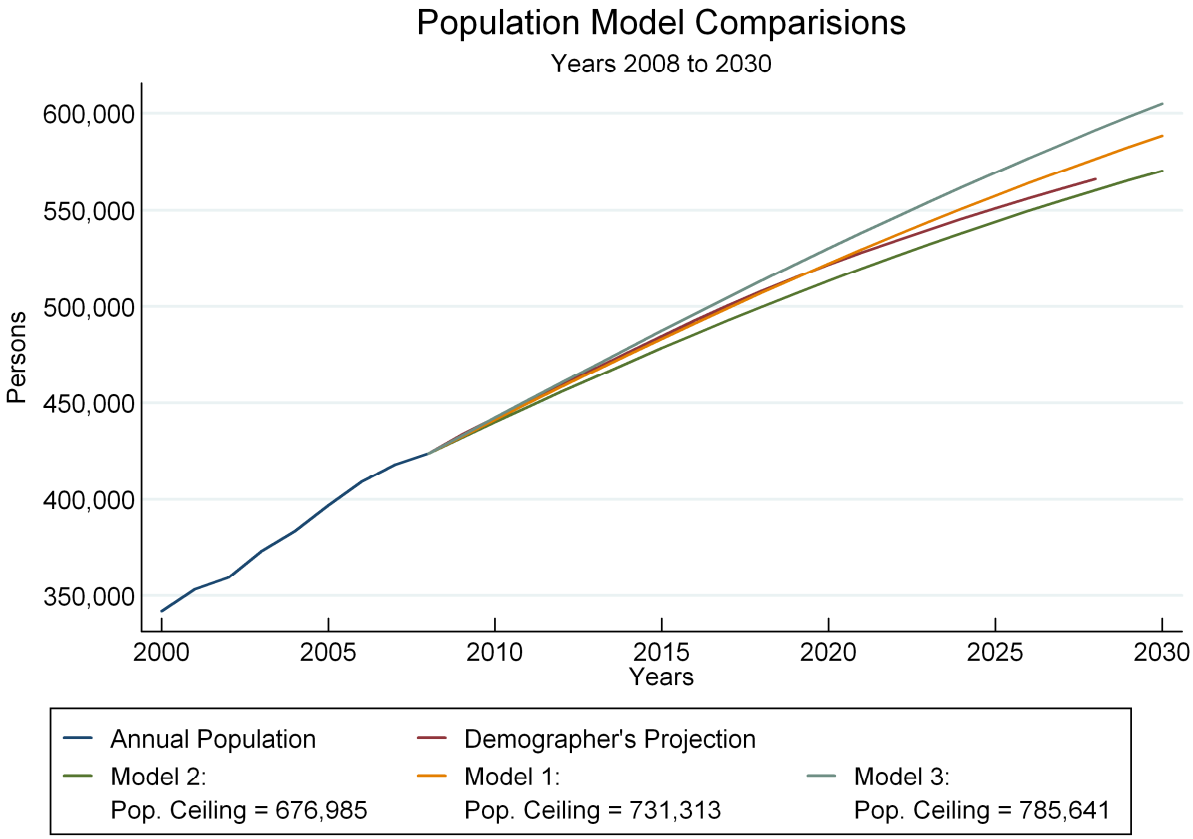

Figure 2: Compare Models 1 to 3 and Demographer's projections.

Figure 3, shows the long-run properties of each of the models. From this graph, Model 3 seems to be the least likely out come, it has a population ceiling of 785,641 persons and given current conditions and the overall trend between the years 2000 and 2030, this model is rejected. While Model 1 is plausible it is rejected in favor of Model 2. The primary reason for selecting Model 2 is the continued slowing economy, which generally results in slow population growth. Model 2 also tracks best with the REMI model projections published by the State Demographer. This is a conservative population projection in that it expects slower growth, but the projection through 2020 from all models are statistically equal.

This model should be updated annually as certified population and/or projections are published.

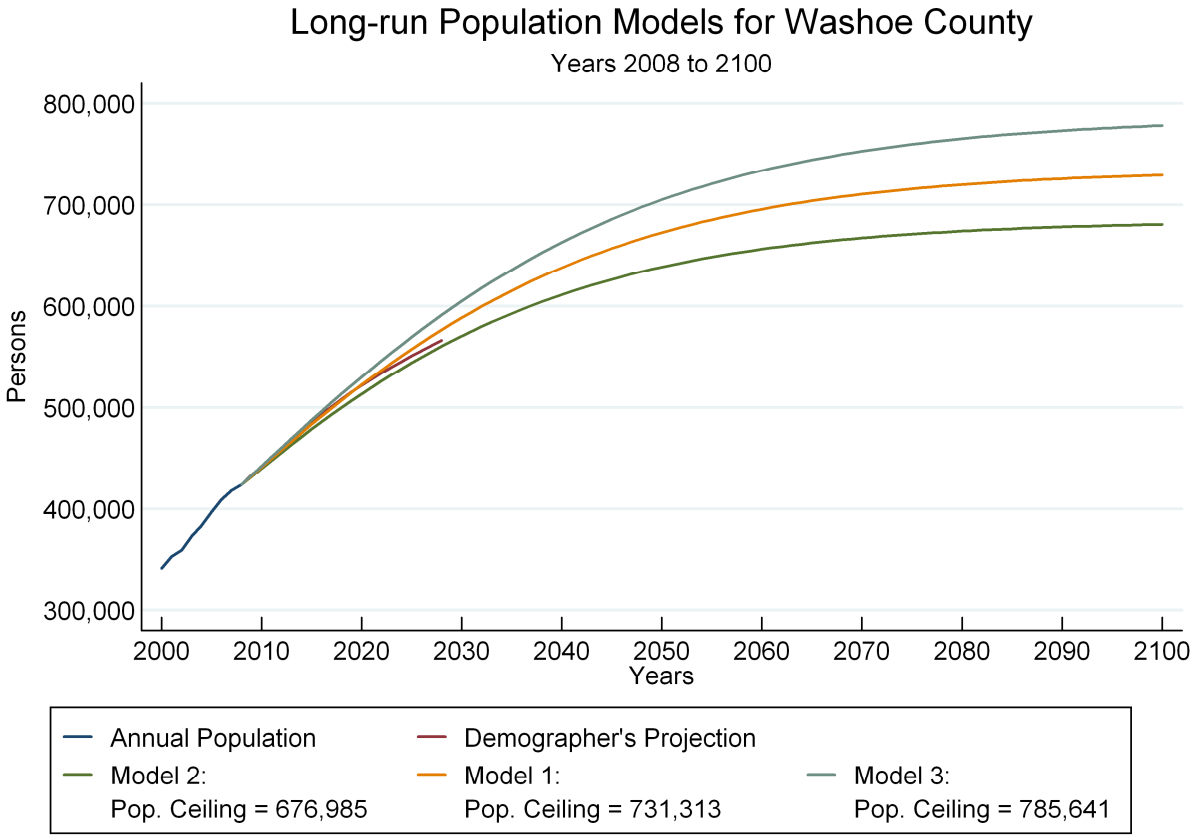

Figure 3: Compare models long-run projections through 2100.

Figure 4 graphs the complete population and population projections from 1950 to 2100. The LCM fits the long-run trend well. The long-run graph shows the Demographer's projection tracking as a section of the overall trend. Thus, the graphical analysis supports the selection of Model 2 as a reasonable model to project population values.

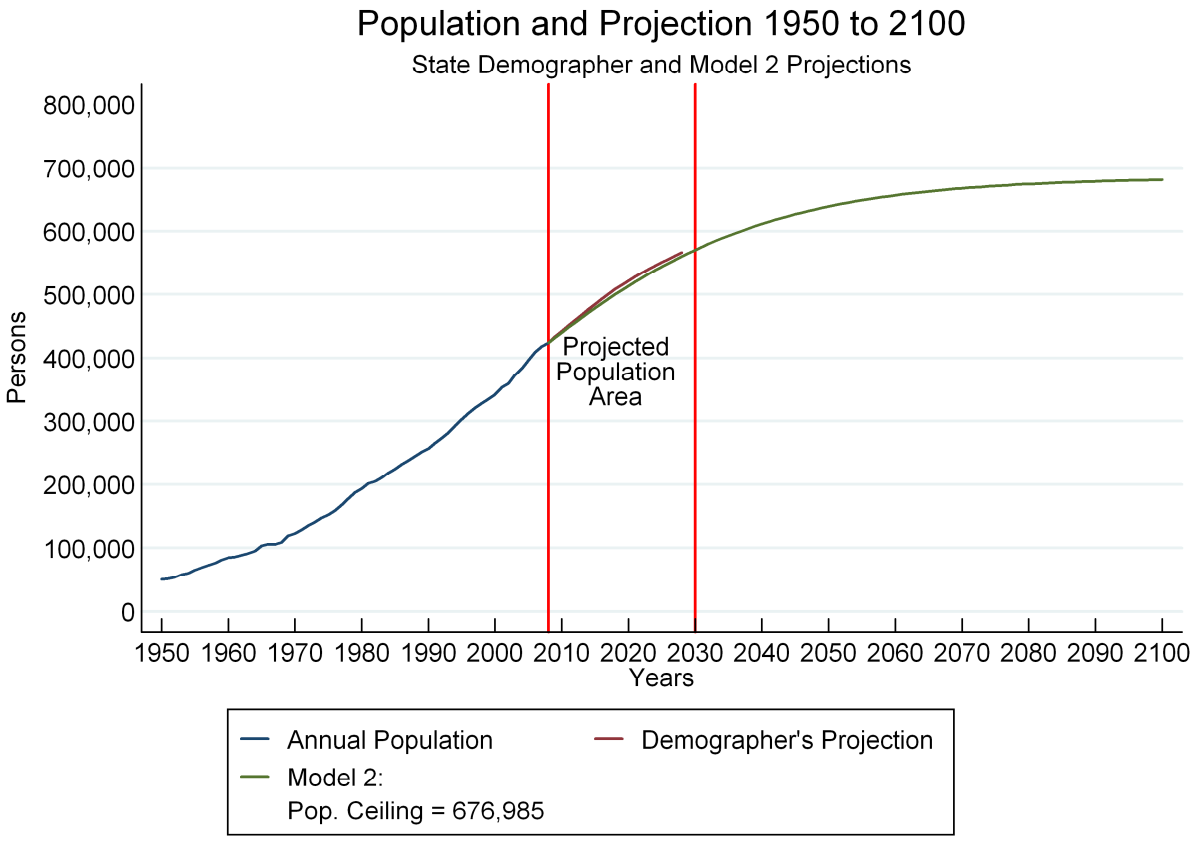

Figure 4: Population, Demographer's and Model 2 Projections 1950 to 2100.

Appendix B lists all the data, model output, historic population, and the Demographer projection used in this analysis.

TPEM Population Projection Appendixes

Appendix A: Population Projection Research Notes. These notes document the analysis process, testing results of various population projection methods and the logic used to select the model to be used for projecting Washoe County Population.

Appendix B: Source Data, documents the data used in the analysis, where to obtain updates to the data, and a listing of the data in the form of tables.

Appendix C: Stata Program Code, To enable others to replicate and or review the analysis in detail all project code is listed and documented. Included are instruction for creating the file folder structure necessary to run the provided code.

Appendix A: Population Projection Research Notes

Current Population and Demographic Data

There are only two sources of population data for the State of Nevada and Washoe County; United States Census Bureau and the State Demographer's Office. The Census Bureau compiles and estimate a wide range of demographic variables for each of Nevade's counties. The State of Nevada Demographer is responsible for estimating population for each county and the State for State Department of Taxation. It is the Demographer's population estimates that must be used for the allocation of state funds. The population used is described in Appendix B.

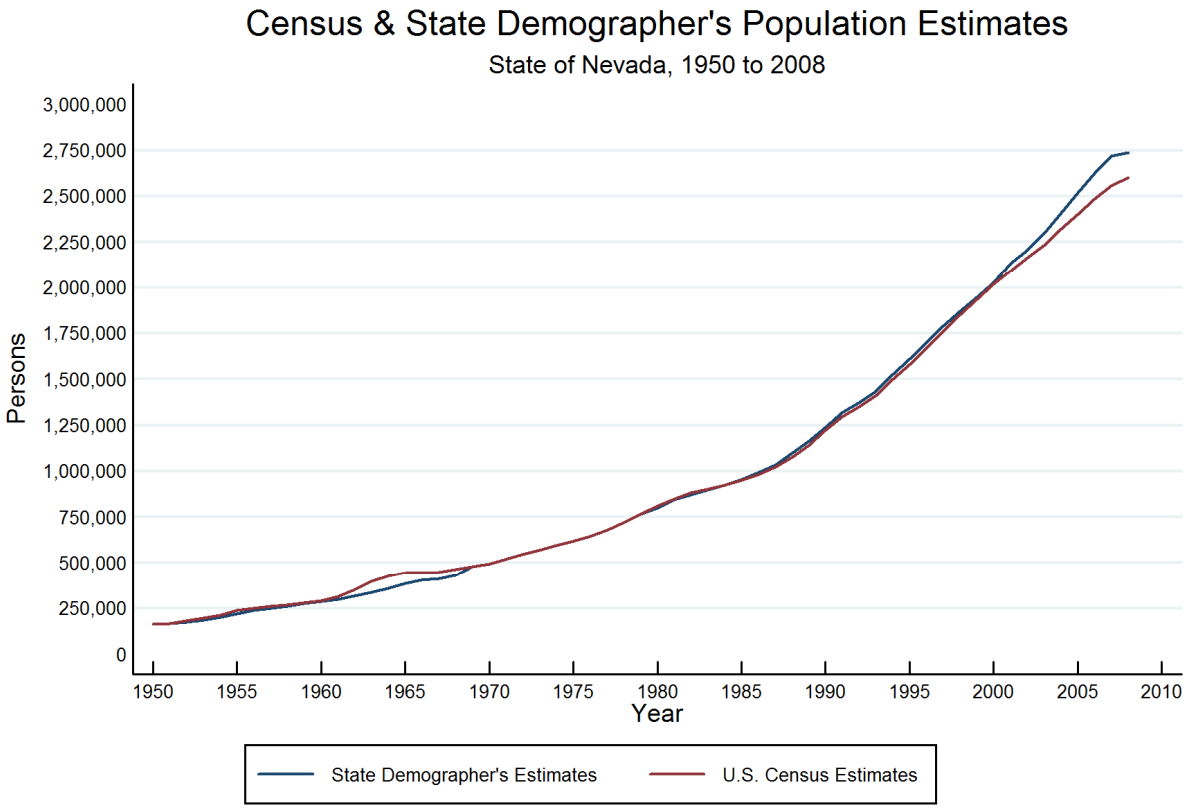

Figure A - 1: Compare Nevada population between Census and Demographer.

The demographer's population and the Census population for most of the years since 1950 are in close agreement (Figure A - 1). The exception to this trend starts with the year 2000 where the estimates provided by the Demographer are increasingly higher than the Census estimates. Also noted is a sharp decrease in population growth starting in 2007. This trend requires the use of Demographer's estimates in population for recent and current years.

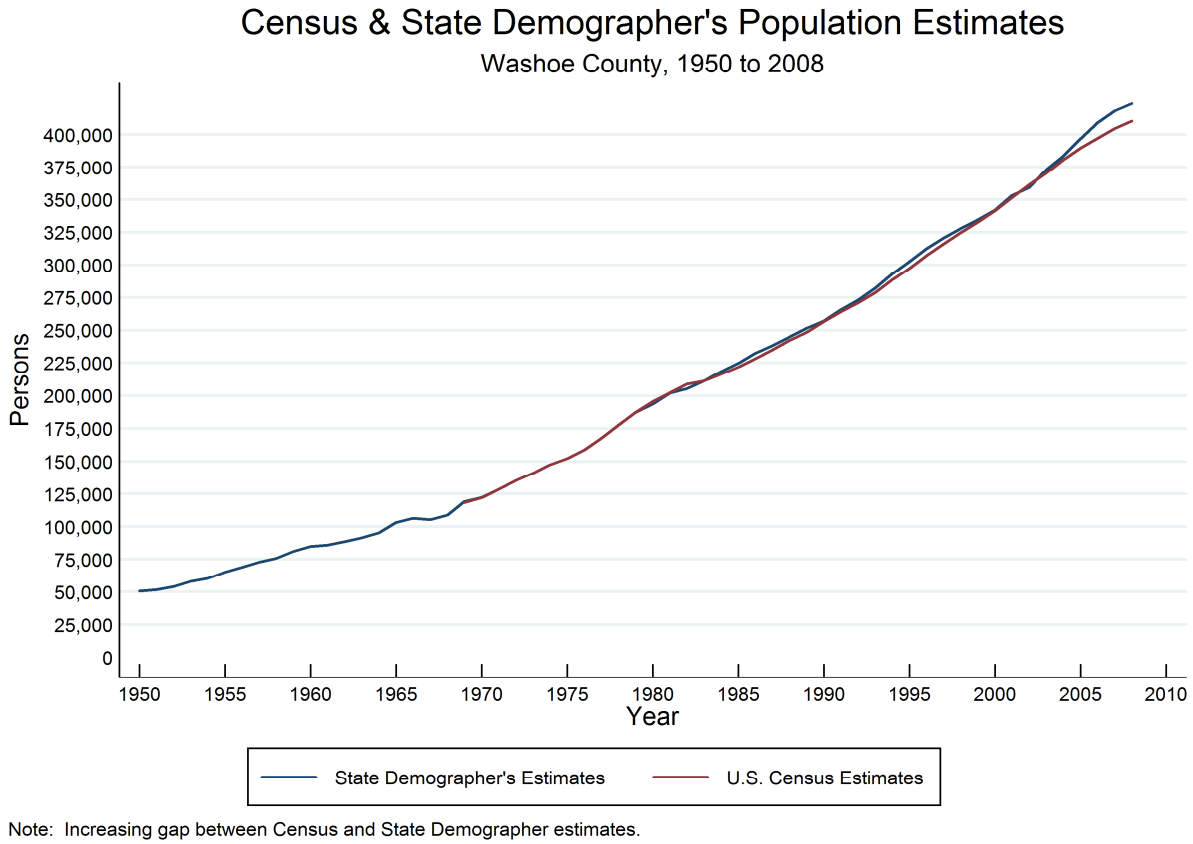

Figure A - 2: Compare Washoe County population between Census and Demographer.

Figure A - 2, shows result similar to the Nevada trends. There is also an increasing gap between Demographer's estimates and the Census estimates. Because the Demographer is working with direct data from local agencies, utilities, and other sources. It will be assumed for modeling purposes that the Demographer's data is a better estimate of population and will be used in all models.

Recent Population Projections

Since the year 2000 there have been various population projections or forecasts published for Washoe County from various local agencies. Summarized here is a graphical comparison of these projections. Each projection is graphed with the Demographer's estimated population for 2000 to 2008 to provide a comparison of each projection's performance.

Projections published since 2000 include:

- TMWA's TPEM 2002
- Washoe County Consensus Forecast 2003
- TMWA's TPEM 2006
- State Demographer Projection 2006
- Washoe County Consensus Forecast 2008
- State Demographer Projection 2008

A graphical analysis is performed to provide insight on which methods have performed best in the past and to assess what could be a reasonable projection give current economic conditions.

Consensus Forecast 2003 and 2008

The Consensus Forecast (CF), published by Washoe County, uses the recent published data from the State Demographer, Woods & Poole, Global Insight, NPA Data Sources and Truckee Meadows Water Authority (TMWA). The CF is in general an averaging of the various published projections with the intent of reducing forecast error over any one forecast or projection.

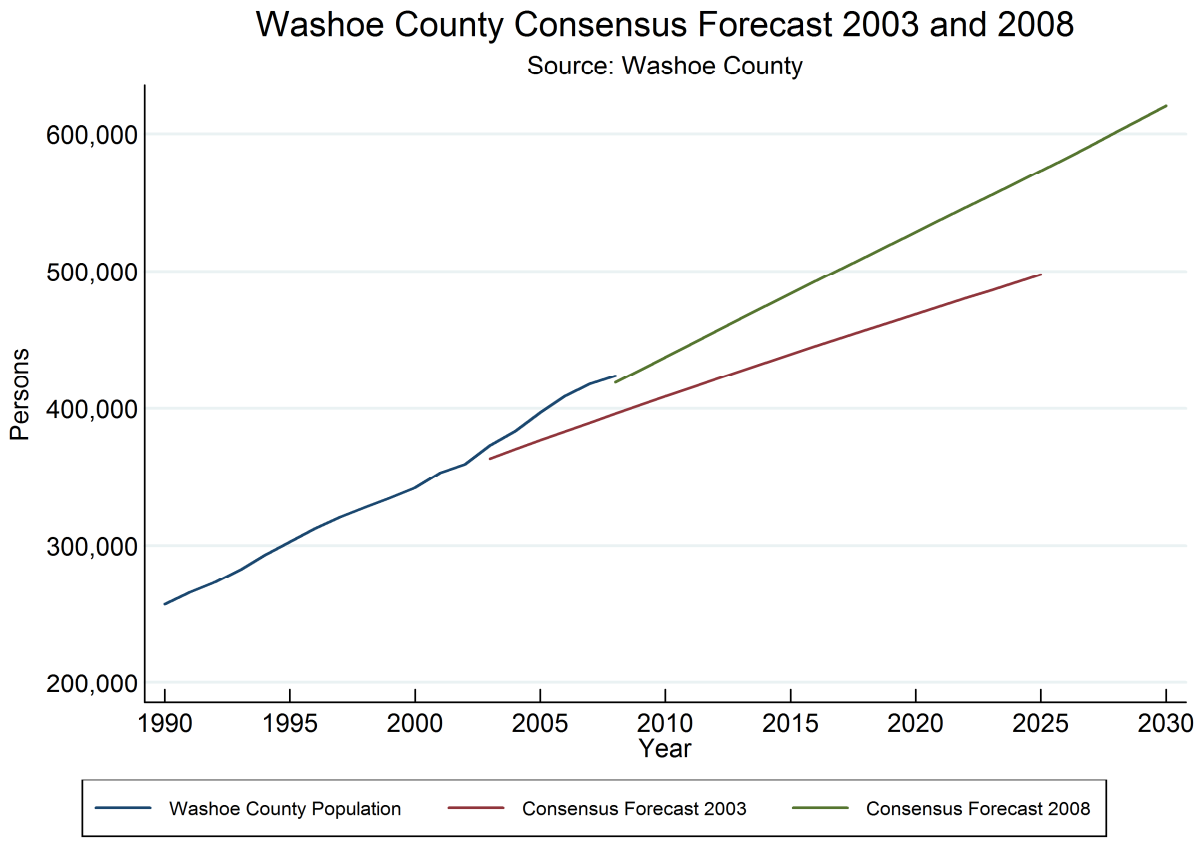

Figure A - 3: Washoe County Consensus Forecast for 2003 and 2008.

Figure A - 3, shows that each of the consensus forecast have the practical effect of a linear extrapolation of the recent population trends at the time of the forecast is published. The 2003 forecast was a reasonable trend using population up to the year 2000, but clearly under estimated the population growth at occurred. The 2008 forecast is reasonable given the population trend form 2000 to 2008, however, this trend show high levels of growth and does not include the recent and current economic conditions. This is to be expected given that most of the projections are based on 2006 data.

The 2008 Consensus Forecast is not suitable for current planning because it based on data at the peak of the growth cycle and the data is two years out of date.

State Demographer's Population Projections

There are two recent population projections from the State Demographer's office, 2006 and 2008. The State Demographer (SD) uses the Regional Economics Model, Inc. (REMI) model for Nevada's 17 counties. The model has a 25-yar history of development and economic theory and is used by a variety of public and private sector users across the county as a tool for conducting projections as well as looking at the economic impacts of specific projects. The REMI model allows the user to look at how regional economics interact with each other and with the nation as a whole. The current model was created with federal data beginning in 2001 using the North American Industrial Classification System (which was implemented at that time). This short history coincides with some of Nevada's counties having had record population growth and mining has recovered from the down cycle of the late 1990's. This history of strong growth is the foundation for the projections and limits the ability to model recent shocks to the economy.

With the above discussion from the SD and the current continuation of the economic downturn, one should expect that the SD 2008 projection is likely to over project population growth for Nevada and the counties. Below, the SD projections are compared with population from 1990 to 2008.

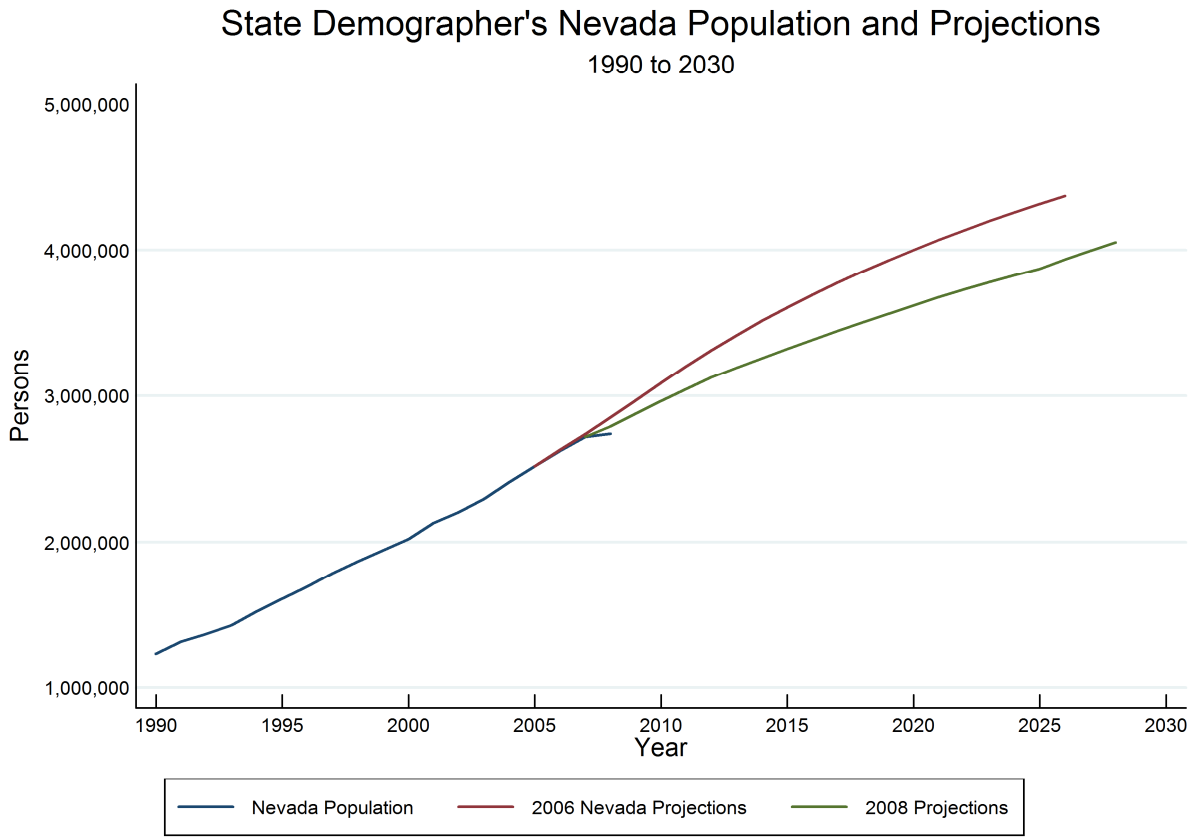

Figure A - 4: Compare State Demographer's Nevada population and projections.

Figure A - 4, the projections for 2008 shows a slowing of grows as when compared to 2006 projections. This is the result of capturing the start of the downturn in the economy that has resulted in a sharp decline in population growth. The 2008 projection is based on 2007 data and thus is missing part of the population change at the state level. As the downturn is continuing as

of July 2009, the decline in growth can be expected to continue through 2009 and possibly into 2010.

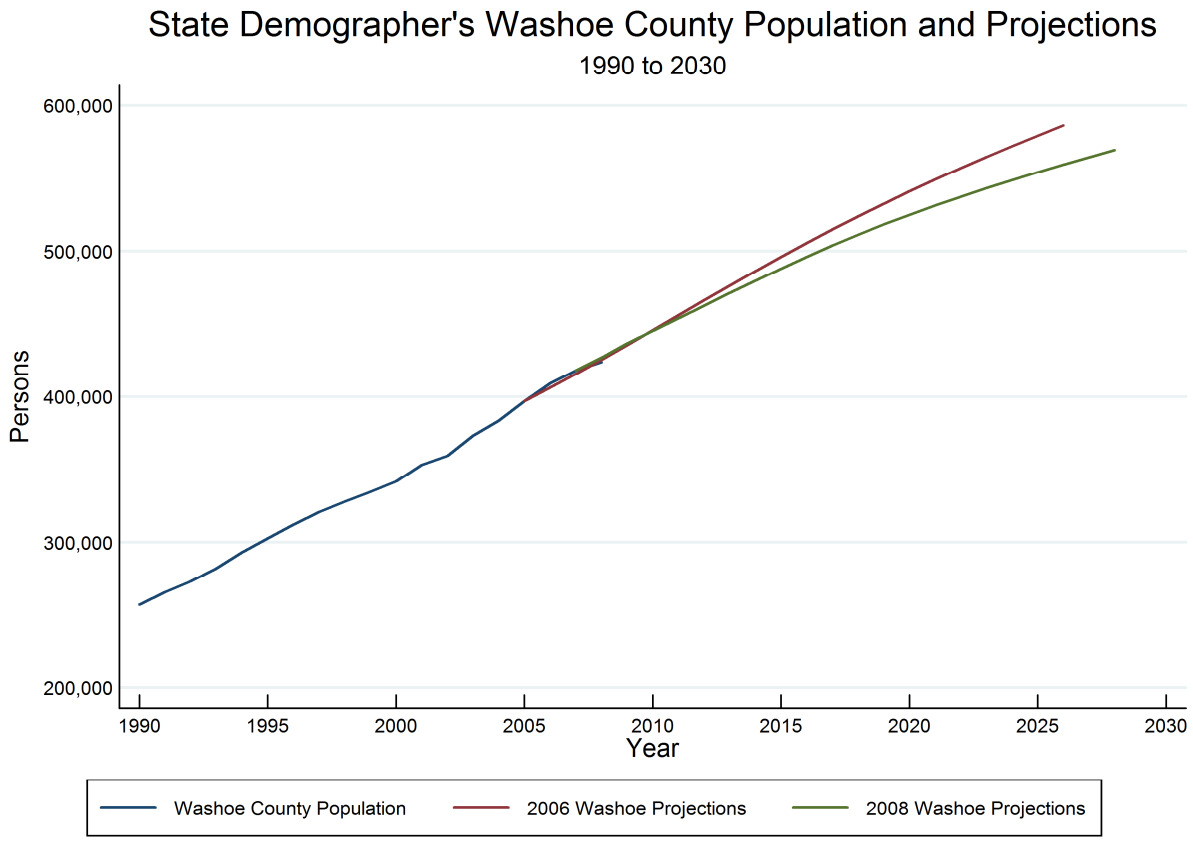

Figure A - 5: Compare State Demographer's Washoe County population and projections.

Figure A - 5 and Figure A - 6 examine the SD's projections for Washoe County. Figure A - 5 looks at a longer-trend from 1990 to 2030 and compares both the 2006 and 2008 projections. We see that both projections fit the trend well and that the 2008 projection is showing a slowing of growth beyond 2010. This fits well with the current conditions and expectations. Figure A - 6, is the same data, just look at the selection of years from 2000 to 2015. What we see here is that both of these projects perform well when compared with the data, the 2008 projection is starting to capture the economic slowdown.

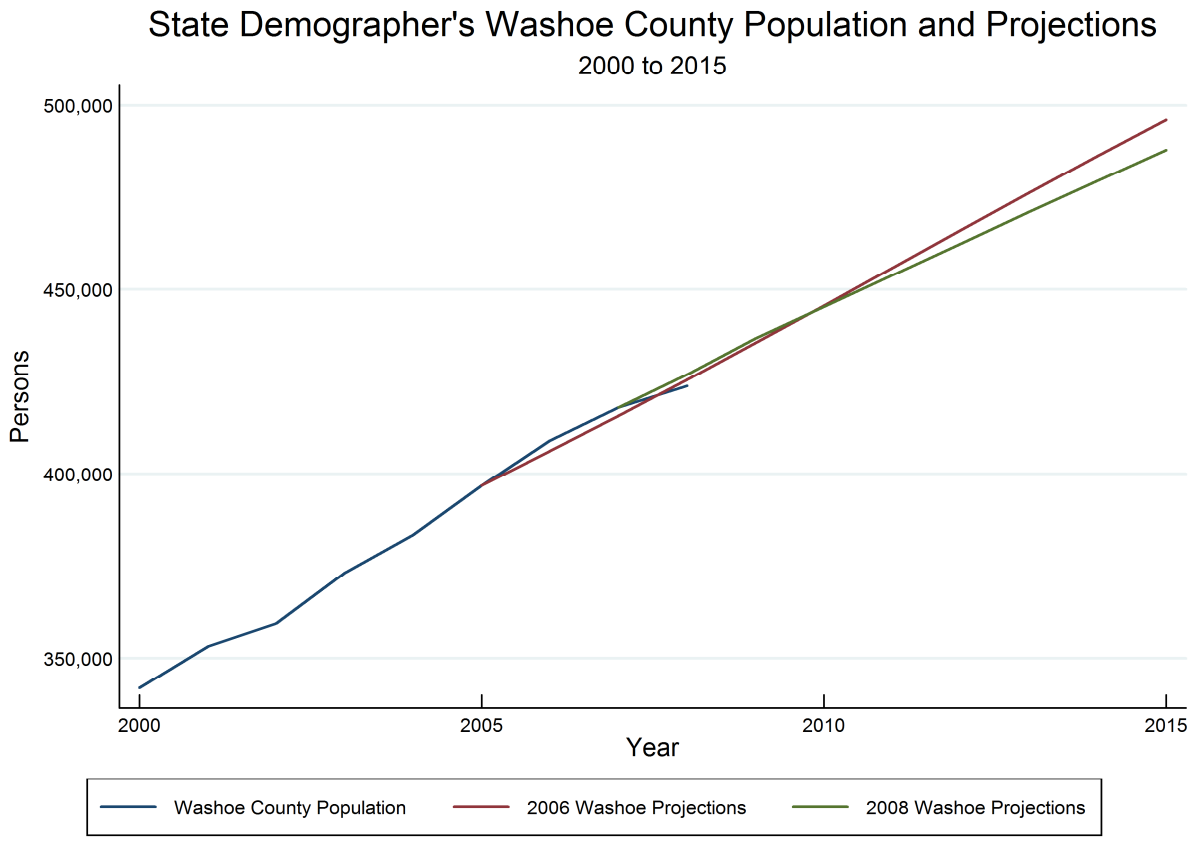

Figure A - 6: State Demographer's Washoe County population and projections, years 2000 to 2015.

TMWA's Projections

TMWA's projections are from its population and employment model. The model first projects both population and employment as if there are no constraints on future growth. As a second stage the population and employment was then constrained base on recent land utilization rates and was then extrapolated to the available buildable land. This approach is very labor intensive and requires several months to perform. The past model created projections that are reasonable with the population trends (Figure A - 7).

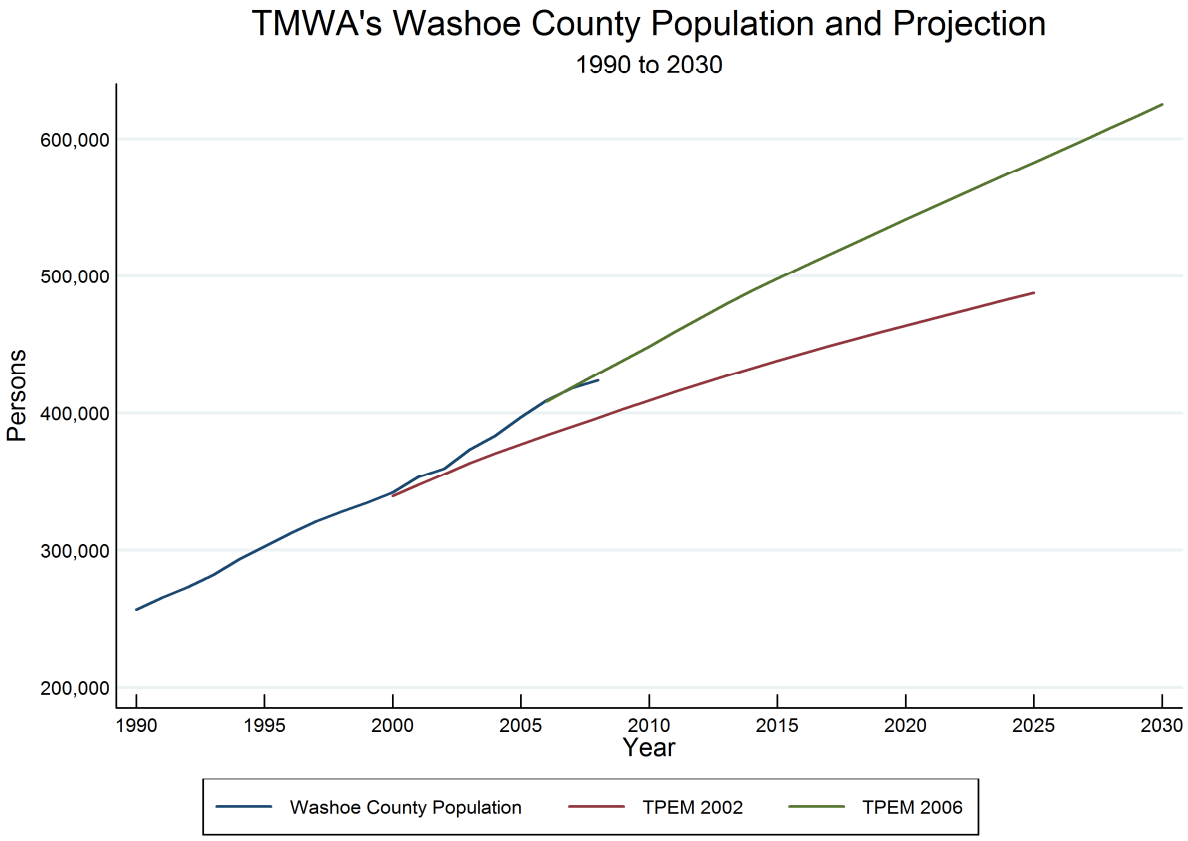

Figure A - 7: Compare TMWA's projections with population for 1990 to 2030.

Graphically compare all recent projections

As can be seen above the 2002 and 2003 projections under estimated the population growth and will not be compared here. This comparison will focus on TPEM 2006, CF 2008, and SD 2008.

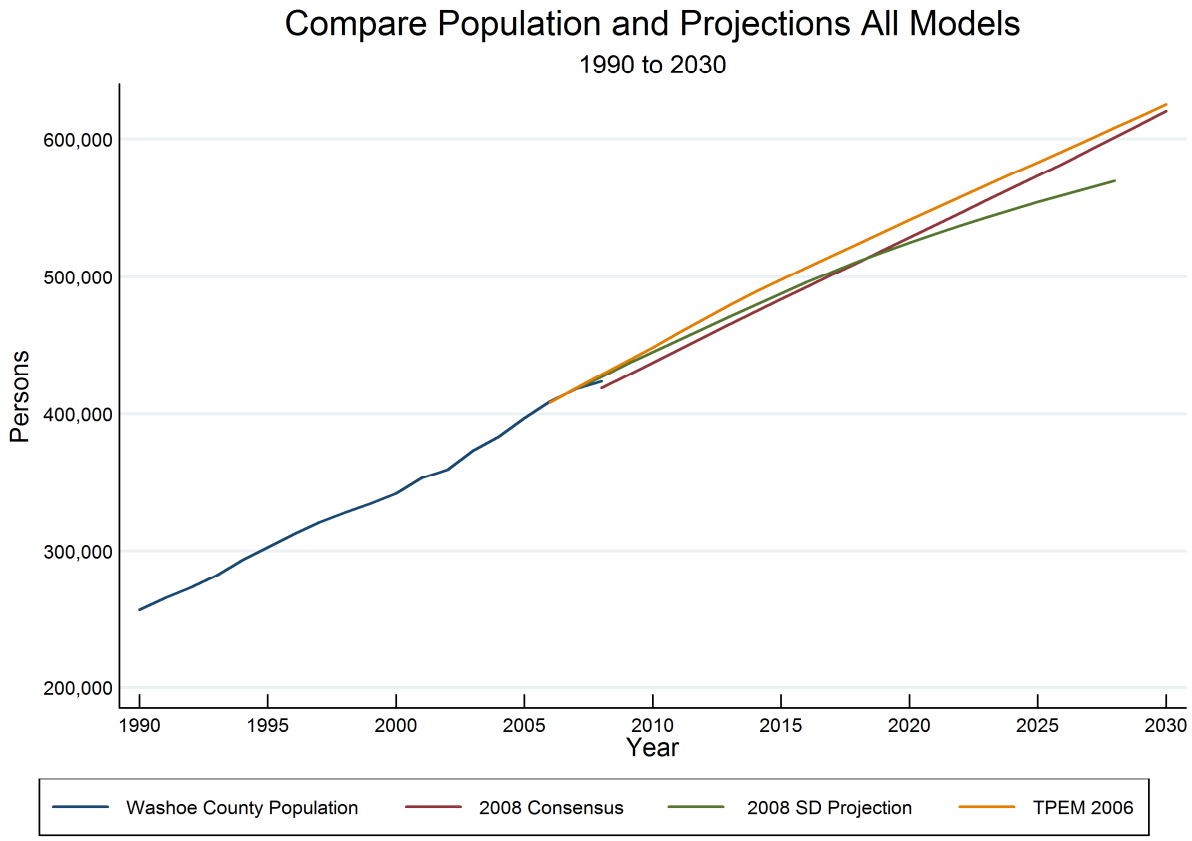

Figure A - 8: Compare the three most recent projections, 1990 to 2030.

Figure A - 8, shows the three most recent projections. The SD model which is the most recent, show the effect of the economic slowdown and how that compounds in the future years.

The 2008 SD model will be calibrated to match 2008 observed population and the used as a comparison with potential models to be used for providing an updated long-run population projection for Washoe County.

State Demographer Adjusted Projections for Nevada and Washoe County

The next two graphs show the adjustments to State Demographer projections. The adjustment is only a shifting of the line to match the currently published population estimates.

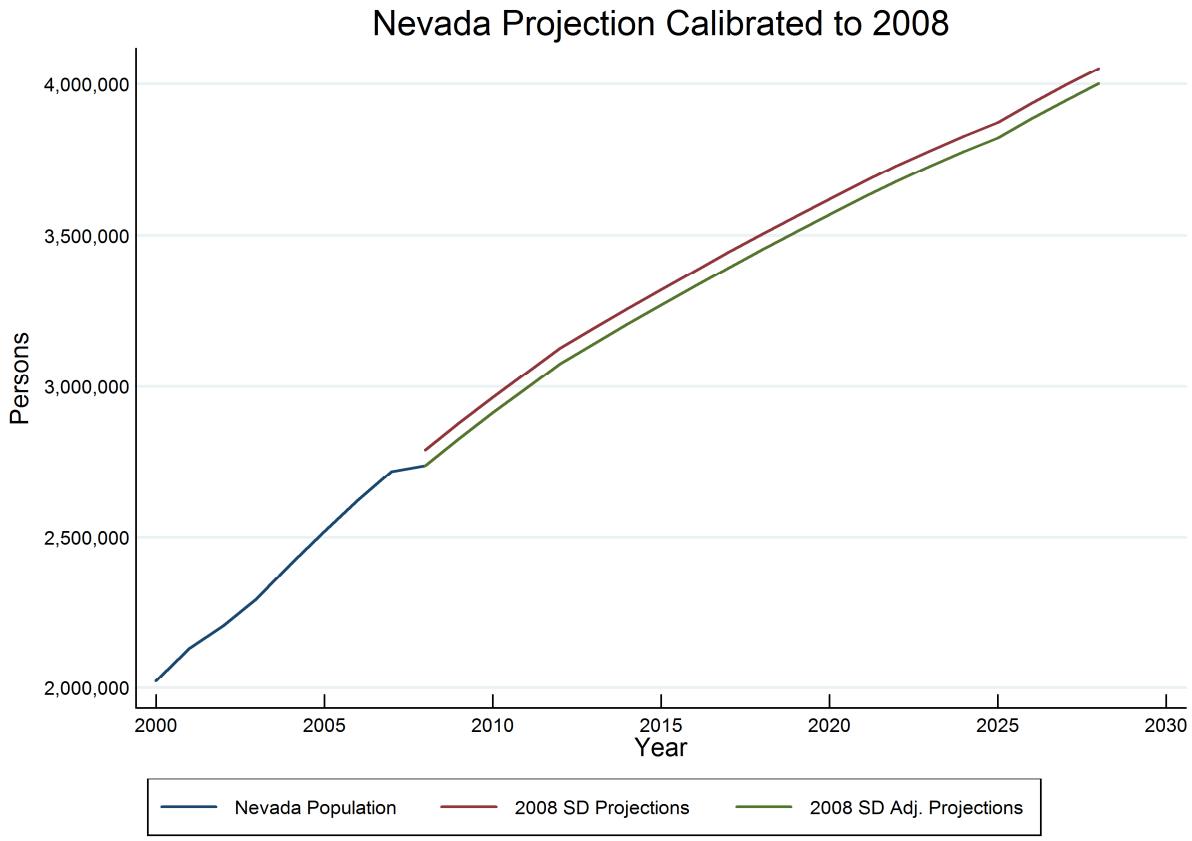

Figure A - 9: Adjusted State Demographer's Nevada Population Projections.

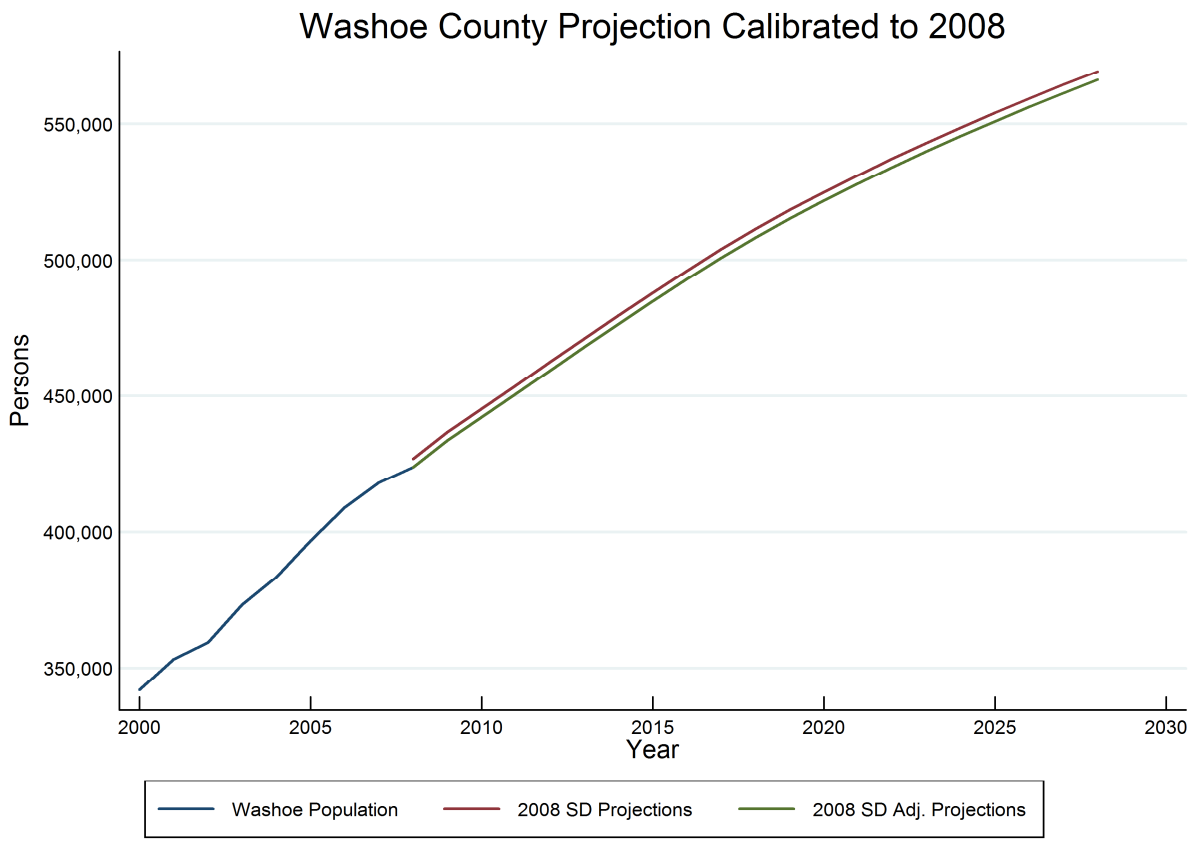

Figure A - 10: Adjusted State Demographer's Washoe County Population Projections.

Population Projection Models

There are many different methods of projecting populations. These model range from the simple with minimum data requirement to the vary complex with large complex data requirements. The goal of this report is to develop a population projection that seek to use more recently published data than that included in the State Demographer's REMI model. The model required by TMWA needs to project both the county population and county employment. The projection also needs to have sufficient detail that it can be disaggregated to smaller sub-county area.

The model search process will start with very simple demographic models and then advance to more complex model. The goal is to find a good working model that will provide a long-run projection of population that improves on the SD model by providing an update for current economic conditions.

Model Search

Simple Trend Extrapolation Models

Linear (LINE)

The linear extrapolation method (LINE) assumes that the population will increase (decrease) by the same number of persons in each future year as the average increase (decrease) observed over the base period. Average annual absolute change is computed as

$$AAAC = \left(P_l - P_b\right) / y$$

where P_l is the population in launch year (2008), P_b

This procedure may be used to compute different $AAAC_{base}$ just by changing the base year. The AAAC is computed for base years 1960, 1970, 1980, 1990, and 2000.

Give the AAAC the population projection is expressed as

$$P_t = P_l + z(AAAC)$$

Where z is the number of years in the projection horizon.

Base Year	AAAC	SD 2028 Adj Proj	AAAC 2028
1960	6,915	566,238	562,137
1970	7,725	566,238	578,324
1980	7,938	566,238	582,598
1990	8,774	566,238	599,320
2000	9,100	566,238	605,828

As can be seen in the above table the longest base period results in a tend of 6,915 person per year. As the base period changes to focus on the more recent years the rate of growth increases. The $AAAC_{1960}$ which is the closest to the long-term results in a projection similar to the Demographer's projection. This method does provide reasonable projection of the total population.

Geometric (GEO) and Exponential (EXPO)

The geometric extrapolation method (GEO) and the Exponential (EXPO) methods, both assumes that the population will increase (decrease) at the same percentage rate during the projection horizon as during the base period. The GEO models assumes an annual percentage rate while the EXPO method assumes continuous compounding. Both of these models will produce nearly identical projections for this reason only the exponential method is applied.

The exponential growth rate *r* is computed as

$$r = \left|\left(P_l / P_b\right)\right| / y$$

Given this formula for the exponential rate, a population projection can be expressed as

$$P_t = P_l e^{rz}$$

The exponential growth rate is calculated for each of the following base periods: 1960, 1970, 1980, 1990, and 2000 to 2008.

Base Year	EXPO Model Rate	SD 2028 Adj Proj	EXPO 2028
1960	3.28%	566,238	816,631
1970	3.18%	566,238	800,756
1980	2.70%	566,238	727,514
1990	2.63%	566,238	717,262
2000	2.39%	566,238	682,998

These models can lead to very high projection in a region that has had periods of high growth. The table above clearly show projections that are unreasonable and assume no limits on growth, such as economic conditions.

Complex Trend Extrapolation Models

Complex extrapolation methods differ for the simple methods in several ways. They use data from a number of points in time, have more complex mathematical structures and require an algorithm for estimating the each methods parameters. Because these methods use more data, they may provide a more complete picture of the historical pattern of population change than the simple extrapolation methods. Their more complex mathematical structures provide a wider range of possibilities regarding population trends than the simpler methods. In addition, the application of statistical algorithms to estimate the model's parameters provides a basis for constructing prediction intervals. However, these methods are more difficult to implement than the simple trend or ratio extrapolation methods. There is discussion as to whether the complex extrapolation provide more accurate forecasts than the simpler methods.

The process of projecting population using a complex extrapolation method has three basic steps:

1. assemble historical population data at equal time intervals between a base year and launch year. The data must be based on consistently defined geographic boundaries for each point in time, i.e. county or state boundaries. Since city boundaries change over time, these methods should not be used for sub-county regions.
2. Select a mathematical model and estimate its parameters through a curve fitting process. The choice of the model should reflect the analyst's judgment regarding the nature of population change and the most likely future population trend. While graphs, statistical correlation measures, and the analysis of residuals are used evaluate how well the model

fits the historical data; however, a close fit does not guarantee an accurate or even a reasonable projection.

3. Use the mathematical model and estimate parameters to prepare the population projections. In this step four methods will be applied to the historic Washoe County data: linear trend, polynomial curve fitting, logistic curve fitting, and ARIMA time series model.

Each of these models will be estimated using STATA statistical software version 10. Each model will be described along with the estimated parameters.

Linear Trend (OLS)

The linear trend model is the simplest of the complex trend extrapolation methods. It is based on the assumption that the population will increase or decrease by a constant numerical amount, as determined by historical population change. This assumption is identical to the assumption underlying the LINE method discussed above. However, it is operationally applied differently. The linear trend model is based on the equation for a straight line:

$$Y = \alpha + \beta X$$

Where Y is the dependent variable (population); X is the independent variable (time); α is a constant or intercept term; and β is the slope of the line. The terms X and Y are the model variables or data used in estimating the model and take on values that vary with each observation. The terms α and β are the model's parameters. The parameters represent the statistical relation between the models independent and dependent variables. They take on values that remain constant for any particular application of the model but will vary from one application to another.

The linear trend model is estimated using ordinary least squares (OLS) regression. The model for Washoe County is:

$$Pop_t = \alpha + \beta_1 t + calib$$

Where population is annual population for Washoe County from 1950 to 2008. Time *t* is 1 for the year 1950 and 59 for the year 2008; *calib* is an adjustment factor.

The adjustment factor is required since any curve fitting procedure is unlikely to produce an estimate for the launch year that is equal to the observed value for the launch year. The adjustment factor is calculated by subtracting the estimated population from the observed population for the launch year. This adjustment produces a parallel shift in the trend line that makes it pass directly through the launch-year population.

STATA results for the OLS estimation of the linear trend model.

Table A - 1: Results of linear model estimation.

```
regress washoe t;

      Source |       SS       df       MS              Number of obs =      59
-------------+------------------------------           F(  1,    57) = 2176.38
       Model |  7.1958e+11     1  7.1958e+11           Prob > F      =  0.0000
    Residual |  1.8846e+10    57   330632934           R-squared     =  0.9745
-------------+------------------------------           Adj R-squared =  0.9740
       Total |  7.3843e+11    58  1.2732e+10           Root MSE      =   18183

------------------------------------------------------------------------------
      washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           t |   6485.086   139.0106     46.65   0.000     6206.722     6763.45
       _cons |    5411.15   4795.363      1.13   0.264      -4191.4     15013.7
------------------------------------------------------------------------------
```

Regression analysis results in the following model:

$$\text{Population} = 5411.15 + 6485.086*t + 35{,}801$$

$$R^2 = 0.97$$

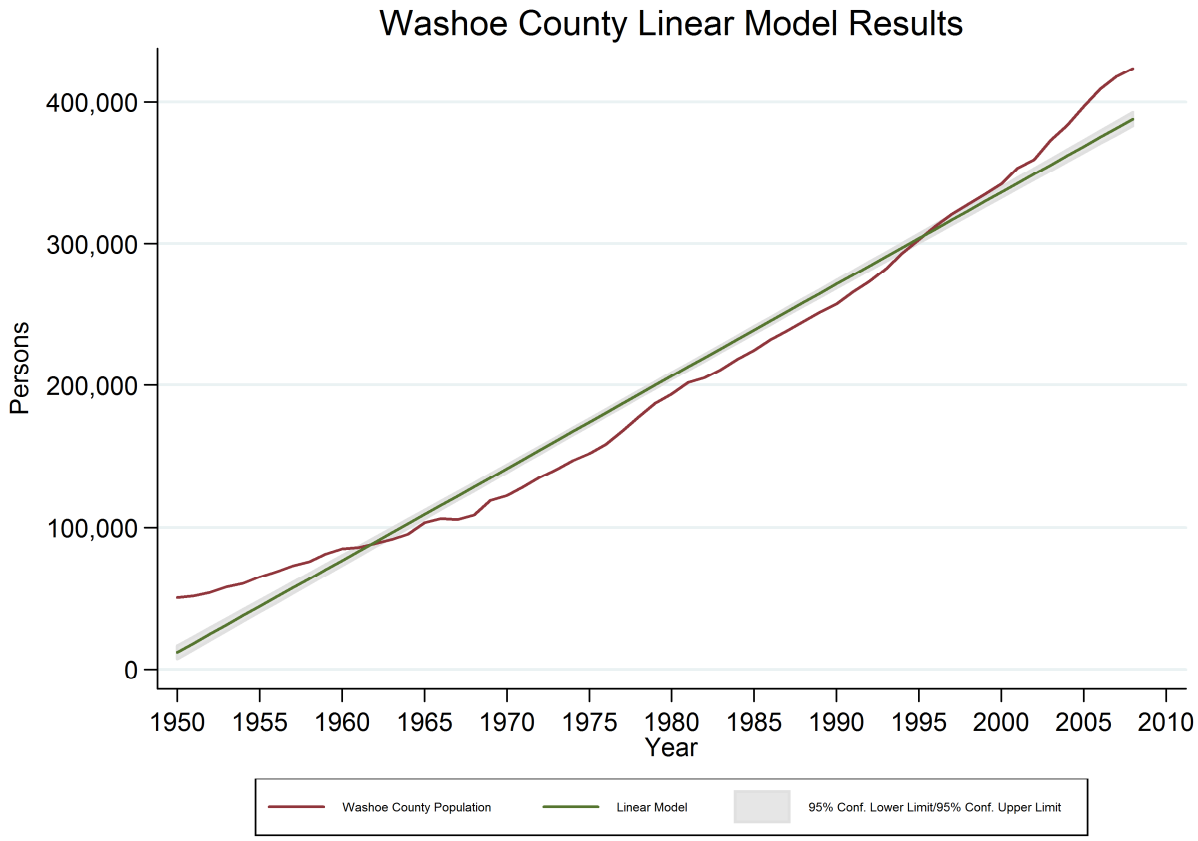

Figure A - 11: Linear Regression Model of population.

Note: while most observations are not within the 95% confidence interval and the R^2 shows that the model explains 97% of the variation(Figure A - 11). This model would not provide a very accurate forecast in most years unless the model is calibrated for a recent launch year. After calibrating the model for 2008 (Figure A - 12), the calibrated models provides a good projection when compared with the State Demographer's 2008 projection. The Demographer's projection is contained in the upper 95% confidence interval of the projection.

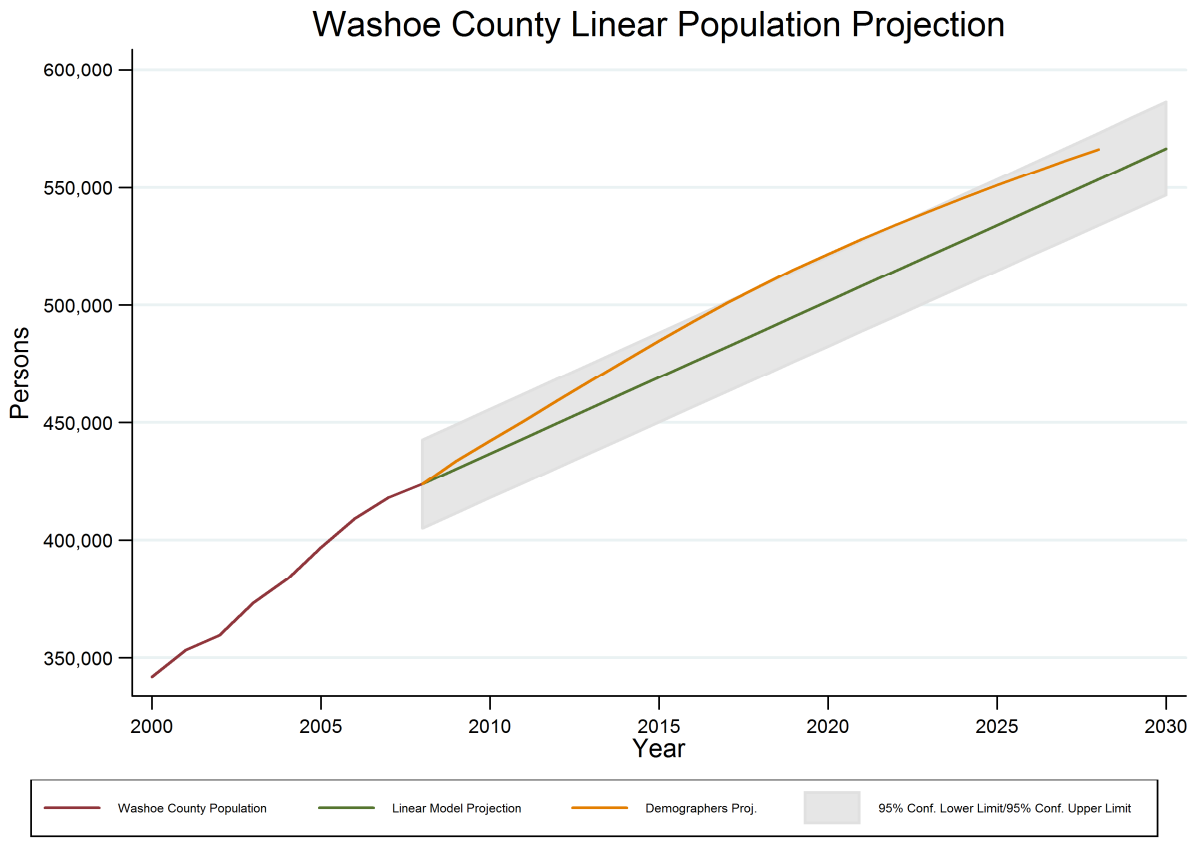

Figure A - 12: Compare linear trend model with Demographer's projections.

A limitation of the linear model is the lack of constraint on future growth that could from resource limitation. The nature of the linear model is the assumption the future will be similar to the past.

In light of the current economic condition the projection could be considered an improvement for total population. As the economic decline continues, this can be expected to result in slower or declining population growth. The linear predicts an average growth 6,485 persons per year.

This is a reasonable short term improvement to the State Demographer's projection, in that it provides a lower but statistically equal projection. Might not be a good long-term projection model.

Polynomial Curve Fitting

Polynomial curve fitting is useful for basing projections on nonlinear patterns (i.e., patterns in which annual population change is not a constant numerical value). The general formula for a polynomial curve is

$$Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \ldots + \beta_n X^n$$

Where Y is population as defined in the linear trend model, X is time. This model differs from the linear model in that powers of time are used as independent variables.

This model is estimated using OLS by first creating variable for each power of time that is desired. Models with only the squared term are called quadratic functions. The highest exponent in the exponent in the equation is the degree of the polynomial.

The quadratic function was estimated as:

$$\text{Population}_t = 46{,}725 + 2{,}421t + 67.72t^2 - 1516$$
$$R^2 = 0.9991 \text{ Root MSE} = 3{,}415.9$$

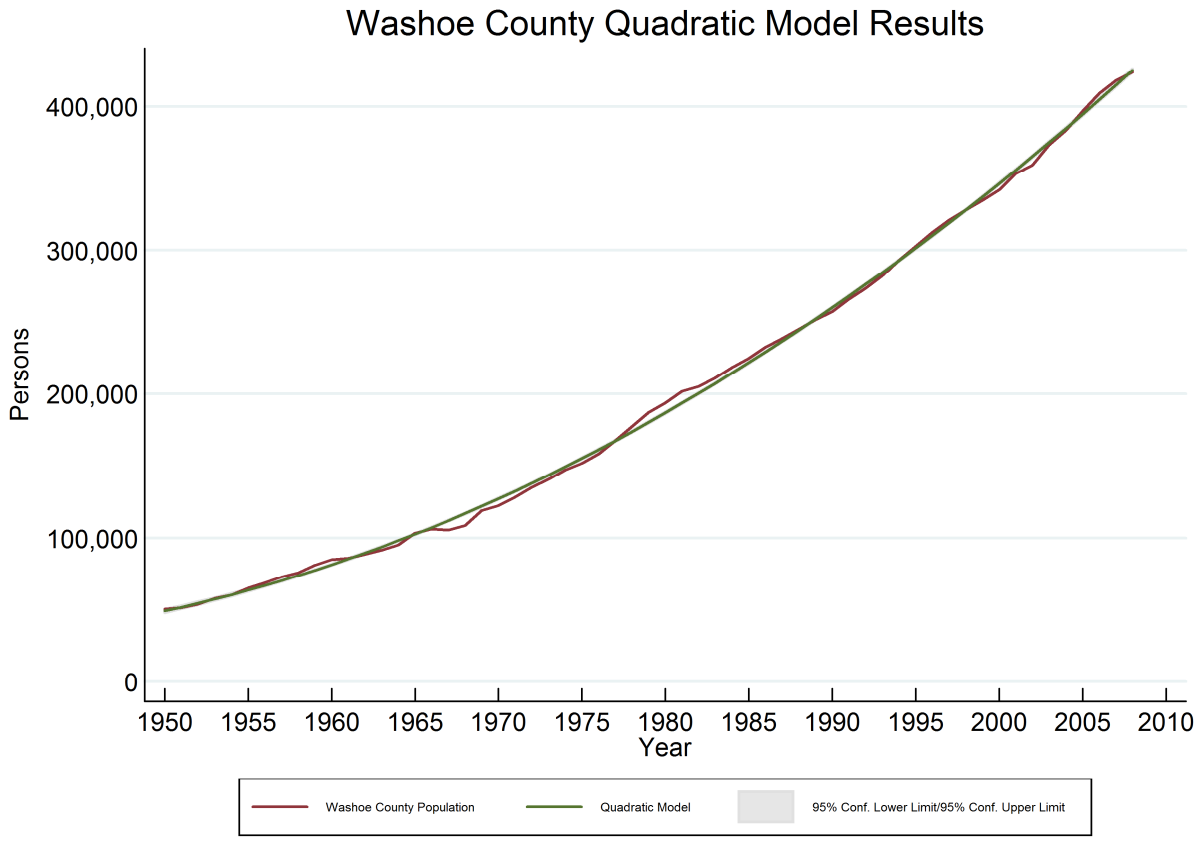

Figure A - 13: Washoe County quadratic model results.

As seen in Figure A - 13, the non-linear model fits the data very well. Because the model fits so well, the 95% confidence interval is to small to be seen on the chart. Figure A - 14 compares the quadratic model with the Demographer's projection. The quadratic model show population growing at an increasing rate. The quadratic does not look to be a reasonable projection.

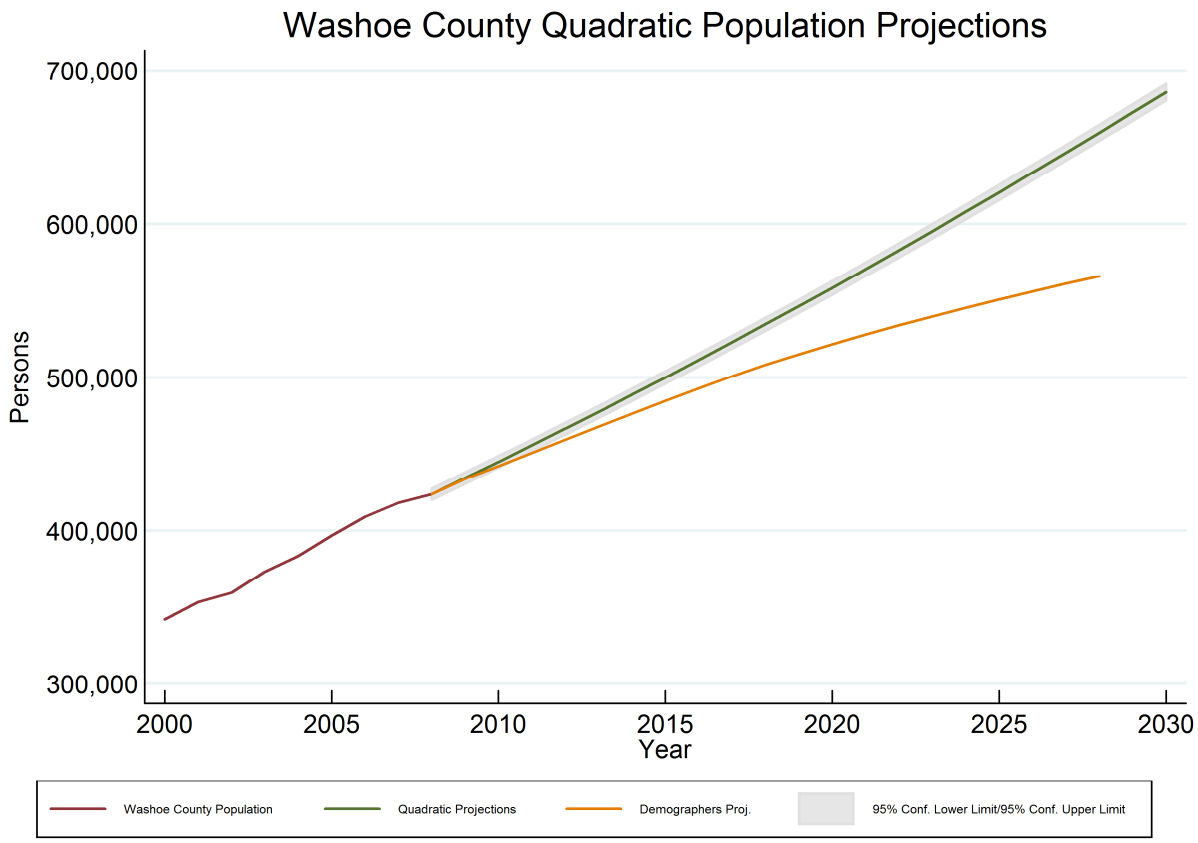

Figure A - 14: Quadratic model population projection.

The cubic function was estimated as:

$$\text{Population}_t = 48{,}663 + 2{,}049t + 83.10t^2 - .1708t^3 - 65.625$$
$$R^2 = 0.9992 \text{ Root MSE} = 3{,}377.9$$

Both of these function provide very good fits to the historic data as can be seen by R^2 and the Root Mean Squared Error (MSE) values being low. The cubic function provides a marginally better fit having the lowest MSE.

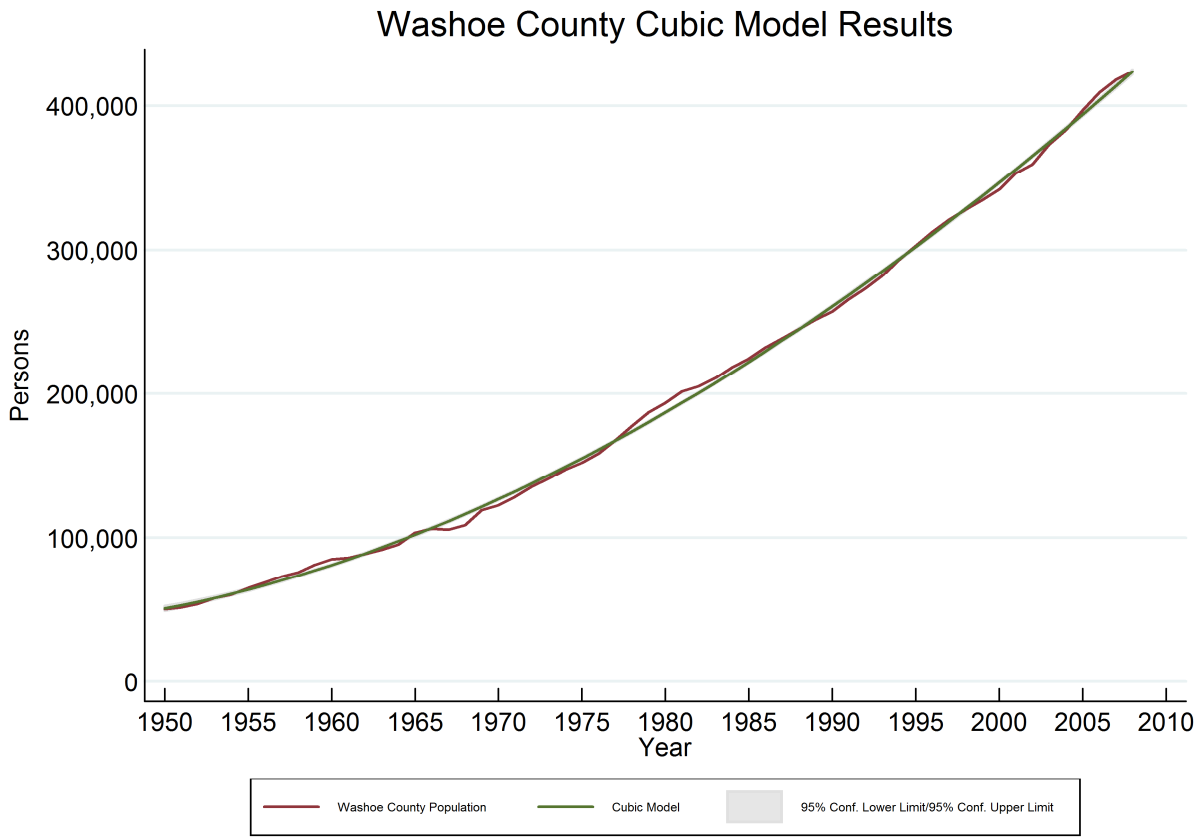

Figure A - 15: Washoe County cubic model results.

Figure A - 15 and Figure A - 16 both show the cubic model results and projects. The fit is about the same as the quadratic model, but with a slower rate of growth.

However, both of these functions suffer from the same issues as the exponential methods. The projections tends to work well in the short-run, but shows population growing at an increasing rate that implies no future limits on growth and growth will continue to increase at an increasing rate. The cubed term in the model has the effect of slowing down the rate of growth resulting in a model that grows slower than the quadratic but still to fast for current economic conditions.

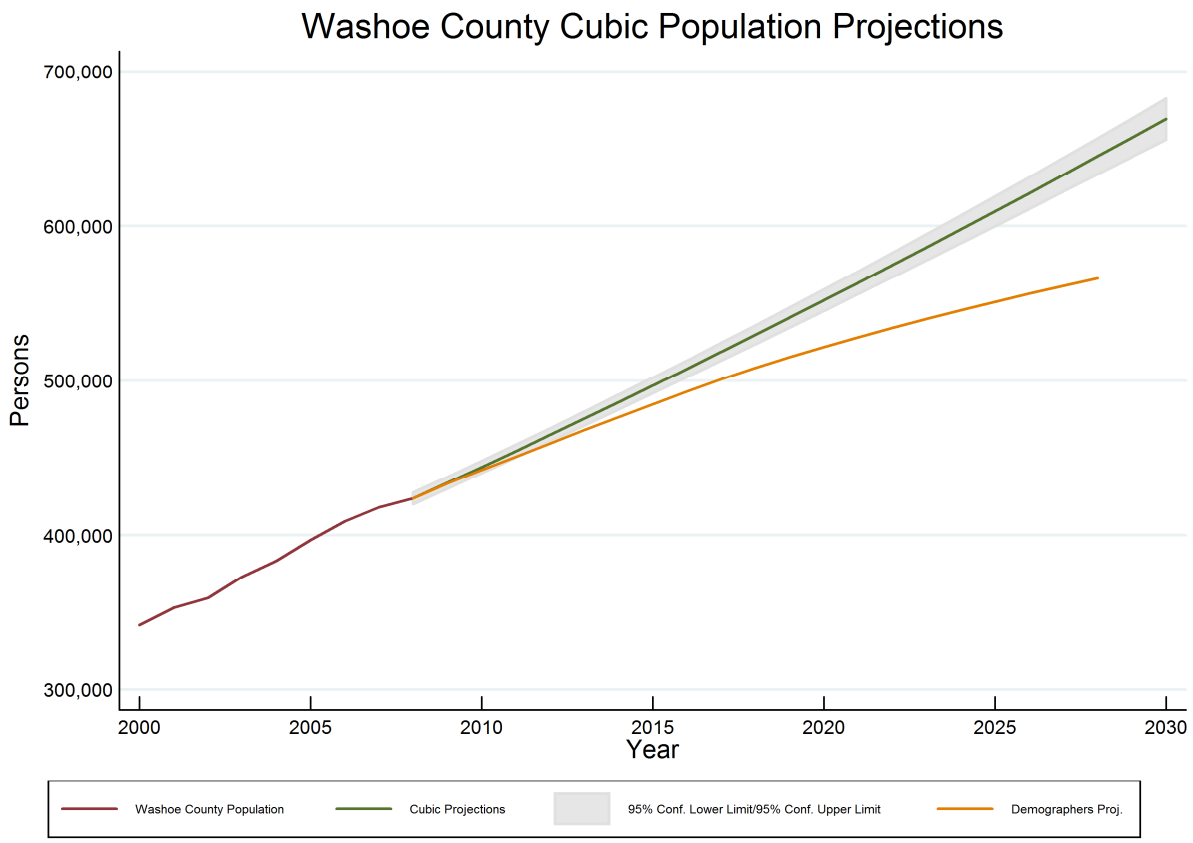

Figure A - 16: Cubic model population projection.

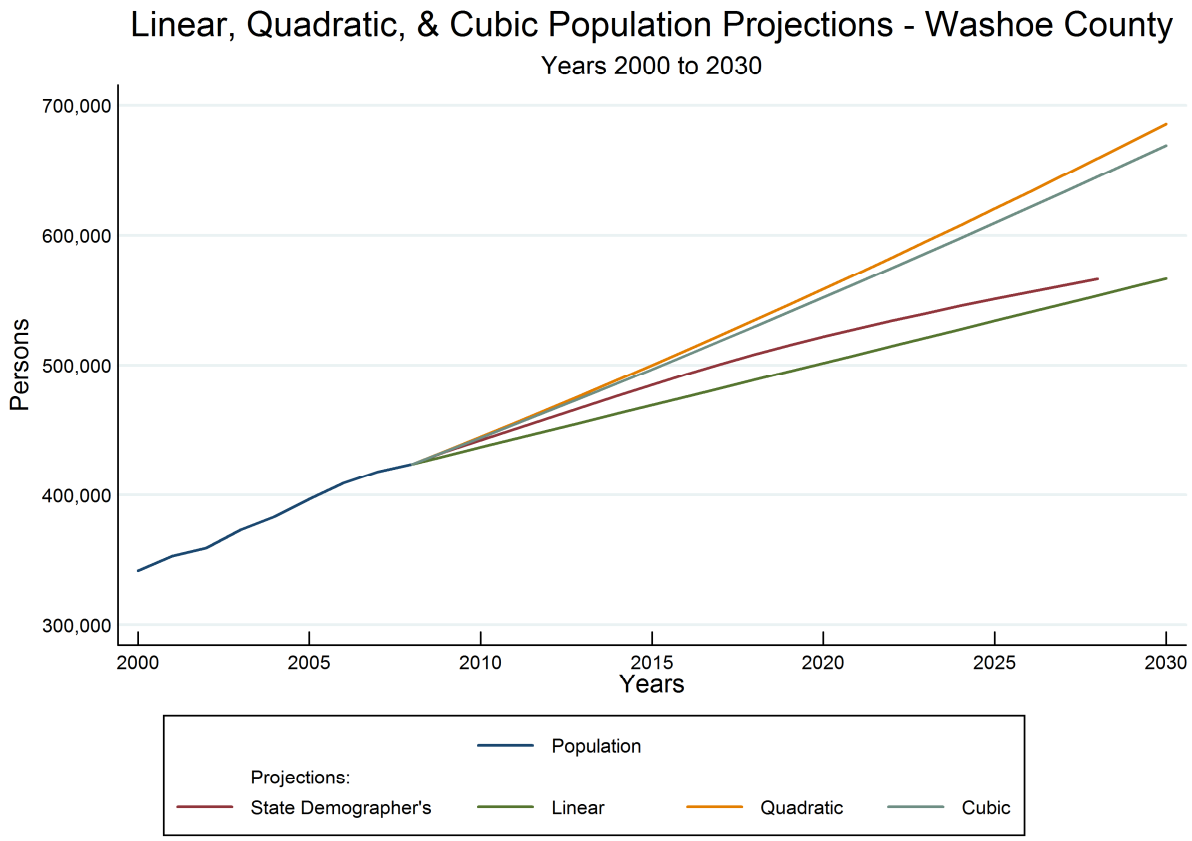

Figure A - 17: Compare linear, quadratic, and cubic population projection models.

Figure A - 17 shows a the results of the three models the polynomial models fit the historic data best, however, as the applied linear projection might be the best of these three models.

When comparing the three projections with the Demographer's projection. The quadratic and cubic project growth that is not economically consistent with current conditions. The linear model projects growth that is reasonable given current conditions. The Demographer's projection based on the REMI economic is a good model that a bias upwards given the limited economic data included since 2001. However, it would reasonable to adopt the linear trend model at this time.

Logistic Curve Fitting

All of the extrapolation methods examined so far are not constrained by any limits on growth. In the above methods, population growth (or decline) can go on forever. In many cases, this will not be a reasonable assumption. In particular, the non-linear models can lead to very high population projections if the projection is used for too long of a planning horizon.

The logistic curve, one of the best-known growth curves in demography, solves this problem by including an explicit ceiling on population. It is a symmetric sigmoid shape (S-shape) curve that has an initial period of slow growth, followed by increasing growth rate, followed by a declining growth rates that eventually approach zero as population size levels off at it upper limit. The idea of limits on growth is intuitively plausible and is consistent with Malthusian theories of

population growth, geographic impediments such as public lands and unbuildable terrain, growth constraints created by water resources and government policies, and filling up of empty residential sites.

The logistic curve was a popular projection method in the early decades of the twentieth century. While its usefulness for projections have been questions, studies have shown that logistic curves often provide reasonably accurate population forecasts. There are other curves that contain asymptotic ceilings on population size include modified exponential and Gompertz models.

In Smith 2000 on pg 171, provides the descriptions of logistic curve fitting. Keyfitz(1968) formula for a three-parameter logistic curve is provided as:

$$Y = \alpha \Big/ \left(1 + \beta_1 e^{-\beta_2 X}\right)$$

where Y is population, X is time, α is the upper asymptote or population ceiling, β_1 and β_2 are parameters that define the shape of the logistic curve. Stata is able to estimate this non-linear function.

The Keyfitz (1968) model is estimated as:

```
Nonlinear regression                                  Number of obs =        59
                                                      R-squared     =    0.9997
                                                      Adj R-squared =    0.9997
                                                      Root MSE      =  3938.771
                                                      Res. dev.     =  1141.233

------------------------------------------------------------------------------
             |             Robust HC2
      washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /a |   731313.3   27120.04    26.97   0.000     676985.4    785641.3
          /b |   13.57627   .4349354    31.21   0.000     12.70499    14.44755
          /c |   .0492867   .0007863    62.68   0.000     .0477115    .0508619
------------------------------------------------------------------------------
```

The population ceiling is estimated as 731,313 persons, β_1 and β_2 are curve shape parameters. This model results in a $R^2 = 0.9997$, Root MSE = 3938.771, this model is the best fit to the historic population data. All parameters are statistically significant. The population ceiling has a 95% confidence interval of 676,985 to 785,641 persons. This implies that in the long-run the population of Washoe County can be expected to mature to some stable level between 676,985 and 785,641. Therefore to estimate an approximate 95% confidence population range the model is re-estimated holding α equal to the 95% interval. The results are display below:

```
Nonlinear regression                                  Number of obs =        59
Lower population ceiling                              R-squared     =    0.9997
                                                      Adj R-squared =    0.9997
                                                      Root MSE      =  4111.782
                                                      Res. dev.     =   1147.35

------------------------------------------------------------------------------
             |             Robust HC2
      washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   12.93262   .1609521    80.35   0.000     12.61031    13.25492
          /c |   .0513267   .0003517   145.94   0.000     .0506224     .052031
------------------------------------------------------------------------------
```

```
Nonlinear regression                                  Number of obs =        59
Upper Population Ceiling                              R-squared     =    0.9997
                                                      Adj R-squared =    0.9997
                                                      Root MSE      =  4039.966
                                                      Res. dev.     =  1145.271

------------------------------------------------------------------------------
             |             Robust HC2
      washoe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          /b |   14.26106   .1633092    87.33   0.000     13.93404    14.58808
          /c |   .0476456   .0002577   184.92   0.000     .0471297    .0481616
------------------------------------------------------------------------------
```

The logistic curve to be used for the Washoe County population is defined as:

$$\text{Population}_t = 676{,}985/(1 + 12.93262 * e^{-0.0513267 * t})$$

Where t is time in years starting at t = 1 for 1950.

A likelihood-ratio test was done to test if model 2 is nested in model 1 and if model 3 is nested in model 1. The models were found to be nested and the restrictions on population ceiling are statistically within the unrestricted population model.

The graph shows the logistic curves compared with the Demographer's projection. Given the current economic conditions one can expect the population to trend closer to the lower bounds of the Logistic curves.

`Figure 1`, `Figure 2`, `Figure 3`, and `Figure 4` in the memo above show the results of the logistic curve fitting. The logistic curve is best fit to the data and provides the most reasonable population projection given current data and staff resources.

Other statistical models were tested such as autoregressive and vector autoregressive model. However, the results at this time suggest the a considerable amount of staff time and resources would be required to fully develop this type of model. The initial result did not suggest that these model would provide equal results. Perhaps the econometric model effort could be reconsidered at a future time when additional data can be developed.

Appendix B: Source Data

Table 1: Historic and projected populations, 1950 to 2100.

Time	Year	Population	Demographer	Model 2	Model 1	Model 3
1	1950	50,484		58,421	56,333	54,731
2	1951	51,600		60,893	58,787	57,170
3	1952	54,000		63,474	61,346	59,710
4	1953	58,100		66,168	64,013	62,354
5	1954	60,500		68,978	66,793	65,108
6	1955	65,200		71,910	69,689	67,973
7	1956	68,900		74,966	72,703	70,954
8	1957	73,000		78,149	75,841	74,054
9	1958	76,000		81,465	79,106	77,276
10	1959	81,300		84,917	82,500	80,625
11	1960	84,988		88,508	86,029	84,103
12	1961	85,969		92,241	89,695	87,714
13	1962	88,648		96,122	93,502	91,461
14	1963	91,705		100,152	97,453	95,349
15	1964	95,289		104,335	101,552	99,380
16	1965	103,420		108,674	105,802	103,557
17	1966	106,356		113,172	110,205	107,884
18	1967	105,541		117,831	114,764	112,364
19	1968	108,776		122,655	119,483	116,999
20	1969	119,192		127,645	124,364	121,792
21	1970	122,574		132,803	129,409	126,746
22	1971	128,600		138,130	134,619	131,863
23	1972	135,400		143,627	139,997	137,145
24	1973	141,000		149,296	145,544	142,595
25	1974	147,400		155,136	151,261	148,212
26	1975	152,200		161,148	157,149	154,000
27	1976	158,700		167,331	163,207	159,958
28	1977	167,800		173,683	169,436	166,088
29	1978	177,600		180,204	175,836	172,389
30	1979	187,200		186,890	182,404	178,861
31	1980	193,623		193,740	189,141	185,505
32	1981	201,680		200,749	196,043	192,318
33	1982	205,130		207,915	203,108	199,300
34	1983	210,990		215,232	210,333	206,448
35	1984	218,320		222,696	217,715	213,761
36	1985	224,580		230,300	225,250	221,235
37	1986	232,270		238,039	232,932	228,867
38	1987	238,360		245,905	240,757	236,653
39	1988	244,890		253,892	248,719	244,589
40	1989	251,580		261,991	256,812	252,669
41	1990	257,120		270,194	265,028	260,889
42	1991	265,762		278,491	273,361	269,243
43	1992	273,178		286,874	281,803	277,724
44	1993	282,214		295,332	290,345	286,324
45	1994	293,141		303,856	298,978	295,038
46	1995	302,748		312,434	307,694	303,856
47	1996	312,366		321,055	316,483	312,772
48	1997	320,828		329,710	325,334	321,775

49	1998	327,899		338,385	334,239	330,857
50	1999	334,601		347,071	343,185	340,008
51	2000	341,935		355,755	352,164	349,219
52	2001	353,271		364,426	361,163	358,481
53	2002	359,423		373,073	370,173	367,782
54	2003	373,233		381,685	379,182	377,112
55	2004	383,453		390,250	388,179	386,461
56	2005	396,844		398,757	397,153	395,818
57	2006	409,085		407,197	406,094	405,173
58	2007	418,061	414,928	415,559	414,991	414,515
59	2008	423,833	423,833	423,833	423,833	423,833
60	2009		433,643	432,010	432,611	433,117
61	2010		442,196	440,081	441,314	442,358
62	2011		450,742	448,038	449,934	451,544
63	2012		459,381	455,872	458,461	460,665
64	2013		467,999	463,577	466,886	469,713
65	2014		476,448	471,146	475,201	478,678
66	2015		484,803	478,572	483,398	487,551
67	2016		492,986	485,851	491,471	496,324
68	2017		500,807	492,977	499,412	504,988
69	2018		508,233	499,946	507,215	513,536
70	2019		515,218	506,754	514,874	521,961
71	2020		521,811	513,398	522,385	530,256
72	2021		528,071	519,876	529,743	538,415
73	2022		534,137	526,185	536,943	546,431
74	2023		539,954	532,324	543,983	554,301
75	2024		545,576	538,291	550,859	562,019
76	2025		551,001	544,088	557,569	569,581
77	2026		556,240	549,713	564,111	576,983
78	2027		561,315	555,166	570,484	584,223
79	2028		566,238	560,450	576,687	591,297
80	2029			565,564	582,718	598,204
81	2030			570,511	588,579	604,942
82	2031			575,293	594,269	611,509
83	2032			579,911	599,789	617,905
84	2033			584,368	605,141	624,130
85	2034			588,667	610,325	630,183
86	2035			592,810	615,344	636,065
87	2036			596,801	620,199	641,777
88	2037			600,644	624,893	647,319
89	2038			604,340	629,428	652,694
90	2039			607,895	633,807	657,902
91	2040			611,312	638,032	662,946
92	2041			614,593	642,108	667,828
93	2042			617,744	646,036	672,551
94	2043			620,767	649,820	677,116
95	2044			623,667	653,465	681,527
96	2045			626,448	656,972	685,787
97	2046			629,112	660,346	689,899
98	2047			631,665	663,591	693,865
99	2048			634,110	666,709	697,690
100	2049			636,450	669,705	701,377

101	2050	638,689	672,582	704,928
102	2051	640,831	675,343	708,348
103	2052	642,879	677,994	711,639
104	2053	644,837	680,536	714,807
105	2054	646,709	682,974	717,853
106	2055	648,497	685,311	720,782
107	2056	650,204	687,551	723,597
108	2057	651,835	689,696	726,301
109	2058	653,392	691,751	728,899
110	2059	654,878	693,719	731,393
111	2060	656,296	695,603	733,787
112	2061	657,649	697,405	736,085
113	2062	658,939	699,130	738,289
114	2063	660,170	700,779	740,402
115	2064	661,343	702,357	742,429
116	2065	662,461	703,865	744,372
117	2066	663,528	705,307	746,234
118	2067	664,544	706,685	748,018
119	2068	665,512	708,002	749,727
120	2069	666,434	709,260	751,363
121	2070	667,312	710,462	752,930
122	2071	668,149	711,610	754,431
123	2072	668,946	712,706	755,867
124	2073	669,705	713,753	757,242
125	2074	670,427	714,752	758,557
126	2075	671,115	715,705	759,815
127	2076	671,770	716,615	761,019
128	2077	672,393	717,484	762,170
129	2078	672,986	718,313	763,271
130	2079	673,550	719,103	764,323
131	2080	674,087	719,858	765,330
132	2081	674,598	720,577	766,292
133	2082	675,084	721,263	767,211
134	2083	675,546	721,918	768,090
135	2084	675,986	722,542	768,930
136	2085	676,405	723,137	769,732
137	2086	676,802	723,704	770,499
138	2087	677,181	724,245	771,231
139	2088	677,541	724,761	771,931
140	2089	677,883	725,253	772,599
141	2090	678,209	725,721	773,237
142	2091	678,518	726,168	773,847
143	2092	678,812	726,593	774,429
144	2093	679,092	726,999	774,984
145	2094	679,358	727,385	775,515
146	2095	679,611	727,754	776,022
147	2096	679,852	728,105	776,505
148	2097	680,080	728,439	776,967
149	2098	680,297	728,758	777,408
150	2099	680,504	729,061	777,829
151	2100	680,700	729,350	778,230

Appendix C: Stata Source Code

```
/*       1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
*********************************************************************************
*  Program Name:   PopProjWashoe_Master.do
*  Created by:     Shawn Stoddard
*  Created on:     7/23/2009
*  Abstract:
*
*
*
*********************************************************************************/
#delimit;
clear;
set more off;
capture log close;

local logpath logs\ ;
local filename PopProjWashoe_Master ;
local logfile = "`logpath'" + "`filename'" ;
clear;
do PopProjWashoe_01;
do PopProjWashoe_02;
do PopProjWashoe_03;

exit;
*********************************************************************************
```

```
/*       1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
*********************************************************************************
*  Program Name:   PopProjWashoe_01.do
*  Created by:     Shawn Stoddard
*  Created on:     7/20/2009
*  Updated on:     7/31/2009
*  Abstract:       Performs a complete graphical analysis of recent projections
*   and start the population models search process.
*********************************************************************************/
#delimit;
pause on;
clear;
set more off;
capture log close;
set linesize 90;
local logpath logs\ ;
local filename PopProjWashoe_01 ;
local logfile = "`logpath'" + "`filename'" ;
log using "`logfile'", replace text;
set memory 500m;
/* Washoe County data filename is */;
local datafile data\\WashoeDataAll_01 ;

/* Start with population from State Demographer's reports **********************/;
use data\populationdata;
keep year nevada washoe;
label var nevada "SD Nv Pop";
label var washoe "SD Washoe Pop";
save `datafile', replace;

/* Get Census population from REIS files */;
use data\reis_ca04_all, clear;
keep fips table year CA04ln_0020;
label var year "Year";
rename CA04ln_0020 ReisPop;
label var ReisPop "Population";

/* Filter the entire data REIS data and keep only the following areas         */;
/* State of Nevada and Washoe County                                          */;
generate keep = 0 /* flag variable for filtering data */;
replace  keep = 1 if fips == "32000" /* Nevada, NV */;
replace  keep = 1 if substr(fips,1,2) == "32" /* Nevada Counties */;
keep if keep == 1 /* delete all records not flagged with 1 */;
drop keep;
compress;

reshape wide ReisPop, i(table year) j(fips) string;
tsset year, yearly;
keep year ReisPop32000 ReisPop32031 /* keep only Nv & Washoe */;
rename ReisPop32000 CenNv;
rename ReisPop32031 CenWas;
label var CenNv "Census Nv Pop";
label var CenWas "Census Washoe Pop";
tempfile rpop;
save `rpop';

use `datafile', clear;
merge year using `rpop';
drop _merge;

/*update 2008 census population from Census web site */;
replace CenNv = 2600167 if year == 2008;
replace CenWas = 410443 if year == 2008;
tsset year, yearly;
save `datafile', replace;

/* Update Nevada Census population from 1950 to 1969 using Census data *********/;
/* this is census data that was collected as part of the 2003 resource plan    */;
merge year using data\CensusPopulation, sort keep(CenNv) update;
drop _merge;
drop if year < 1950;
tsset year, yearly;
save `datafile', replace;
```

```
/* all the possible employment data for whatever years possible ****************/;
/* start with DETR Labor force data - this is the State's source of data  ******/;
/* reported to BLS */;
use data\detrlabforyearly, clear;
keep if fips == "32000";
drop area fips;
rename lf lf_nv;
rename emp emp_nv;
rename uemp uemp_nv;
rename uempr uempr_nv;
label var lf_nv "DETR Nv LF";
label var emp_nv "DETR Nv Emp";
label var uemp_nv "DETR Nv UEmp";
label var uempr_nv "DETR Nv UE Rate";
tempfile emp;
save `emp', replace;

use `datafile', clear;
merge year using `emp', sort;
drop _merge;
save `datafile', replace;

use data\detrlabforyearly, clear;
keep if fips == "32031";
drop area fips;
rename lf lf_was;
rename emp emp_was;
rename uemp uemp_was;
rename uempr uempr_was;
label var lf_was "DETR Was LF";
label var emp_was "DETR Was Emp";
label var uemp_was "DETR Was UEmp";
label var uempr_was "DETR Was UE Rate";
tempfile emp;
save `emp', replace;
use `datafile', clear;
merge year using `emp', sort;
drop _merge;
save `datafile', replace;

/* Get the REIS Total Employment, Wage & Salary, and Proprietors ***************/;
use data\REIS_CA04_all, clear;
keep fips year CA04ln_7010 CA04ln_7020 CA04ln_7040;
keep if fips == "32000" ;
drop fips;
rename CA04ln_7010 bea_temp_nv;
rename CA04ln_7020 bea_wemp_nv;
rename CA04ln_7040 bea_pemp_nv;
label var bea_temp "BEA Total Emp Nv";
label var bea_wemp "BEA Wage Emp Nv";
label var bea_pemp "BEA Proprietors Nv";
save `emp', replace;
use `datafile', clear;
merge year using `emp', sort;
drop _merge;
save `datafile', replace;

use data\REIS_CA04_all, clear;
keep fips year CA04ln_7010 CA04ln_7020 CA04ln_7040;
keep if fips == "32031" ;
drop fips;
rename CA04ln_7010 bea_temp_was;
rename CA04ln_7020 bea_wemp_was;
rename CA04ln_7040 bea_pemp_was;
label var bea_temp_was "BEA Total Emp Was";
label var bea_wemp_was "BEA Wage Emp Was";
label var bea_pemp_was "BEA Proprietors Was";
save `emp', replace;
use `datafile', clear;
merge year using `emp', sort;
drop _merge;
save `datafile', replace;
```

```
/* merge in population project data for graphical analysis ********************/;
merge year using data\PopulationProjectionsAll, sort;
drop sdnvpop sdwapop;
drop _merge;
/* add a variable t for use in time analysis */;
generate t = _n;
order t year;
tsset year, yearly;
save `datafile', replace;

/* Start graphical review and analysis of population data                     */;
/* Create graphs for TPEM Series No. 1 - Appendix A                           */;
/* Figure A-1:  Historic Nevada Population - Census & Demographer *************/;
tsline nevada CenNv if tin(1950,2010),
  title("Census & State Demographer's Population Estimates", color(black) size(medium))
  subtitle("State of Nevada, 1950 to 2008", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(0(250000)3000000, noticks labsize(vsmall) angle(horizontal) format(%10.0fc))
  xlabel(1950(5)2010 , ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(2) size(vsmall) symxsize(6) rowgap(.5)
         span
         order(1 "State Demographer's Estimates"
               2 "U.S. Census Estimates"))
  note("Note:  Increasing gap between Census and State Demographer estimates.",
       color(black) size(vsmall) span);
graph export graphs\TPEMFig_A-01.png, width(3600) replace;
graph export graphs\TPEMFig_A-01.emf, replace;

/* Figure A-2:  Historic Washoe County Popuation - Census & Demographer *********/;
tsline washoe CenWas if tin(1950,2010),
  title("Census & State Demographer's Population Estimates", color(black) size(medium))
  subtitle("Washoe County, 1950 to 2008", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(0(25000)400000, noticks labsize(vsmall) angle(horizontal) format(%10.0fc))
  xlabel(1950(5)2010 , ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(2) size(vsmall) symxsize(6) rowgap(.5)
         span
         order(1 "State Demographer's Estimates"
               2 "U.S. Census Estimates"))
  note("Note:  Increasing gap between Census and State Demographer estimates.",
       color(black) size(vsmall) span);
graph export graphs\TPEMFig_A-02.png, width(3600) replace;
graph export graphs\TPEMFig_A-02.emf, replace;

/* Figure A-3: Compare Consensus 2003 and 2008 Forecast with Population       */;
tsline washoe wcf2003 wcf2008 if tin(1990,2030),
  title("Washoe County Consensus Forecast 2003 and 2008", color(black) size(medium))
  subtitle("Source: Washoe County", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(, noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(1990(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Washoe County Population" 2 "Consensus Forecast 2003"
               3 "Consensus Forecast 2008"));
graph export graphs\TPEMFig_A-03.png, width(3600) replace;
graph export graphs\TPEMFig_A-03.emf, replace;

/* Figure A-4: Nevada population & Demographer's projections ********************/;
tsline nevada sdfnv2006 sdfnv2008 if tin(1990,2030),
  title("State Demographer's Nevada Population and Projections", color(black) size(medium))
  subtitle("1990 to 2030", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(, noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(1990(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
```

```
         span
         order(1 "Nevada Population" 2 "2006 Nevada Projections"
               3 "2008 Projections"));
graph export graphs\TPEMFig_A-04.png, width(3600) replace;
graph export graphs\TPEMFig_A-04.emf, replace;

/* Figure A-5: Washoe County population & Demographer's projections           */;
tsline washoe sdfwa2006 sdfwa2008 if tin(1990,2030),
  title("State Demographer's Washoe County Population and Projections",
        color(black) size(medium))
  subtitle("1990 to 2030", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(,noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(1990(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Washoe County Population" 2 "2006 Washoe Projections"
               3 "2008 Washoe Projections"));
graph export graphs\TPEMFig_A-05.png, width(3600) replace;
graph export graphs\TPEMFig_A-05.emf, replace;

/* Figure A-6: Washoe County population & Demographer's projections           */;
tsline washoe sdfwa2006 sdfwa2008 if tin(2000,2015),
  title("State Demographer's Washoe County Population and Projections",
        color(black) size(medium))
  subtitle("2000 to 2015", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(,noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(2000(5)2015, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Washoe County Population" 2 "2006 Washoe Projections"
               3 "2008 Washoe Projections"));
graph export graphs\TPEMFig_A-06.png, width(3600) replace;
graph export graphs\TPEMFig_A-06.emf, replace;

/* Figure A-7: TMWA's Washoe County Projections                               */;
tsline washoe tmwac2002 tmwac2006 if tin(1990,2030),
  title("TMWA's Washoe County Population and Projection", color(black) size(medium))
  subtitle("1990 to 2030", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(,noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(1990(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Washoe County Population"  2 "TPEM 2002" 3 "TPEM 2006"));
graph export graphs\TPEMFig_A-07.png, width(3600) replace;
graph export graphs\TPEMFig_A-07.emf, replace;

/* Figure A-8: Compare all recent projections                                 */;
tsline washoe wcf2008 sdfwa2008 tmwac2006 if tin(1990,2030),
  title("Compare Population and Projections All Models", color(black) size(medium))
  subtitle("1990 to 2030", color(black) size(small))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(,noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(1990(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(4) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Washoe County Population"  2 "2008 Consensus"
               3 " 2008 SD Projection" 4 "TPEM 2006"));
graph export graphs\TPEMFig_A-08.png, width(3600) replace;
graph export graphs\TPEMFig_A-08.emf, replace;


/* adjust State Demographer 2008 projection to match 2008 population          */;
```

```
/* Figure A-9:  Adjusted SD projections SDFnv2008 to current population ********/;
quietly summarize nevada if year == 2008,detail;
local pop08 = `r(mean)';
quietly summarize sdfnv2008 if year == 2008, detail;
local fe2008 = `r(mean)' -`pop08';
display "Population forecase error for sefnv2008:  `fe2008'";
generate sdfnv2008adj = sdfnv2008 - `fe2008';
label var sdfnv2008adj "2008 Nv SD Adj Proj";
tsline  nevada if tin(2000, 2008)
  || tsline sdfnv2008 sdfnv2008adj if tin(2008,2030),
  title("Nevada Projection Calibrated to 2008", color(black) size(medium))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(, noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(2000(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Nevada Population" 2 "2008 SD Projections"
               3 "2008 SD Adj. Projections"));
graph export graphs\TPEMFig_A-09.png, width(3600) replace;
graph export graphs\TPEMFig_A-09.emf, replace;

/* Adjust Washoe County SDFwa2008 to current population ************************/;
/* Figure A-10: Adjusted SD Projections SDFwa2008 to current population        */;
quietly summarize washoe if year == 2008,detail;
local pop08 = `r(mean)';
quietly summarize sdfwa2008 if year == 2008, detail;
local fe2008 = `r(mean)' -`pop08';
display "Washoe forecase error for sef2008:  `fe2008'";
generate sdfwa2008adj = sdfwa2008 - `fe2008';
label var sdfwa2008adj "2008 Washoe SD Adj Proj.";
tsline  washoe if tin(2000, 2008)
  || tsline sdfwa2008 sdfwa2008adj if tin(2008,2030),
  title("Washoe County Projection Calibrated to 2008", color(black) size(medium))
  graphregion(color(white))
  ytitle("Persons", color(black) size(small))
  xtitle("Year", color(black) size(small))
  ylabel(,noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
  xlabel(2000(5)2030, ticks tposition(inside) labsize(vsmall))
  legend(on lcolor(black) cols(3) size(vsmall) symxsize(6) rowgap(*.5)
         span
         order(1 "Washoe Population" 2 "2008 SD Projections"
               3 "2008 SD Adj. Projections"));
graph export graphs\TPEMFig_A-10.png, width(3600) replace;
graph export graphs\TPEMFig_A-10.emf, replace;

/*****************************************************************************/;
/* Begin a population projection model search                                */;
/*****************************************************************************/;
/* Trend Extrapolation Models                                                */;
/*****************************************************************************/;
/* Linear (LINE) model compute AAAC for washoe county                        */;
/* base row is 11 and launch row is 59  for base year 1960*/;
local brow = 11;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local AAAC = (`pl' - `pb')/`y';
display "LINE Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              AAAC        = `AAAC'";
/* project Washoe AAAC */;
gen wash_aaac_60 = .;
replace wash_aaac_60 = washoe if year == 2008;
replace wash_aaac_60 = wash_aaac_60[_n-1] + `AAAC' if year > 2008;
replace wash_aaac_60 = round(wash_aaac_60,0);
```

```
/* base row is 21 and launch row is 59  for base year 1970*/;
local brow = 21;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local AAAC = (`pl' - `pb')/`y';
display "LINE Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              AAAC        = `AAAC'";
/* project Washoe AAAC */;
gen wash_aaac_70 = .;
replace wash_aaac_70 = washoe if year == 2008;
replace wash_aaac_70 = wash_aaac_70[_n-1] + `AAAC' if year > 2008;
replace wash_aaac_70 = round(wash_aaac_70,0);

/* base row is 31 and launch row is 59  for base year 1980*/;
local brow = 31;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local AAAC = (`pl' - `pb')/`y';
display "LINE Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              AAAC        = `AAAC'";
/* project Washoe AAAC */;
gen wash_aaac_80 = .;
replace wash_aaac_80 = washoe if year == 2008;
replace wash_aaac_80 = wash_aaac_80[_n-1] + `AAAC' if year > 2008;
replace wash_aaac_80 = round(wash_aaac_80,0);

/* base row is 41 and launch row is 59  for base year 1990*/;
local brow = 41;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local AAAC = (`pl' - `pb')/`y';
display "LINE Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              AAAC        = `AAAC'";
/* project Washoe AAAC */;
gen wash_aaac_90 = .;
replace wash_aaac_90 = washoe if year == 2008;
replace wash_aaac_90 = wash_aaac_90[_n-1] + `AAAC' if year > 2008;
replace wash_aaac_90 = round(wash_aaac_90,0);

/* base row is 51 and launch row is 59  for base year 2000*/;
local brow = 51;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
```

```
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local AAAC = (`pl' - `pb')/`y';
display "LINE Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              AAAC        = `AAAC'";
/* project Washoe AAAC */;
gen wash_aaac_00 = .;
replace wash_aaac_00 = washoe if year == 2008;
replace wash_aaac_00 = wash_aaac_00[_n-1] + `AAAC' if year > 2008;
replace wash_aaac_00 = round(wash_aaac_00,0);

/* Geometric Exponential (GEO and EXPO) methods                                */;
/* base row is 11 and launch row is 59  for base year 1960*/;
local brow = 11;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local r = ln(`pl'/`pb')/`y';
display "EXPO Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              r           = `r'";
/* project Washoe population */;
gen wash_expo_60 = .;
replace wash_expo_60 = washoe if year == `lyear';
replace wash_expo_60 = `pl'*exp(`r'*(year-`lyear')) if year > `lyear';
gen wash_expo_all_60 = .;
replace wash_expo_all_60 = washoe if year == `byear';
replace wash_expo_all_60 = washoe[`brow']*exp(`r'*(year-`byear')) if year > `byear';

/* base row is 21 and launch row is 59  for base year 1970*/;
local brow = 21;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local r = ln(`pl'/`pb')/`y';
display "EXPO Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              r           = `r'";
/* project Washoe population */;
gen wash_expo_70 = .;
replace wash_expo_70 = washoe if year == `lyear';
replace wash_expo_70 = `pl'*exp(`r'*(year-`lyear')) if year > `lyear';
gen wash_expo_all_70 = .;
replace wash_expo_all_70 = washoe if year == `byear';
replace wash_expo_all_70 = washoe[`brow']*exp(`r'*(year-`byear')) if year > `byear';

/* base row is 31 and launch row is 59  for base year 1980*/;
local brow = 31;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local r = ln(`pl'/`pb')/`y';
```

```
display "EXPO Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              r           = `r'";
/* project Washoe population */;
gen wash_expo_80 = .;
replace wash_expo_80 = washoe if year == `lyear';
replace wash_expo_80 = `pl'*exp(`r'*(year-`lyear')) if year > `lyear';
gen wash_expo_all_80 = .;
replace wash_expo_all_80 = washoe if year == `byear';
replace wash_expo_all_80 = washoe[`brow']*exp(`r'*(year-`byear')) if year > `byear';

/* base row is 41 and launch row is 59  for base year 1990*/;
local brow = 41;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local r = ln(`pl'/`pb')/`y';
display "EXPO Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              r           = `r'";
/* project Washoe population */;
gen wash_expo_90 = .;
replace wash_expo_90 = washoe if year == `lyear';
replace wash_expo_90 = `pl'*exp(`r'*(year-`lyear')) if year > `lyear';
gen wash_expo_all_90 = .;
replace wash_expo_all_90 = washoe if year == `byear';
replace wash_expo_all_90 = washoe[`brow']*exp(`r'*(year-`byear')) if year > `byear';

/* base row is 51 and launch row is 59  for base year 2000*/;
local brow = 51;
local lrow = 59;
local byear = year[`brow'];
local lyear = year[`lrow'];
count if tin(`byear',`lyear');
local y = `r(N)';
local pl = washoe[`lrow'];
local pb = washoe[`brow'];
local r = ln(`pl'/`pb')/`y';
display "EXPO Model for Washoe County: Base year   = `byear'";
display "                              Launch year = `lyear'";
display "                              Pl          = `pl'";
display "                              Pb          = `pb'";
display "                              y           = `y'";
display "                              r           = `r'";
/* project Washoe population */;
gen wash_expo_00 = .;
replace wash_expo_00 = washoe if year == `lyear';
replace wash_expo_00 = `pl'*exp(`r'*(year-`lyear')) if year > `lyear';
gen wash_expo_all_00 = .;
replace wash_expo_all_00 = washoe if year == `byear';
replace wash_expo_all_00 = washoe[`brow']*exp(`r'*(year-`byear')) if year > `byear';
/* drop all created variables because none of these models are useful         */;
drop wash_exp*;
save `datafile', replace;
graph drop _all;

log close;
exit;
```

```
/*       1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
*********************************************************************************
*  Program Name:   PopProjWashoe_02.do
*  Created by:     Shawn Stoddard
*  Created on:     7/20/2009
*  Abstract:       All the projection attemps so far have provided very good
*   results.  This script is a go back to the drawing board and see if something
*   was missed.
*
*********************************************************************************/
pause on
#delimit;

set more off;
capture log close;
set linesize 90;
local logpath logs\ ;
local filename PopProjWashoe_02 ;
local logfile = "`logpath'" + "`filename'" ;
log using "`logfile'", replace text;
/* Washoe County data filename is */;
local datafile data\\WashoeDataAll_01 ;
use `datafile', clear;
local datafile data\\WashoeDataAll_02 ;
/*******************************************************************************/;
/* Clean up the data a bit by dropping variables that are not required        */;
/*******************************************************************************/;
/* if we need any of these variables we can just undo this action             */;
drop CenNv CenWas sdfnv2006  sdfwa2006  wcf2003 wcf2008 tmwau2002 tmwac2002
     tmwau2006 tmwac2006 tmwau2008;
drop  wash_aaac_60 wash_aaac_70 wash_aaac_80 wash_aaac_90 wash_aaac_00;

/*******************************************************************************/;
/* Complex Trend Extapolation models                                           */;
/*******************************************************************************/;
/* Linear Trend model (OLS)                                                    */;
/*******************************************************************************/;
regress washoe t;
predict wash_ols01;
label var wash_ols01 "Predicted linear values";
predict wash_ols01e, stdp;
label var wash_ols01e "Standard Error of Prediction";
predict wash_ols01f, stdf;
label var wash_ols01f "Standard Error of Forecast";
generate wash_ols01l = wash_ols01 - wash_ols01e;
label var wash_ols01l "95% Conf. Lower Limit";
generate wash_ols01h = wash_ols01 + wash_ols01e;
label var wash_ols01h "95% Conf. Upper Limit";
local calib = washoe[59] - wash_ols01[59];
display "Calib = `calib'";

twoway rarea wash_ols01l wash_ols01h year if tin(1950,2008),
       sort bcolor(gs14) ||
       line washoe year if tin(1950,2008), ||
       line wash_ols01 year if tin(1950,2008),
       title("Washoe County Linear Model Results", color(black) size(medium))
       graphregion(color(white))
       ytitle("Persons", color(black) size(small))
       xtitle("Year", color(black) size(small))
       ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
       xlabel(1950(5)2010, ticks tposition(inside) labsize(small))
       legend(on lcolor(black) col(3) size(tiny) symxsize(6) rowgap(*.5)
       order(2 "Washoe County Population" 3 "Linear Model"  1));

graph export graphs\TPEMFig_A-11.png, width(3600) replace;  /* this line locks up STATA */
graph export graphs\TPEMFig_A-11.emf, replace; /* this line works */

/* Calibrated Projections                                                     */;
replace  wash_ols01  = wash_ols01 + `calib' if tin(2008,2030);
replace  wash_ols01l = wash_ols01 - wash_ols01f if tin(2008,2030);
replace  wash_ols01h = wash_ols01 + wash_ols01f if tin(2008,2030);
```

```
twoway rarea wash_ols01l wash_ols01h year if tin(2008,2030),
       sort bcolor(gs14) ||
       line washoe year if tin(2000,2008), ||
       line wash_ols01 sdfwa2008adj year if tin(2008,2030),
       title("Washoe County Linear Population Projection", color(black) size(medium))
       graphregion(color(white))
       ytitle("Persons", color(black) size(small))
       xtitle("Year", color(black) size(small))
       ylabel(, noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
       xlabel(2000(5)2030, ticks tposition(inside) labsize(vsmall))
       legend(on lcolor(black) col(4) size(tiny) symxsize(6) rowgap(*.5)
              span
              order(2 "Washoe County Population" 3 "Linear Model Projection"
                    4 "Demographers Proj." 1));
graph export graphs\TPEMFig_A-12.png, width(3600) replace;
graph export graphs\TPEMFig_A-12.emf, replace;

/*****************************************************************************/;
/* estimate Polynomial curve of degree 2 and degree 3                        */;
/*****************************************************************************/;
/* generate time squared & time cubed                                        */;
gen t2 = t^2;
gen t3 = t^3;
/* estimate quadratic function*/;
regress washoe t t2;
predict wash_pcf01;
label var wash_pcf01 "Quadratic Function Model";
predict wash_pcf01e, stdp;
label var wash_pcf01e "Standard Error of Prediction";
predict wash_pcf01f, stdf;
label var wash_pcf01f "Standard Error of Forecast";
generate  wash_pcf01l = wash_pcf01 - wash_pcf01e;
label var wash_pcf01l "95% Conf. Lower Limit";
generate  wash_pcf01h = wash_pcf01 + wash_pcf01e;
label var wash_pcf01h "95% Conf. Upper Limit";
local calib = washoe[59] - wash_pcf01[59];
display "Calib = `calib'";

twoway rarea wash_pcf01l wash_pcf01h year if tin(1950,2008),
       sort bcolor(gs14) ||
       line washoe year if tin(1950,2008), ||
       line wash_pcf01 year if tin(1950,2008),
       title("Washoe County Quadratic Model Results", color(black) size(medium))
       graphregion(color(white))
       ytitle("Persons", color(black) size(small))
       xtitle("Year", color(black) size(small))
       ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
       xlabel(1950(5)2010, ticks tposition(inside) labsize(small))
       legend(on lcolor(black) col(3) size(tiny) symxsize(6) rowgap(*.5)
       order(2 "Washoe County Population" 3 "Quadratic Model"  1));
graph export graphs\TPEMFig_A-13.png, width(3600) replace;
graph export graphs\TPEMFig_A-13.emf, replace;

/* very good fit to the historic data */
replace  wash_pcf01  = wash_pcf01 + `calib'     if tin(2008,2030);
replace  wash_pcf01l = wash_pcf01 - wash_pcf01f if tin(2008,2030);
replace  wash_pcf01h = wash_pcf01 + wash_pcf01f if tin(2008,2030);

twoway rarea wash_pcf01l wash_pcf01h year if tin(2008,2030),
       sort bcolor(gs14) ||
       line washoe year if tin(2000,2008), ||
       line wash_pcf01 sdfwa2008adj year if tin(2008,2030),
       title("Washoe County Quadratic Population Projections", color(black) size(medium))
       graphregion(color(white))
       ytitle("Persons", color(black) size(small))
       xtitle("Year", color(black) size(small))
       ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
       xlabel(2000(5)2030, ticks tposition(inside) labsize(small))
       legend(on lcolor(black) col(4) size(tiny) symxsize(6) rowgap(*.5)
              span
              order(2 "Washoe County Population" 3 "Quadratic Projections"
                    4 "Demographers Proj." 1));
graph export graphs\TPEMFig_A-14.png, width(3600) replace;
graph export graphs\TPEMFig_A-14.emf, replace;
```

```
/* estimate cubic model                                                    */;
regress washoe t t2 t3;
predict wash_pcf02;
label var wash_pcf02 "Cubic Function Model";
predict wash_pcf02e, stdp;
label var wash_pcf02e "Standard Error of Prediction";
predict wash_pcf02f, stdf;
label var wash_pcf02f "Standard Error of Forecast";
generate  wash_pcf02l = wash_pcf02 - wash_pcf02e;
label var wash_pcf02l "95% Conf. Lower Limit";
generate  wash_pcf02h = wash_pcf02 + wash_pcf02e;
label var wash_pcf02h "95% Conf. Upper Limit";
local calib = washoe[59] - wash_pcf02[59];
display "Calib = `calib'";

twoway rarea wash_pcf02l wash_pcf02h year if tin(1950,2008),
       sort bcolor(gs14) ||
       line washoe year if tin(1950,2008), ||
       line wash_pcf02 year if tin(1950,2008),
       title("Washoe County Cubic Model Results", color(black) size(medium))
       graphregion(color(white))
       ytitle("Persons", color(black) size(small))
       xtitle("Year", color(black) size(small))
       ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
       xlabel(1950(5)2010, ticks tposition(inside) labsize(small))
       legend(on lcolor(black) col(3) size(tiny) symxsize(6) rowgap(*.5)
       order(2 "Washoe County Population" 3 "Cubic Model"  1));
graph export graphs\TPEMFig_A-15.png, width(3600) replace;
graph export graphs\TPEMFig_A-15.emf, replace;

/* very good fit to the historic data */
replace  wash_pcf02  = wash_pcf02 + `calib'     if tin(2008,2030);
replace  wash_pcf02l = wash_pcf02 - wash_pcf02f if tin(2008,2030);
replace  wash_pcf02h = wash_pcf02 + wash_pcf02f if tin(2008,2030);

twoway rarea wash_pcf02l wash_pcf02h year if tin(2008,2030),
       sort bcolor(gs14) ||
       line washoe year if tin(2000,2008), ||
       line wash_pcf02 sdfwa2008adj year if tin(2008,2030),
       title("Washoe County Cubic Population Projections", color(black) size(medium))
       graphregion(color(white))
       ytitle("Persons", color(black) size(small))
       xtitle("Year", color(black) size(small))
       ylabel(, noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
       xlabel(2000(5)2030, ticks tposition(inside) labsize(vsmall))
       legend(on lcolor(black) col(4) size(tiny) symxsize(6) rowgap(*.5)
              span
              order(2 "Washoe County Population" 3 "Cubic Projections"
                    1 4 "Demographers Proj." ));
graph export graphs\TPEMFig_A-16.png, width(3600) replace;
graph export graphs\TPEMFig_A-16.emf, replace;

/* Graph the three models with demographer's projection                    */;
   tsline washoe if tin(2000,2008)
|| tsline sdfwa2008adj if tin(2008,2030)
|| tsline wash_ols01 wash_pcf01 wash_pcf02 if tin(2008,2030) ,
   title("Linear, Quadratic, & Cubic Population Projections - Washoe County",
         color(black) size(medium))
   subtitle("Years 2000 to 2030", color(black) size(small))
   graphregion(color(white))
   ytitle("Persons", color(black) size(small))
   xtitle("Years", color(black) size(small))
   ylabel(, noticks labsize(vsmall) angle(horizontal) format(%12.0fc))
   xlabel(2000(5)2030, ticks tposition(inside) labsize(vsmall))
   legend(on lcolor(black) col(4) size(vsmall) symxsize(6) rowgap(*.5)
          span
          order(- " " 1 "Population"  - " " - " "
                - "Projections:" - " " - " " - " "
                2 "State Demographer's" 3 "Linear" 4 "Quadratic" 5 "Cubic"));
graph export graphs\TPEMFig_A-17.png, width(3600) replace;
graph export graphs\TPEMFig_A-17.emf, replace;

save `datafile', replace;
```

```
log close;
exit;
```

```
/*       1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
********************************************************************************
*  Program Name:   PopProjWashoe_03.do
*  Created by:     Shawn Stoddard
*  Created on:     7/27/2009
*  Abstract:       Estimate an Logistic Curve
*
*
*
********************************************************************************/
#delimit;
clear;
set more off;
capture log close;
set linesize 90;
local logpath logs\ ;
local filename PopProjWashoe_03 ;
local logfile = "`logpath'" + "`filename'" ;
log using "`logfile'", replace text;
/* Washoe County data filename is */;
local datafile data\\WashoeDataAll_02 ;
use `datafile', clear;
local datafile data\\WashoeDataAll_03 ;
/*******************************************************************************/;
/* Complex Trend Extapolation models                                           */;
/*******************************************************************************/;
/*******************************************************************************/;
/* Logistic Curve Fitting                                                      */;
/*******************************************************************************/;
/* project to the year 2050                                                    */;
local newN = _N + 70;
set obs `newN';
replace t = _n if t == .;
replace year = t + 1949 if year == .;

nl (washoe = {a} / (1 + {b} * exp( -1* {c} * t) ) ),
    variables(washoe t) initial(a 400000 b 5.0 c .5) vce(hc2);
estimates store m1;

predict wash_lcf01;
label var wash_lcf01 "Keyfitz Logistic Model Estimated Ceiling";
local calib = washoe[59] - wash_lcf01[59];
display "Calib = `calib'";
generate wash_lcf01c = wash_lcf01 + `calib';
/* Compute the upper and lower population values based on the 95% conf.       */;
/* interval of b0 - the population ceiling                                     */;
/* change b0 to lower limit of b0 and re-estimate model (676985)               */;
/* change b0 to upper values of b0 and re-estimate model(785641)               */;

/* estimate lower curve                                                        */;
nl (washoe = 676985 / (1 + {b} * exp( -1* {c} * t) ) ),
    variables(washoe t) initial(b 5.0 c .5) vce(hc2);
estimates store m2;

predict wash_lcf02;
label var wash_lcf02 "Keyfitz Logistic Model b0 = 676,985";
local calib = washoe[59] - wash_lcf02[59];
display "Calib = `calib'";
generate wash_lcf02c = wash_lcf02 + `calib';
/* estimate upper curve                                                        */;
nl (washoe = 785641 / (1 + {b} * exp( -1* {c} * t) ) ),
    variables(washoe t) initial(b 5.0 c .5) vce(hc2);
estimates store m3;

predict wash_lcf03;
label var wash_lcf03 "Keyfitz Logistic Model b0 = 785,641";
local calib = washoe[59] - wash_lcf03[59];
display "Calib = `calib'";
generate wash_lcf03c = wash_lcf03 + `calib';


/* Create Graphs for the Population Memo                                       */;
```

```
/* Figure 1: logistic curve and population                                    */;
/* models with historic populaiton                                            */;
   tsline washoe wash_lcf01 wash_lcf02 wash_lcf03 if tin(1950,2008),
   title("Washoe County Population", color(black) size(medium))
   subtitle("Logistic Curve Model", color(black) size(medium))
   graphregion(color(white))
   ytitle("Persons", color(black) size(small))
   xtitle("Years", color(black) size(small))
   ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
   xlabel(1950(5)2010, ticks tposition(inside) labsize(small))
   legend(on lcolor(black) col(3) size(small) symxsize(3) rowgap(*.5)
          span
          order(1 "Annual Population 1950 to 2008"  - " " - " "
                3 "Model 2:" 2 "Model 1:" 4 "Model 3:"
                - "Pop. Ceiling = 676,985"
                - "Pop. Ceiling = 731,313"
                - "Pop. Ceiling = 785,641" ));

graph export graphs\TPEMFig_01.png, width(3600) replace;
graph export graphs\TPEMFig_01.emf, replace;

/* Figure 2:  Population projection models 2008 to 2030             */;
/* Graph 2030 projections                                           */;
   tsline washoe if tin(2000, 2008), lwidth(medium)
|| tsline sdfwa2008adj if tin(2008,2030)
|| tsline wash_lcf02c wash_lcf01c wash_lcf03c if tin(2008,2030),
   title("Population Model Comparisions", color(black) size(medium))
   subtitle("Years 2008 to 2030", color(black) size(small))
   graphregion(color(white))
   ytitle("Persons", color(black) size(small))
   xtitle("Years", color(black) size(small))
   ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
   xlabel(2000(5)2030, ticks tposition(inside) labsize(small))
   legend(on lcolor(black) col(3) size(small) symxsize(3) rowgap(*.5)
          span
          order(1 "Annual Population"  2 "Demographer's Projection" - " "
                3 "Model 2:" 4 "Model 1:" 5 "Model 3:"
                - "Pop. Ceiling = 676,985"
                - "Pop. Ceiling = 731,313"
                - "Pop. Ceiling = 785,641" ));
graph export graphs\TPEMFig_02.png, width(3600) replace;
graph export graphs\TPEMFig_02.emf, replace;

/* Findings:  Population projection model 2010 to 2030             */;

   tsline washoe if tin(2000, 2008), lwidth(medium)
|| tsline wash_lcf02c if tin(2008,2030),
   title("Population Projection 2009 to 2030", color(black) size(medium))
   graphregion(color(white))
   ytitle("Persons", color(black) size(small))
   xtitle("Years", color(black) size(small))
   ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
   xlabel(2000(5)2030, ticks tposition(inside) labsize(small))
   legend(on lcolor(black) col(1) size(small) symxsize(3) rowgap(*.5)
          span
          order(1 "Annual Population"
                2 "Model 2:  Pop. Ceiling = 676,985" ));
/* Figure 3: Compare models  1 to 3 through year 2100                         */;
/* Graph 2100 projections                                           */;
   tsline washoe if tin(2000, 2008), lwidth(medium)
|| tsline sdfwa2008adj if tin(2008,2030)
|| tsline wash_lcf02c wash_lcf01c wash_lcf03c if tin(2008,2100),
   title("Long-run Population Models for Washoe County", color(black) size(medium))
   subtitle("Years 2008 to 2100", color(black) size(small))
   graphregion(color(white))
   ytitle("Persons", color(black) size(small))
   xtitle("Years", color(black) size(small))
   ylabel(, noticks labsize(small) angle(horizontal) format(%12.0fc))
   xlabel(2000(10)2100, ticks tposition(inside) labsize(small))
   legend(on lcolor(black) col(3) size(small) symxsize(3) rowgap(*.5)
          span
          order(1 "Annual Population"  2 "Demographer's Projection" - " "
                3 "Model 2:" 4 "Model 1:" 5 "Model 3:"
                - "Pop. Ceiling = 676,985"
```

```
               - "Pop. Ceiling = 731,313"
               - "Pop. Ceiling = 785,641" ));

graph export graphs\TPEMFig_03.png, width(3600) replace;
graph export graphs\TPEMFig_03.emf, replace;

/* Figure 4: graph population & model 2 1950 to 2100                          */;
/* Graph 2100 projections                                                  */;
   tsline washoe if tin(1950, 2008), lwidth(medium)
|| tsline sdfwa2008adj if tin(2008,2030)
|| tsline wash_lcf02c if tin(2008,2100),
   title("Population and Projection 1950 to 2100", color(black) size(medium))
   subtitle("State Demographer and Model 2 Projections", color(black) size(small))
   graphregion(color(white))
   xline(2008, lcolor(red)) xline(2030, lcolor(red))
   text(380000 2009 "Projected" "Population" "Area", place(e) size(small))
   ytitle("Persons", color(black) size(small))
   xtitle("Years", color(black) size(small))
   ylabel(0(100000)800000, noticks labsize(small) angle(horizontal) format(%12.0fc))
   xlabel(1950(10)2100, ticks tposition(inside) labsize(small))
   legend(on lcolor(black) col(2) size(small) symxsize(3) rowgap(*.5)
          span
          order(1 "Annual Population"  2 "Demographer's Projection"
                3 "Model 2:" - " "
                - "Pop. Ceiling = 676,985"
                ));
graph export graphs\TPEMFig_04.png, width(3600) replace;
graph export graphs\TPEMFig_04.emf, replace;
exit;


/* likelihood ratio test of models */;

/* estimate lower curve                                                       */;

lrtest m1 m2, stats dir;
lrtest m1 m3, stats dir;


/* send the results to an Excel file for creating a report table               */;
outsheet t year washoe sdfwa2008adj wash_lcf02c wash_lcf01c wash_lcf03c
         using data\PopProjLCFmodel.csv, comma replace;
tsset year, yearly;
save `datafile', replace;
exit;
*************************************************************************
Stata stops reading the file at the exit statement so
you can type whatever you want down here in the form of
comments.
```