Population Growth of Women in STEM

MATH 1360: Mathematical Modeling

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December 4^{th}, 2017

1 Introduction

Science consists everyone's everyday lives. Technology is expanding more than ever. Engineering brings innovation to different aspect of today's world. Mathematics is used in almost every area of study. The acronym STEM – fairly comprehensible in nature – is referring to Science, Technology, Engineering, and Mathematics. In the 21st Century, where scientific and technological innovation is ever more increasing, following the trend and developing capabilities in STEM became inevitable. STEM education is now a focus of students and parents, STEM activities are encouraged by many institutions, and STEM jobs are genuinely welcomed by industries. While the number of STEM occupations is growing at the rate of 17 percent, non-STEM occupations are increasing at the rate of 9.8 percent.[3] Plus, occupations related to STEM are comparatively higher-paying jobs, and STEM degree holders have a higher income even in non-STEM careers. Thus, naturally, there is an increase in STEM graduate every year. However, although women now dominate men in attainment of college degrees and makeup nearly half of the U.S. workforce, women are still vastly underrepresented in STEM occupations: women hold less than 25 percent of STEM jobs[1]. For how long will such gender disparity persist?

Assuming there is a strong correlation between education attainment, specifically bachelor's degree, and fields of occupation, this project attempts to forecast the future of the women's place in STEM and whether they will be able to surpass men in STEM fields by understanding how women's share in obtaining bachelor's degrees in STEM major fields changes over time.

2 Classification of STEM

There is no standard definition for a STEM degree. In this report, we have followed Economics and Statistics Administration's (ESA) definition of a STEM occupation[1]. To be consistent with the definition, STEM majors include fields that span computer science and mathematics, engineering, and life and physical sciences but exclude business, healthcare, and social science majors.[1]

3 Logistic Model for Population of Women in STEM

Using National Science Foundation (NSF)'s data that record the number of bachelor's degrees awarded to women, by major field group, from 1966 to 2014[3], we have attempted to fit various analysis of population models and found that the logistic equation had the best fit.

<u>Variables</u>

- $N(t)$:= number of STEM bachelor's degrees awarded to women
- K := carrying capacity
- r := growth rate (exponential)

<u>Assumptions</u>

- Population has fixed maximum carrying capacity, K
- At "low" population, the growth rate is r
- Exponential growth is self-limiting

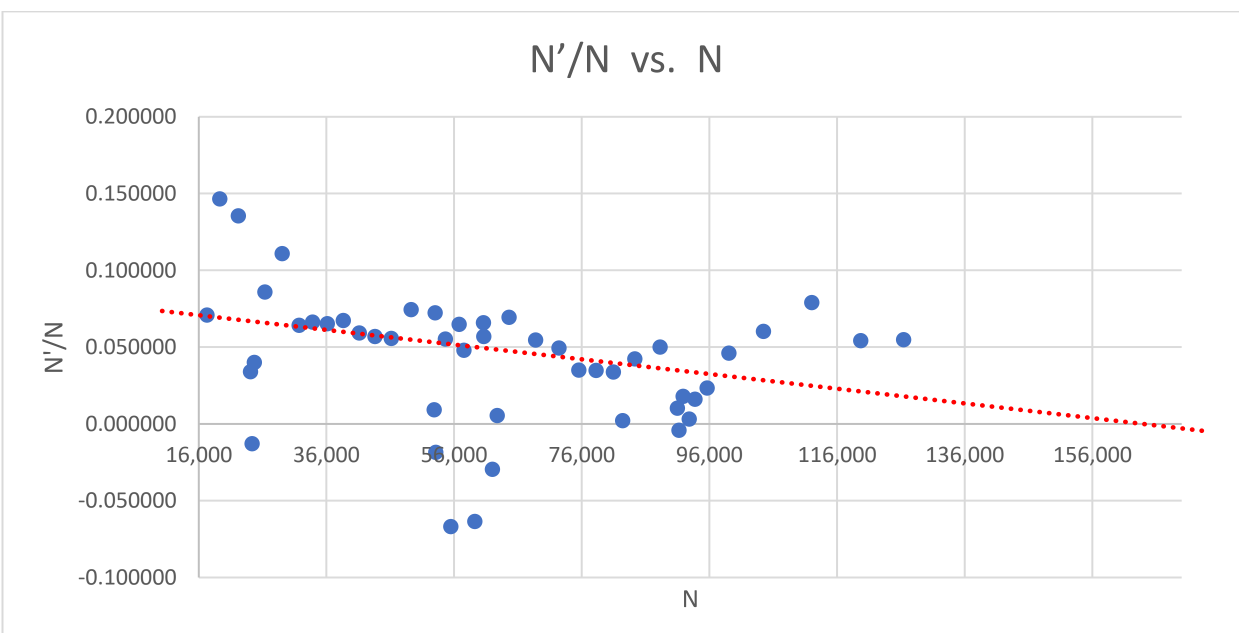
N(t) represents the number of STEM bachelor's degrees award to women, where t represents the year those degrees were awarded. Because we believe that the logistic model, out of different types of population models, has the best fit, we assumed that the population has the exponential growth rate of r at "low" population and a fixed maximum carrying capacity, K. The exponential growth does not persist forever and is self-limiting; as the population approaches the carrying capacity of K, the growth rate r approaches zero. A more straightforward depiction of this growth rate can be shown as a linear function. A linear regression line satisfying the growth rate a(N) = r (1 -N/K) is calculated by interpolating data points. With the equation of the line,

$$y = -4E\text{-}07x + 0.0685,$$

we have determined K as its x-intercept and r at the y-intercept:

$$K = 170{,}750 \quad r = 0.0685$$

Figure 1. As the number of women with STEM bachelor's degrees (N) increases to approach carrying capacity (K), growth rates (N'/N) decrease to zero.



Then, inserting a(N) into $N'(t) = a(N)N(t)$ gives the famous logistic equation of

$$N'(t) = rN(t)\,(1 - N(t)/K).$$

The solution of this differential equation is given by

$$N(t) = K/\,(1 + e^{C - rt}).$$

By using the given data points, we are able to calculate C, a constant of integration.

$$C = 136.8964578$$

Thus, the predicted population of women with STEM bachelor's degrees is given by:

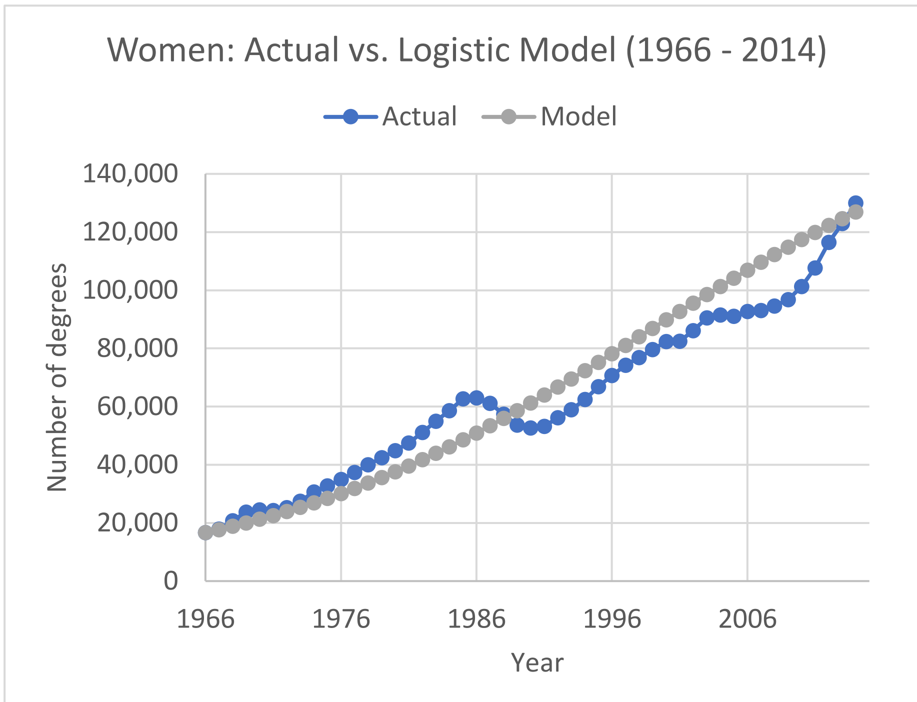
$$N(t) = 170750\,/\,(1 + e^{136.8964578 - 0.0685t})$$

Using the above equation, the number of STEM bachelor's degrees awarded to women could be easily predicted. Comparing the actual data with the predicted data constructed by the logistic model in the following chart and graph reveals that the logistic analysis produces a fairly good fit.

Table 1. Predicted and actual number of STEM bachelor's degrees awarded to women, from 1966 to 2014.

Figure 2. Predicted and actual number of STEM bachelor's degrees awarded to women in N(t) versus t graph, from 1966 to 2014.

Time	Actual	Model
1970	24,522	21,240
1975	32,723	28,470
1980	44,857	37,542
1985	62,608	48,519
1990	52,653	61,230
1995	66,875	75,223
2000	82,336	89,791
2005	91,057	104,106
2010	101,321	117,394
2014	129,926	126,897

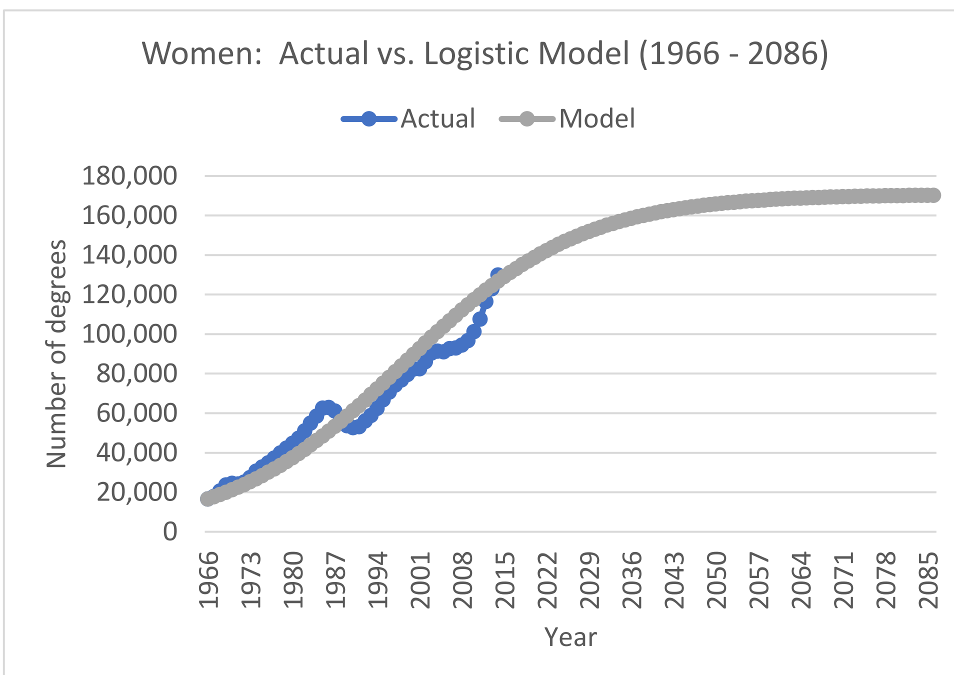


Extending the calculation, using the same logistic equation, up to 2086, where we are near its estimated carrying capacity of about 170,000, we now have a clear view of a graph of 120 points portrayed from 1966 to 2086.

Table 2. Predicted and actual number of STEM bachelor's degrees awarded to women, from 1966 to 2086.

Figure 3. Predicted and actual number of STEM bachelor's degrees awarded to women in N(t) versus t graph, from 1966 to 2086.

time	Model
2015	129,092
2025	146,860
2035	157,810
2045	163,972
2055	167,265
2065	168,975
2075	169,851
2085	170,295



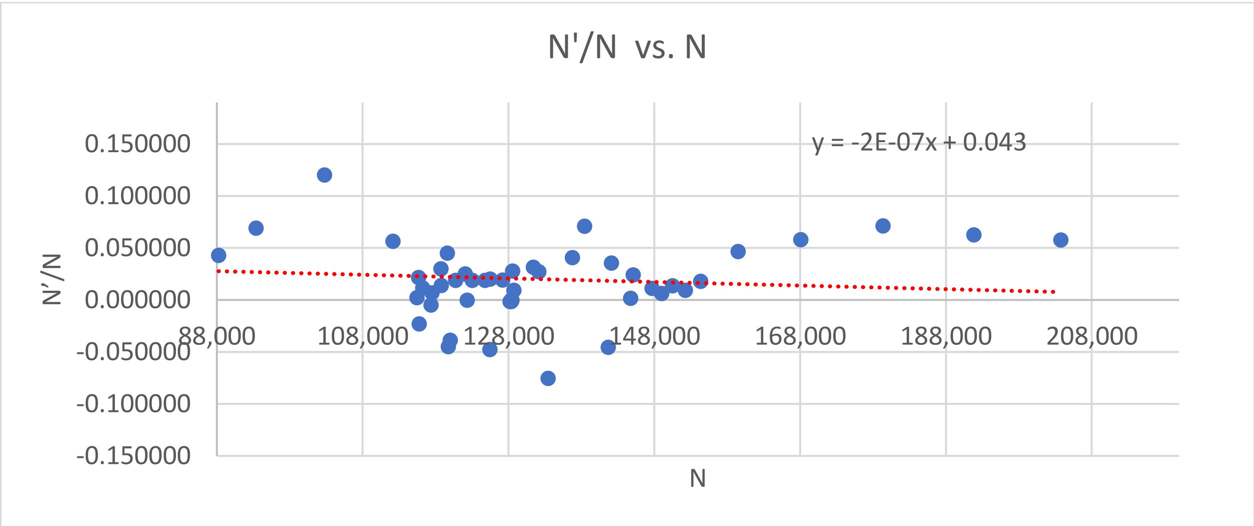
The logistic model forecasts that from about 2030, the exponential growth will begin to slow down, the growth rate will approach zero, and the number of bachelor's degree in STEM awarded to women will self-limit its growth from the upper bound of about 170,000.

4 Logistic Model for Population of Men in STEM

Next, we will model the number of bachelor's degree in STEM awarded to men to compare to the analysis of the same degrees attained by women and see any evidence of gender disparity enhancement.

Although data for men had less apparent indication of which population model would have the best fit, the logistic model, after a few trials of fitting various models with the graph of growth rate (N'/N) versus number of degrees (N), we have concluded that even with the data for men, the logistic model had the best fit.

Figure 4. As the number of men with STEM bachelor's degrees (N) increases to approach carrying capacity (K), growth rates (N'/N) decrease to zero.



Using the same calculation method as the population growth model of women, we obtained a(N) through a linear regression line of

$$y = -2E\text{-}07x + 0.043$$

as well as $K = 215{,}000$, $r = 0.043$.

With the same differential equation $N'(t) = rN(t)\,(1 - N(t)/K)$ but with above K and r values, the given solution $N(t) = K/\,(1 + e^{C - rt})$ with $C = 84.93693834$, determined with the given data points, we attain

$$N(t) = 215000 \,/\, (1 + \exp(84.93693834 - 0.043t))$$

Using the above solution, the logistic model's prediction is depicted, as shown in the below graphs.

Figure 5. Predicted and actual number of STEM bachelor's degrees awarded to men in N(t) versus t graph, from 1966 to 2014.

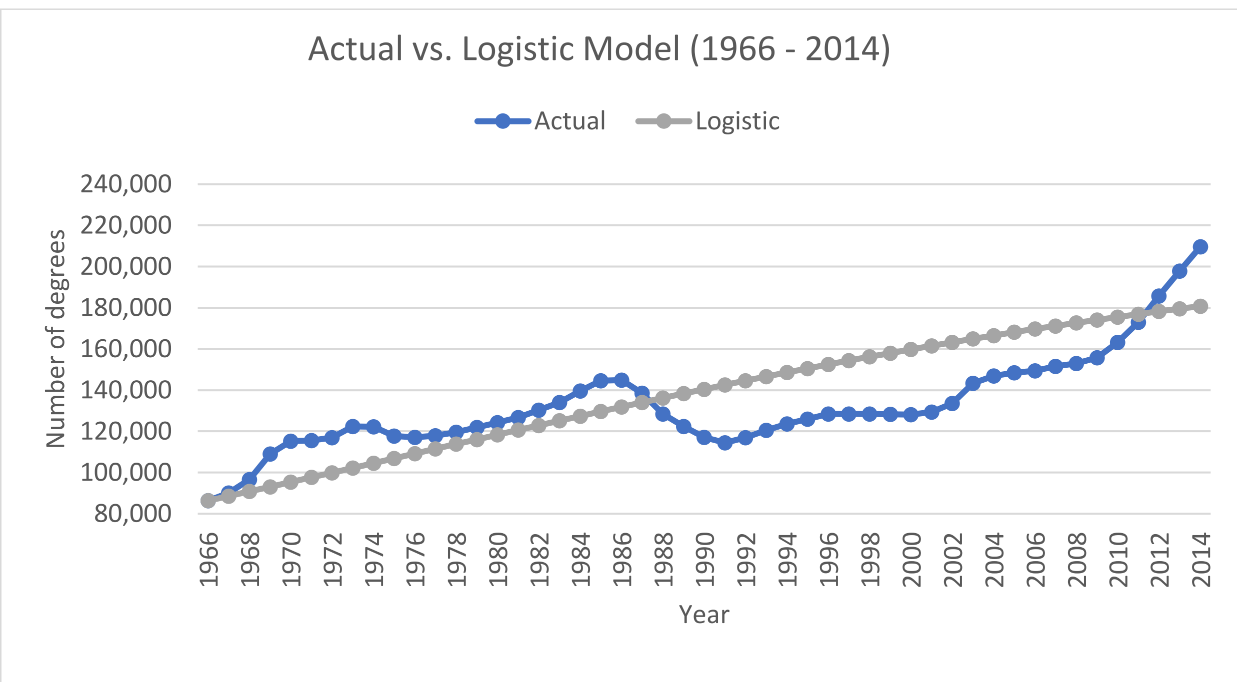
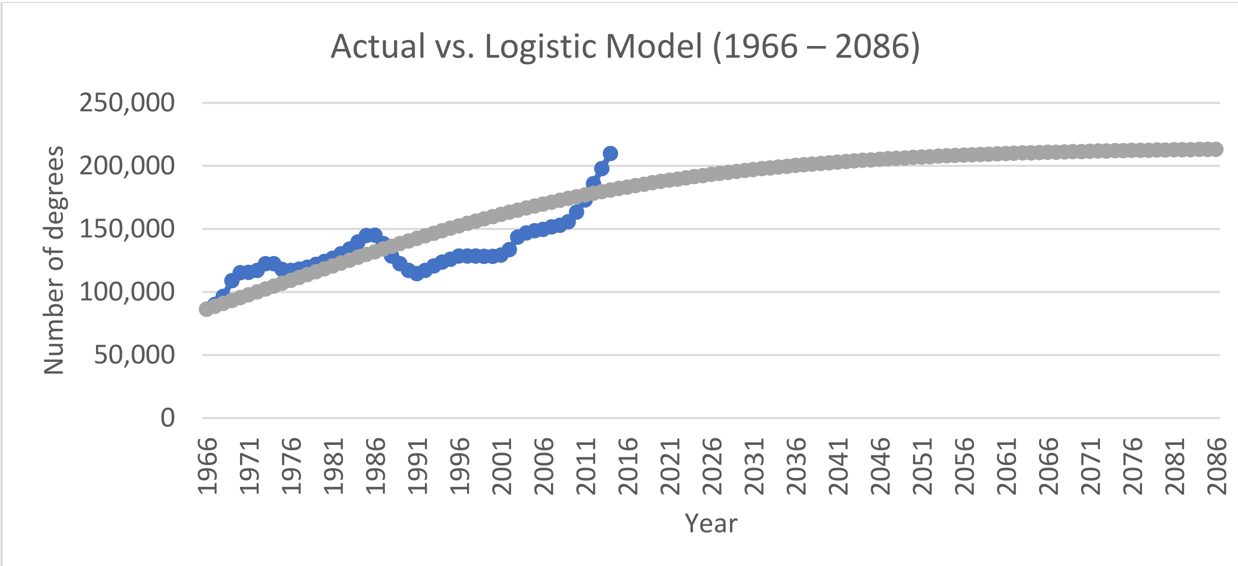
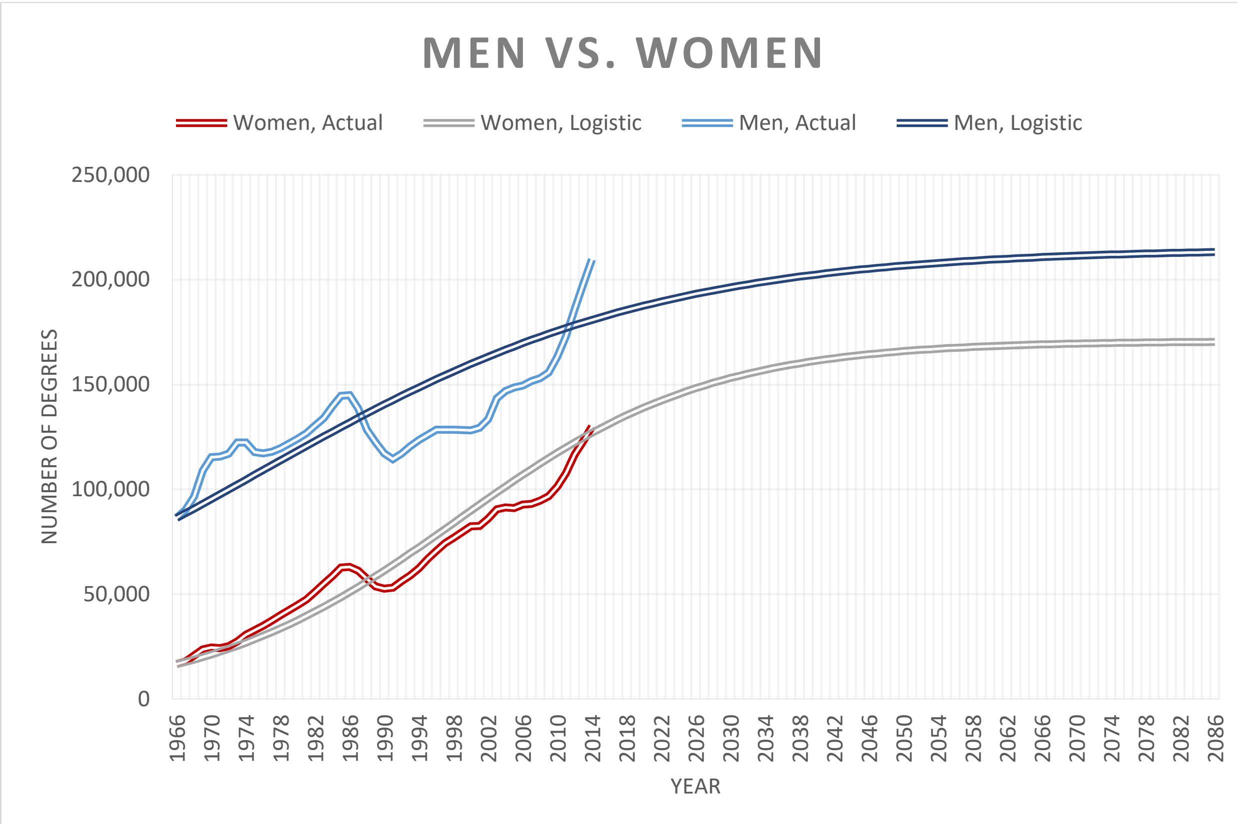


Figure 6. Predicted and actual number of STEM bachelor's degrees awarded to men in N(t) versus t graph, from 1966 to 2086.



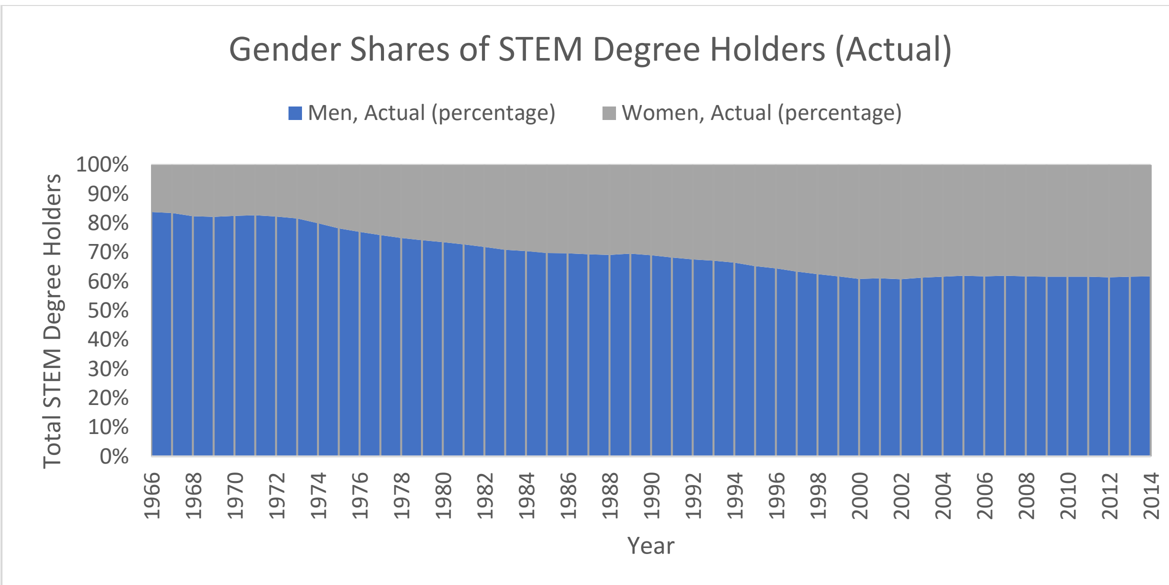
The number of STEM bachelor's degrees awarded to men could not achieve as good fit with the logistic model as it was for the women's. We envisage that this is most likely because the data for men had large fluctuations with uneven, inconsistent pattern. However, the logistic analysis can be considered a decent fit, taking into an account that the model's data seems to be fairly close to the actual data, with no significantly big difference.

Figure 7. Predicted and actual number of STEM bachelor's degrees awarded to women and men in N(t) versus t graph, from 1966 to 2086.



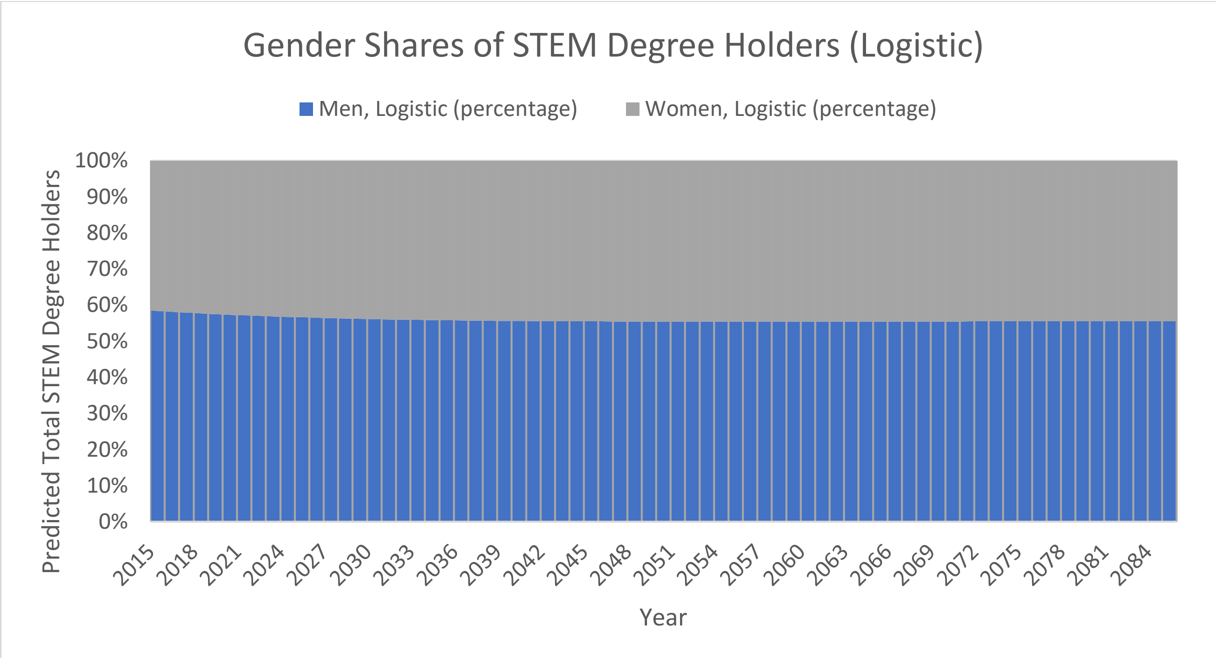
The comparison graph shows the forecasts of both women and men population with bachelor's degree in STEM. Without an attempt to deeply analysis this forecast graph, it seems that women will never surpass men in STEM fields. Also, just simply comparing the values of carrying capacity of the two gender – men's carrying capacity is about 215,000 and women's about 171,000 – tells us that women and men would never be able to have the same share in STEM fields, since increase in growth is limited when the population is near its carrying capacity and since the population will never increase above the carrying capacity of this logistic model. However, some significant notes to make is that the exponential growth rate of women is greater than that of men and that the gender gap is slowly closing. The following 100 percent stacked area chart gives a clearer idea of the change in gender disparity.

Figure 8. Gender shares of STEM degrees awarded, calculated with actual data from 1966 to 2014.



100 percent in this chart represents the total number of STEM degrees awarded to both men and women. The bottom area represents the percentage of men who obtained STEM degrees, and the top area embodies the percentage of women who obtained STEM degrees. This chart is extracted from the actual population data, from 1966 to 2014. We can already see that the gender gap has been closing with rapidness.

Figure 9. Gender shares of STEM degrees awarded, calculated with logistic model from 2015 to 2086.



The forecasted data, which is the result of an analysis with the logistic model, shows little to no improvement in closing the gender disparity. The share percentage, which is about 55 percent for men and about 45 percent for women, seems to have almost zero slope and to be stable and consistent all the way through 2086. This can be interpreted as that even the number of women in STEM fields may be increasing, at the same time the number of men in STEM will also increase, not allowing women to surpass men and keeping women to be underrepresented.

5 Sources of Error

This section of the report will list and explain some possible causes of inaccuracy of the logistic forecast.

1. For some reason – the provider of the data did not enclose an explanation – only the data for 1999 was missing for both men and women. However, because we obtained accurate data at every year from 1966 to 2014, we assumed the data for 1999 exists and set it as an average of 1998 and 2000 data. Thus, we simply filled the gap by averaging out from the nearby data points. Although there could have resulted some error with this haste assumption, we do not think that having a real, accurate 1999 data would have changed the result significantly since we already had nearly 50 data points.
2. The report is focused on the gender disparity of the STEM workforce in the real world, assuming that there is a correlation between the type of bachelor's degree attainment and occupation field. However, the assumption proved to be wrong after a belated finding of a new data that states that only about 1 out of 4 STEM graduates are employed in a STEM occupation[1]. Thus, the report lost its generality in its forecast of STEM workforce.
3. The actual data, as well as the forecast, could be misleading because we did not consider each major field separately. Women are heavily concentrated in Life and Physical Sciences while men are concentrated in the field of Engineering. An observed increase in population of women in STEM could be a result of rapidly increasing popularity in Life and Physical Sciences and not as much increase in the other fields. Because the source did provide separate data for each of major field group, we could have done a separate research and comparison to attain a less biased result.

6 Conclusion

There is a clear increase in the population of women in STEM fields. we are currently still in the middle of the exponential growth and would still need many years to see the growth rate approach zero. Thus, we could still hope for a surge, caused by some even not accounted in this report. Plus, although women have been rapidly working to close the gender disparity according to the actual data, this report's forecast concludes that women will always be underrepresented in STEM fields. However, because this logistic model analysis is exposed to errors from different sources, the forecast could be inaccurate.

One possible area for further research is in gender wage gap. Since STEM careers have higher income and since STEM fields hire less women and more men, there could be possible direct and indirect impact in gender wage gap. Another path to further pursue research could be underrepresented races in STEM. Blacks and Hispanics have been consistently underrepresented in STEM employment. In 2011, only 6 percent of STEM jobs belonged to Blacks, and 7 percent were Hispanics.[1]

While this report could not explain why gender differences in STEM exist or how the gap could improve so that both gender have equal opportunities, this finding is an evidence that women in STEM should be encouraged and supported.

7 References

[1] Women in STEM: A Gender Gap to Innovation. *Economics And Statistics Administration*, 2011. Accessed: 2017-10-13.

[2] Disparities in STEM Employment by Sex, Race, and Hispanic Origin. *American Community Survey Reports*, U.S. Census Bureau, Washington, D.C., 2013. Accessed: 2017-10-13.

[3] Science and Engineering Degrees: 1966–2012. *National Science Foundation*, National Center for Science and Engineering Statistics, Arlington, VA, 2015. Accessed: 2017-10-13.