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M3 Challenge Champions, Summa Cum Laude Team Prize: $20,000

Dear High School Administrator,

Senior year is often the most anticipated year for high school students nationwide. The independence and freedom that come with graduation leads into an exciting time for change. Perhaps the most important decision is deciding whether or not to apply for college, which has not only a growing price tag but also a hefty opportunity cost—the forgone income from getting a job straight out of high school. For many families, college is a burden, especially because college sticker prices can be misleading. In addition to the question of whether attending college is worth it or not, students are forced to consider the pros and cons of different career fields. STEM industries are growing rapidly and are touted by the media as having greater financial return and higher job stability. How can high school students make the right decisions that will ensure that they reach their targeted quality of life in the future?

Our job was to develop a mathematical model that can be used as a tool to help students evaluate different higher education choices, such as STEM vs. non-STEM majors and 4-year degrees vs. 2-year associate degrees. The first step in this process is to give a more accurate summary of how much attending college would cost. The current method of determining this value is by using the EFC (expected family contribution) value. However, the EFC does not account for the amount of loans one would be expected to pay back or the yearly increases in the cost of college. Our college cost metric accounts for both of these factors, as well as different kinds of higher education plans and forgone working time. Surprisingly, for most students, this loss in the form of monetary wages, approximately \$15,750 per year, is the largest cost of attending college. Based on this information, a student and his/her family can decide whether the student should pursue a degree, and if so, what type of degree.

We then sought to create a model that evaluates the costs and rewards of pursuing a STEM degree as compared to other higher education choices. We created a simulation that measured the amount of money that students with different degrees would earn, taking into account factors such as unemployment and inflation. We observed that STEM degrees generally yield higher returns than non-STEM and associate degrees, and all three tend to earn more money than a high school diploma.

Finally, we devised a tool that could help students determine what field of higher education they should enter, if they do decide to enroll in post-secondary education. The tool considers not only a student's personal career field preference but also job satisfaction factors such as level of responsibility, opportunity for advancement, location and contribution to society. Therefore, this important life decision will be based not only on personal interests or monetary compensation, but also on other important but oft-forgotten factors that might affect the quality of life.

Our model accurately evaluates various objective criteria, and provides means by which a student can incorporate personal preference for degree options; however, higher education is ultimately a very personal decision, and some students may opt away no matter how financially beneficial it is.

Team #4902

STEM Sells: What is higher education really worth?

Team #4902

March 1, 2015

Contents

1 Introduction

1.1 Background

We live in an era driven by technological innovation where STEM (Science, Technology, Engineering or Mathematics) graduates are more in demand than ever, with projections for the next 10 years showing growth rates of up to 17% in these fields [8]. The United States has has often played a major role in STEM advancements. In fact, President Obama's Council of Advisors on Science and Technology (PCAST) estimates "a need for approximately one million more STEM professionals than the U.S. will produce at the current rate over the next decade."

However, today's students and their families are faced with the daunting cost of college. State funding for public universities has substantially fallen, thus increasing the burden of debt (the US News has reported that average student debt is approaching \$30K [9]). Given the financial strain, high schools are growing increasingly aware of the price of higher education and the monetary compensation of different fields.

1.2 Restatement of the Problem

Given the increasing cost of higher education, we have responded to the needs of high school administrators to develop a mathematical model to solve the following problems:

1. Is a college education really worth it? Are the sticker prices accurate representations of the price associated with attending a university? If a student decides to pursue post-secondary education, how much would it *really* cost them?

2. In the media, STEM jobs have generally been portrayed as being more stable and more lucrative than non-STEM jobs such as those in the humanities. Is this stigma accurate? In other words, are STEM jobs truly more financially stable, and do STEM majors have greater earning potential/salaries in the short term and in the long term?

3. Monetary return is just one factor that must be considered as high school students weigh their career options. It is also important for students to think about how their career choice influences factors that affect overall quality of life. Life is short, and many students do not find cash flow to be their #1 priority or their sole source of happiness.

2 Looking Beyond Sticker Prices

There are many statistics and calculators on the web for average college tuition and EFC (expected family contribution), but these two values alone fail to capture the true cost

of college. They do not factor in the opportunity cost of the four years spent earning an undergraduate degree or the money that must be repaid in student loans.

To obtain a baseline for our model, we used the Quick EFC Calculator from FinAid [6] to determine financial aid packages and college student loan debt.

2.1 Assumptions/Simplifications

In order to further generalize our model for the average high school graduate, we made the following assumptions and simplifications:

- **Assumption:** The age of the older parent of the student is 45.
  Justification: When calculating the EFC using the Quick EFC calculator, small deviations in the age of the older parent alone have relatively small impact (no more than a couple hundred dollars) [6]. Therefore, we adopted a reasonable standard age of 45 years to maintain consistancy.

- **Assumption:** When calculating the amount of money that a household is expected to contribute, we assume the student's income and assets to be $0.
  Justification: Student income does not factor into a family's expected contribution to college until it exceeds the standard tax deduction, which was $6,300 in 2015 [1]. Most high school students, who either do not work or work only part-time jobs, will not earn enough money for student income to make an appreciable difference in the cost of college. Families are also expected to contribute a greater amount of student assets towards college than parent assets [18]. Therefore, parents should simply include their child's assets under their own assets in order to save more money on college tuition.

- **Assumption:** When looking at data for household income and contributing assets, we used median values instead of mean values.
  Justification: The distribution of household incomes is right skewed, and high-earning or high-saving outliers greatly affect the mean income. However, the median is not affected appreciably by these outliers, so it is a more representative measure of income.

- **Assumption:** Only 25% of the average household's assets are actually factored into the EFC calculation.
  Justification: According to data collected by the Federal Reserve Board, a large majority of the average household's assets are in the form of houses and vehicles or other non-financial assets. On average, other financial assets and stocks and bonds represent only 25% of a household's assets [2]. Since most colleges do not factor the value of houses into their financial aid calculations [3], only the 25% mentioned above will affect the EFC value. This 25% is the contributing assets amount and falls under Parent Assets (Other) on the Quick EFC calculator.

- **Simplification:** Families hold contributing assets equal to 60% of their family income.
  Justification: While most high schoolers probably do not know the amount of

assets held by their family, they probably do know the annual household income. To determine the contributing assets, we looked at the median assets of families based on data collected in the 2010 US Census [4]. Due to the proximity of these values to 60% of the household income value (i.e., $40,000 in assets for $75,000 in household income, and $75,000 in assets for $125,000 in income), we chose to adopt this simplification.

2.2 Using the EFC Calculator

We used our assumptions above to input the age and the amount of student assets in the EFC calcuator. For the case of a household income of $35,000, we set contributing assets to $0, since contributing assets do not matter if household income is below $50,000 [17]. The tables for all six scenarios are shown below.

Single Parent/One Child		
Household Income	Contributing Assets	EFC
$35,000	$0	$1,775
$75,000	$45,000	$11,793
$125,000	$75,000	$29,193

Two Parents/Three Children				
Household Income	Contributing Assets	EFC per Child (1 in College)	EFC per Child (2 in College)	EFC per Child (3 in College)
$35,000	$0	$0	$0	$0
$75,000	$45,000	$6,473	$3,792	$2,938
$125,000	$75,000	$24,025	$12,699	$8,922

2.3 Determining the True Cost of College

Once we establish how much a family is expected to pay for a college, we need to factor in how much of the remaining college tuition fees are loans and how much are grants.

2.3.1 Grant Money vs. Loan Money

From statistics provided by the Federal Student Aid office, federal student aid makes up the majority of student aid, and 80% of federal student aid is in the form of loans [5]. In calculating student debt, grants are not included because they do not require repayment and therefore do not contribute to debt. Therefore, we assume that 80% of the money covered by student aid must be repaid at some point.

Also, earnings from scholarships vary considerably from student to student and depend on many unpredictable factors, such as merit and athletic ability. Therefore, we omit scholarships from our cost calculation.

2.3.2 Factoring in the Rising Cost of College

Even adjusted for inflation, the price of college has been increasing at alarming rates. Using trends provided by the College Board [**?**], we expect the cost of both public and private 4-year universities to increase by roughly 10% over the course of 5 years. This correlates to approximately a 2% increase in price per year.

Therefore, given an initial price P in the first year, we can expect to pay

$$\text{Tuition and Fees over 4 Years} = \sum_{i=1}^{4} P \cdot 1.02^{i-1}$$
$$\approx 4.12P$$

or an average of $1.03P$ per year.

2.3.3 Addressing Opportunity Cost

While attending college, students are unable to work full-time jobs. However, according to a study released by Citi Group and Seventeen Magazine, 80% of college students work part-time jobs, and the average student works 19 hours per week [16].

Compared to a high school graduate working 40 hours per week, with an average yearly salary of \$30,000 [15], a college students loses out on approximately $\frac{21}{40} \cdot \$30,000 = \$15,750$ in potential wages per year (in addition to unquantifiable work experience).

2.3.4 Finally Meshing Everything Together

The following equation shows the average yearly cost of going to college as a function of three factors: EFC, annual college tuition (P), and opportunity cost in the form of lost wages.

$$\text{Average yearly cost} = \text{EFC} + \text{Loans} + \text{Opportunity Cost}$$
$$= \text{EFC} + 0.8(1.03P - \text{EFC per year}) + \$15,750.$$

Note that in this equation, if the EFC exceeds the tuition of the college for a certain year, then the equation for that year becomes:

$$\text{Cost} = \text{Tuition} + \text{Opportunity Cost}.$$

Using these equations, we may calculate the average cost per year of college for each of the six scenarios, for the cases of enrollment in 4-year public, and 4-year private institutions.

2.3.5   Enrolling in a 4-Year Public Institution

Using data provided by the College Board, we determined the annual tuition and fees, P, of a 4-year public institution for in-state students to be $8,655 [14]. We then applied our formula for average 4-year cost to each of the given scenarios to determine the true cost of college.

Single Parent/One Child	
Household Income	Yearly Cost
$35,000	$23,237
$75,000	$24,664
$125,000	$24,664

Two Parents/Three Children			
Household Income	Yearly Cost (1 in College)	Yearly Cost (2 in College)	Yearly Cost (3 in College)
$35,000	$22,674	$22,674	$22,674
$75,000	$24,176	$23,640	$23,469
$125,000	$24,664	$24,664	$24,608

2.3.6   Enrolling in a 4-Year Private Institution

Once again, from data provided by The College Board, the annual tuition and fees, P, of a 4-year private institution was determined to be $29,056 [14], yielding these totals.

Single Parent/One Child	
Household Income	Yearly Cost
$35,000	$40,047
$75,000	$42,051
$125,000	$45,524

Two Parents/Three Children			
Household Income	Yearly Cost (1 in College)	Yearly Cost (2 in College)	Yearly Cost (3 in College)
$35,000	$39,692	$39,692	$39,692
$75,000	$40,987	$40,451	$40,280
$125,000	$44,497	$42,232	$41,477

2.4   Assessing the Reasonableness of the Model

Notice that these average yearly costs are much higher than the typically quoted costs of college education (i.e., $30K total debt per student). This is due to us factoring in the opportunity cost of not being able to work full-time jobs while attending college.

Take, for example, the cost of one child with a single parent and household income of \$75,000 attending a private institution. According to our model, his yearly cost is \$42,051. If you remove the \$15,750 in opportunity cost, this yearly cost falls to \$26,301. Now assume that he is an average student, working 19 hours a week for his part-time job. This job pays roughly $\frac{19}{40} \cdot \$30,000 = \$14,250$ a year. If he puts this money towards college, his yearly cost becomes \$12,051. While this number seems much more familiar and reasonable, unlike our model, it does not represent the true cost of college.

2.5 Effects of Implementing Two Years of Free Community College

President Obama's recent suggestion of implementing two years of free community college is expected to cost \$60 billion [12]. While this may seem like an exceedingly large sum, it is less than the amount of money appropriated to Pell Grants in any given two-year time frame [13]. If high school students chose to complete two years of free community college before transferring to a 4-year public or private institution to complete their degree, they would save on the EFC and loan costs of those two years. However, as has already been seen in our model, the largest cost, opportunity cost, is still present. As the largest cost, our model also suggests opportunity cost as the largest determinant in whether one should or should not complete a higher education. Those that are in immediate need of the money provided by a full-time job will still enter the work force directly, while those that are more fortunate may be more inclined to pursue higher education due to the decreased cost as a result of President Obama's plan. This will lead to an overall increase in the education level of workers, which will in turn expedite the technological advancement of our nation. However, our model does not change significantly.

3 Show Me the Money!

To contrast the financial stability of students with undergraduate STEM degrees with students following other career paths (such as obtaining 2-year certificates or non-STEM degrees), we first developed a method to determine the probability that a major of a certain field would be employed t months after graduation. We then built a computational model that took into account inflation as well as various factors specific to degree (2-year, 4-year STEM, 4-year non-STEM) such as unemployment rate and median salary to model how likely and how quickly the degree would be financially advantageous over no post-secondary education.

3.1 Assumptions and Justifications

- **Assumption:** The probability that an employed graduate stays employed, p, is a logistic function in E, the amount of job experience the graduate has.
  Justification: We reasoned that as job experience increases, a current employee is less likely to be fired and p approaches 1. Furthermore, an employee with less job

experience is less likely to hold onto a job. Thus the plot of p versus the number of months employed E can be thought of as a logistic function.

- **Simplification:** In our computational model for earnings by degree type, we assumed the probability of an unemployed person to become employed in any given month to be constant. In reality, this probablity is dependent upon the length of time that person has been unemployed and amount of experience he or she has.
  Justification: There is not enough data avaliable on how the above factors affect probablity of employment to account for it in our model. Our model has the power to account for these factors, and given the proper resources, surveys could be conducted to model this behavior.

- **Simplification:** The salaries of employeed graduates are always the average salary of the field that they are in and does not change over time.
  Justification: Due to a lack of real-world data, we were not able to take into account the evolution of salaries of graduates over time. Therefore, we resorted to assuming that the employees always earn the same salary, dependent on a simple Gaussian distribution. Given additional data, however, we can easily incorporate the change of salary over time by including another probabilistic variable in our computational model.

3.2 Markov Chains

First, we modeled employment-unemployment dynamics using Markov chains. At any time, a graduate of a certain major can exist in two independent states: employed, EM, or unemployed, UE. Furthermore, after each month, a graduate can either remain in the same state or change states. Therefore, at any given month, there is an associated transition matrix T with entries a_{ij} that give the probability that a graduate will move from state i to state j. The matrix T is as follows:

$$\begin{array}{c} \text{States} \quad EM \quad UE \\ \begin{array}{c} EM \\ UE \end{array} \begin{pmatrix} p & 1-p \\ 1-q & q \end{pmatrix}, \end{array}$$

where p is the probability that an employed graduate stays employed and q is the probability that an unemployed graduate stays unemployed. A diagram corresponding to this transition matrix is shown below:
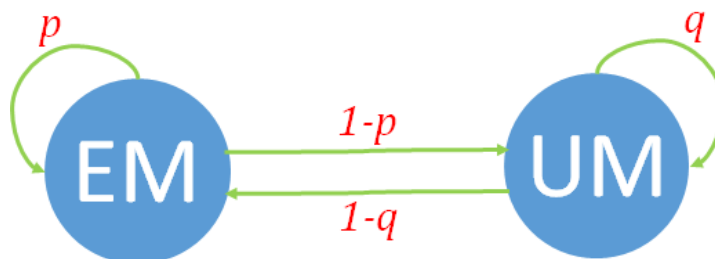

Figure 1: Diagram showing the transitions between the employed (EM) and unemployed (UE) states, and their associated probabilities.

From our assumption, p satisfies the following differential equation:

$$\frac{dp}{dE} = \frac{p}{t_1} \cdot (1 - p),$$

which has the solution

$$p = \frac{1}{1 + k_1 e^{-E/t_1}},$$

where k_1 and t_1 are constants and E is the job experience and is incremented over time. Similarly, we reasoned that if you are unemployed, the probability that you remain unemployed depends on the number of months that you have been unemployed, R, since this accounts for how "up to date" you are with your field. However, an unemployed graduate does have the option of acquiring an entry level job by accepting a pay cut, meaning that a logistic function would not be appropriate to model q. For simplicity reasons, we assumed a constant q value for each type of career. Our initial conditions (conditions at $t = 0$) were $(EM, UM) = (0, 1)$. Therefore at time t the probability that you are employed, EM, and the probability that you are unemployed, UM, can be represented as

$$(EM_t, UM_t) = (EM_{t-1}, UM_{t-1}) \cdot \begin{pmatrix} p & 1-p \\ 1-q & q \end{pmatrix}_t,$$

where

$$\begin{pmatrix} p & 1-p \\ 1-q & q \end{pmatrix}_t$$

represents the transition matrix at time t and EM_t and UM_t represent the probability of being employed and the probability of being unemployed at time t, respectively. To find the values of the constants k_1, t_1, and q for various career paths (STEM, non-STEM, Associate degree, and High School diploma), we first researched unemployment rates for each career based on number of years since graduation [21]. We then used Python to write a function which used these Markov chains to numerically simulate what these values should be, based upon k_1, t_1, and q, and wrote an error function which utilized the Sum of Squares difference between this function and the data collected. The values of k_1, t_1, and q for each career were then found by minimizing this error with the Nelder–Mead method [22] included in the SciPy package for Python. These three values were then used in the numerical model below.

Degree	k_1	t_1	q
STEM	0.026	81.864	.8698
Non-STEM	0.029	84.728	.8683
Associate	0.034	82.578	.8747
High School	0.050	74.080	.8903

3.3 Computational Model

After we ran the previous optimization function to find the values of k_1, t_1, and q that best represented real-world data, the program was run again to incorporate the net real income of the three degrees compared to that for a worker who has only a high school diploma. To do this, the program simulated the career trajectories of 1000 seeds, each with the following variables continuously updated over a period of 240 months:

- Employed or not employed

- Months of experience

- Salary when employed

- Total real earnings compared to equivalent diploma-only worker

Each person in the program was seeded as an unemployed, just-graduated college student and given a salary based upon a Gaussian distribution with data taken from Thomas Publishing Company [20], and a current (negative) real earnings equivalent equal to the opportunity cost of the 4-year college degree.

Over a timespan of 20 years, the program continuously updated the state of all 1000 simulated people. The Markov chain above, which incorporates job experience, k_1, t_1, and q, was used to probabilistically determine whether each person was employed or not. The average monthly income of a high school diploma-only worker multiplied by their employment rate was subtracted from the total real earnings (opportunity cost of attending college). If a seed was currently employed, his or her monthly income was added to the total real earnings and months of experience. The total real earning was then multiplied by the monthly inflation rate, and the data was stored each month for all 1000 simulated people.

Using the Matplotlib library of Python, the total real earnings were plotted in green if the person had made more than they would with only a high school diploma, and red if they had not. Additionally, the median number of years needed to break even was calculated for the simulated 1000 seeds.

3.4 Results of the Program

The figure below shows, for each of 2-year associate, 4-year non-STEM, and 4-year STEM graduates, the earnings of 1000 simulated people relative to that of a typical high school graduate. The horizontal axis represents the number of months since graduation from college, and the vertical axis represents the difference between the earnings of the college graduate and the high school graduate.
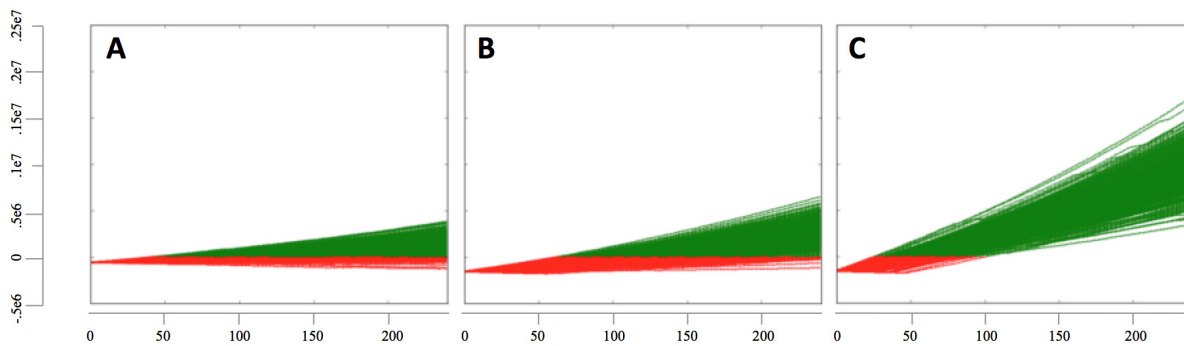
Figure 2: Graphs of the time required for (A) **2-year Associate**, (B) **4-year non-STEM**, and (C) **4-year STEM** graduates to earn more than their high-school graduate counterparts, factoring in the opportunity cost of the extra time spent in education for these options.

From graph (A), we see that most people with Associate degrees break even within 200 months, as shown by the increase in green area around this time, with some people breaking even as early as 46 months after graduation from college. In fact, the median time required to break even is 99 months. However, a few of the Associate graduates actually show a decrease in earnings relative to a typical high school graduate. This is because these graduates may have unusually long periods of initial unemployment and thus will not be able to quickly pay back culminating interest from student debt. In general, Associate degree earners have earned more in 240 months compared to high school graduates, even when considering opportunity costs.

From graph (B), we see many of the same trends. Because a 4-year non-STEM degree results in higher costs of education and opportunity costs, the higher median salaries of these graduates does not translate directly into an increase of earnings over high school graduates. Thus, the earliest graduates break even is approximately 57 months after college graduation, and the median time to break even is 112 months. Notice that this is longer than the median Associate degree-holder, whom typically break even within 99 months. Therefore, in the short term, Associate degree-holders will benefit from their lessened debt compared to graduates of four year institutions and will pay off their debt even earlier due to earlier entry into the work force. However, as can be seen from the graphs, long term, the increased salaries and higher education do mean that most non-STEM graduates have earned more than both high school graduates and associate majors by the end of 240 months.

From graph (C), because of the much higher median salaries, none of the 1000 simulated STEM graduates have earned less than high school graduates after about 100 months, with some people breaking even as early as 24 months after graduation and the median time to break even as 49 months. Additionally, the graph of STEM graduates was the only one whose long-term behavior resulted in all graduates having earned more than high school graduates.

In conclusion, nearly all STEM graduates and most non-STEM and Associate graduates will have earned more than a high school graduate in the course of a lifetime, and based on these results, the benefits of higher education generally outweigh both the costs of education and the opportunity costs of attending college.

3.5 Sensitivity Analysis

The figure below shows the earnings of 1000 simulated people with STEM degrees relative to those of a typical high school graduate.
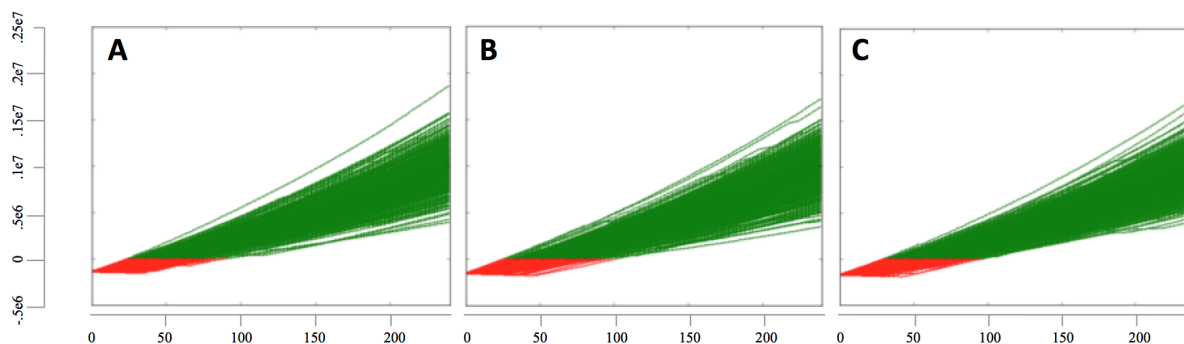

Figure 3: Graphs of the time required for STEM graduates with (A) **$144,000**, (B) **$160,000**, and (C) **$176,000** in college and opportunity costs to earn more than their high-school graduate counterparts.

As can be seen from the three graphs, a 10% difference in initial college and opportunity costs relative to a high school graduate does not greatly change the lifelong earnings of a STEM graduate. We calculated the median time to break even for each of the three graphs. For graph (A), the median time is 43 months; for graph (B), it is 49 months; and for graph (C), it is 53 months. Therefore, a 10% decrease in costs leads to a 12% decrease in median time before breaking even, while a 10% increase leads to a 8% increase in median time.

From this sensitivity analysis, we see that changing the initial cost of college by a certain amount changes the median time to break even by a similar amount, as would be expected.

4 Life Is Short...

We created a metric for overall quality of life that takes into account additional factors besides just salary. Life is short, and students want to choose a career that not only provides them enough financial sustenance to live their desired life but also provides them satisfaction (leading to a higher quality of life).

First, the student needs to determine whether or not they should even pursue a college education and, if they do, should they pursue a 4-year degree versus an Associate degree. The results of our computational model prove that most higher education produces returns within eight to nine years regardless of whether it is an Associate degree or a 4-year degree. However, the results also indicate that a 4-year degree is worth more than an associates degree as long as one remains in the work force, with a STEM degree being worth more than a non-STEM degree. Therefore, we suggest that, barring immediate need for income, all high school graduates that have the opportunity for higher education should pursue it (either in the form of a 4-year degree or a 2-year Associates degree followed by two more years at a 4-year institution). In the case that one needs to go

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straight into the work force, we suggest that once able to, one should return to obtain a higher degree.

4.1 Investment into Education

For example, suppose we have a fictional female student F_1 with household income of $95,000 and a family size of 4 who wants to attend a college with an annual college tuition of $10,000. In addition, suppose that F_1 is the only person currently attending college in the family. Then using our metric from Part 1, the yearly cost for F_1 to attend college will be

$$
\begin{aligned}
\text{Average yearly cost} &= \text{EFC} + 0.8(1.03P - \text{EFC per year}) + \$15,750 \\
&= \$14,328 + 0.8(1.03 \cdot \$10,000 - \$14,328) + \$15,750 \\
&= \$26,855.60.
\end{aligned}
$$

If F_1's family is capable and willing to deal with a loss of (a potential) $26,855.60 a year for four years, F_1 should attend a 4-year institution.

4.2 STEM or Not? A Case of Job Satisfaction

Given that F_1 decides to attend college, we have created a tool that could be used to help the student determine which field of study they may want to pursue.

Given that the student wishes to pursue a 4-year degree, we first ask them to rank the following 10 characteristics from 1–10, where 1 represents the least appealing characteristic while 10 represents the most appealing characteristic.

Opportunity for Advancement	Benefits
Intellectual Challenge	Degree of Independence
Degree of Independence	Location
Job Security	Salary
Time to Pay Off Debts	Contribution to Society

Given the gender of the student, we can then use the table above to calculate the resulting Job Satisfaction, J, of a student who pursues a science, engineering, or non-STEM career as follows:

$$
J_{\text{Field}} = \frac{\sum_{i=1}^{10} C_i \cdot (R_i)}{55},
$$

where C_i is the scaling constant of the factor i from the Job Satisfaction Weightings table above and R_i is the ranking of the factor. C_i and R_i vary based on gender, to account for career trajectory disparities between males and females (for example, males are often paid more than females). We then compare the three resulting score values (one for each of science, engineering, and non-STEM) and recommend that the student pursue the field with the highest score.

Job Satisfaction Weightings (Female, Male)			
Factor	Science(F,M)	Engineering(F,M)	Non-STEM(F,M)
Opportunity for Advancement	(2.96, 3.06)	(2.99, 2.99)	(2.99, 3.03)
Benefits	(3.30, 3.24)	(3.28, 3.20)	(3.21, 3.25)
Intellectual Challenge	(3.58, 3.57)	(3.47, 3.57)	(3.50, 3.49)
Degree of Independence	(3.70, 3.69)	(3.68, 3.69)	(3.66, 3.71)
Location	(3.38, 3.40)	(3.36, 3.42)	(3.38, 3.35)
Level of Responsibility	(3.55, 3.52)	(3.34, 3.49)	(3.53, 3.50)
Job Security	(3.19, 3.42)	(3.26, 3.52)	(3.29, 3.53)
Contribution to Society	(3.57, 3.57)	(3.55, 3.57)	(3.57, 3.56)
Salary	(3.47, 3.55)	(3.50, 3.54)	(2.14, 2.24)
Time to Pay Off Debts	(3.78, 3.78)	(3.78, 3.78)	(2.53, 2.53)

The first eight scaling factors were found from a National Science Foundation (NSF) [19] survey of over 200,000 male and female professionals in the science, engineering, and non-STEM fields. Each of the factors is ranked from 1 to 4, with 4 representing highest satisfaction and 1 representing dissatisfaction. The last two factors, salary and time needed to pay off student debts, were calculated from normalized values obtained from the financial metric described in Part 2.

4.2.1 Case Study Example

Now suppose that F_1 ranks the 10 factors as follows:

Factor	Rank	Factor	Rank
Time to Pay off Debts	10	Contribution to Society	5
Opportunity for Advancement	9	Benefits	4
Intellectual Challenge	8	Degree of Independence	3
Location	7	Level of Responsibility	2
Salary	6	Job Security	1

Then the Job Satisfaction score of science of S would be calculated as follows:

$$J_{\text{science}} = \frac{10(3.78) + 9(2.96) + \cdots + 2(3.55) + 1(3.19)}{55} = 3.45.$$

Similarly, we can find the scores of Engineering and non-STEM, which are 3.43 and 3.06, respectively. However, this formula for Job Satisfaction does not include the student's personal preference. The student may have personal preference towards a STEM or non-STEM career based on their grades in STEM classes, success in STEM extracurriculars,

or the earning potential gap between STEM and non-STEM fields. Therefore we will introduce an additional factor to this tool that represents the student's current bias b. Student F_1 may be 60% sure that they are leaning towards a STEM field and 40% sure that they are leaning towards a non-STEM field. Therefore our final metric, $J_{\text{field}} * b_{\text{field}}$, will help the student make a reasonable decision.

In this test case, we would recommend that F_1 pursue a STEM career. In particular, the student should pursue a degree in a Science major.

5 Strengths and Weaknesses

5.1 Strengths

- Our career decision tool includes not only personal career preference but also job satisfaction elements such as level of responsibility, opportunity for advancement, location, and contribution to society. Therefore, this important life decision is based not only on personal interest or monetary compensation, but also on other important factors that can affect the quality of life.

- Our Markov chain model is discrete and not continuous. This allows us to consider more variables in our model such as personal experience and create a computational model to keep track of employment of a large population over time on an individual basis.

- We derived constants from real-world data, which ensures that the results of our model are fairly accurate.

- Our model is probabilistic, which allows us to visualize a wide variety of career trajectories.

- We accounted for inflation in our model to determine the real opportunity costs of pursuing an Associate degree or a 4-year degree versus a High School Diploma.

5.2 Weaknesses

- Our Markov chain model is discrete and not continuous. Real-world job hirings and firings are not discrete processes since employees are being hired and fired at any given time while our model assumes that hirings and firings happen monthly.

- We assumed that there is no significant change in the availability of jobs in the chosen field over time. This was due to the unpredictability of economic recessions and to maintain the simplicity of the model.

- Our model assumes that as job experience increases, so does the probability that a STEM major will retain his or her job or become employed if they become unemployed. However, a recent IEEE study reported that older IT-industry employees are increasingly considered "technology obsolete" and therefore ripe for replacement by younger STEM graduates at the age of 40 or less, regardless of experiences [23].

6 Conclusion

In our solution, we modeled the cost, return, and value of a college education. First, we created a more accurate metric to elucidate the real price a student would pay for an undergraduate degree that was constrained by the lack of information incorporated in the standard Expected Family Contribution metric.

The average yearly cost of going to college, given EFC, annual college tuition (P), and opportunity cost in the form of lost wages, was calculated to be

$$\text{EFC} + 0.8(1.03P - \text{EFC per year}) + \$15,750.$$

Then we used this higher education price calculator to determine the opportunity cost of forgoing a job straight out of high school and the debt of a college graduate. We simulated the career paths of 1000 workers by incorporating factors such as the probability of finding a job and the probability of losing a job. Using this employment-unemployment Markov chain, we found the time it would take to break even with the sum of the inflation-adjusted opportunity cost and the total amount of college debt accumulated. This simulation gave us more insight into the financial stability and earning potential of workers with different types of education degrees.

Finally, we created a tool that could be used by high school students to help them determine if they should pursue higher education, and if so, what type of degree and what field to join. The tool is based not just on monetary return or personal interest but also on career-related factors that affect an employee's quality of life and satisfaction. Our use of personalized survey results allows our tool to be customized for students at various high schools across the nation.

References

[1] KELLY PHILIPS ERB, *IRS Announces* 2015 *Tax Brackets, Standard Deduction Amounts and More*, Forbes, 106 (2014), pp. 11812–11817.

[2] KELLY PHILIPS ERB, *Homeownership Remains a Key Component of Household Wealth*, National Association of Home Builders, 2013.

[3] LYNN O'SHAUGHNESSY, *Will Your Home Equity Hurt Financial Aid Chances?*, The College Solution, 2014.

[4] JESSE BRICKER, LISA J. DETTLING, ALICE HENRIQUES, JOANNE W. HSU, KEVIN B. MOORE, JOHN SABELHAUS, JEFFREY THOMPSON, AND RICHARD A. WINDLE, *Changes in U.S. Family Finances from* 2010 *to* 2013: *Evidence from the Survey of Consumer Finances*, Federal Research Bulletin, 2014.

[5] FEDERAL STUDENT AID, *What Are the Title* IV *Programs?*, Federal Research Bulletin, 2005.

[6] FINAID, *Quick EFC Calculator Results*, The SmartStudent Guide to Financial Aid, 2014.

[7] National Center of Education Statistics, *Tuition Costs of Colleges and Universities*, Institute of Education Sciences, 2012.

[8] D. Langdon, G. McKittrick, D. Beede, B. Khan, and M. Doms, *STEM: Good Jobs Now and for the Future*, U.S. Department of Commerce, Economics and Statistics Administration, 2011.

[9] Allie Bidwell, *Average Student Loan Debt Approaches* $30,000, U.S. News, 2011; http://www.usnews.com/news/articles/2014/11/13/average-student-loan-debt-hits-30-000.

[10] Natalie Kitroeff, *Student Debt May Be Sabotaging Your Shot at Buying a Home*, Bloomberg, 2015; http://www.bloomberg.com/news/articles/2015-02-18/student-debt-may-be-sabotaging-your-shot-at-buying-a-home.

[11] Reyna Gobel, *How College Savings Can Affect Financial Aid*, U.S. News, 2015; http://www.usnews.com/education/best-colleges/paying-for-college/articles/2013/05/13/how-college-savings-can-affect-financial-aid.

[12] Jonathan Alter, *The Free Community College Plan is Obama's G.I. Bill*, The Daily Beast, 2015; http://www.thedailybeast.com/articles/2015/01/24/the-free-community-college-plan-is-obama-s-gi-bill.html.

[13] Federal Grant Pell Program, *Funding*, U.S. Department of Education, 2015; http://www2.ed.gov/programs/fpg/funding.html.

[14] CollegeBoard, *College Costs: FAQs*, Big Future, 2015; https://bigfuture.collegeboard.org/pay-for-college/college-costs/college-costs-faqs.

[15] National Center for Education Statistics, *Income of Young Adults*, Institution of Education Sciences, 2012.

[16] 2013 College Student Pulse, *New Citi/Seventeen Survey: College Students Take Control of Their Financial Futures*, Seventeen Magazine & Citi, 2013.

[17] FinAid, *Simplified Needs Test Chart*, The SmartStudent Guide to Financial Aid, 2013.

[18] FinAid, *Simplified Needs Test Chart*, Maximizing Your Aid Eligibility, 2013.

[19] Meghna Sabharwal and Elizabeth A. Corley, *Faculty job satisfaction across gender and discipline*, The Social Science Journal, 46 (2009), pp. 539–556.

[20] David Butcher, *What Is a STEM Education Worth?*, ThomasNet Industry News, 2013.

[21] Anthony P. Carnevale, Ban Cheah, and Jeff Struhl, *College Majors, Unemployment and Earnings*, Georgetown University Center for Education and the Workforce, 2013.

[22] J. A. Nelder and R. Mead, *A simplex method for function minimization*, The Computer Journal, 1964.

[23] Robert N. Charette, *What Ever Happened to STEM Job Security?*, IEEE Spectrum, 2013.