

Payback Time: A Solution to the Student Loan Debt Crisis

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"There are two ways to conquer and enslave a nation. One is by the sword and the other is by debt."

~John Adams, 1826

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Problem Research

Rachel is a first-generation graduate that grew up poor and took out \$36,000 in student loans during her time in college ("Student Debt Crisis", 2020). Ten years later, she is a single mother making payments of \$600 monthly towards her debt. Her debt has grown to \$48,000 due to the exorbitant interest rates on her loans ("Student Debt Crisis", 2020). This is what is meant when we say there is a student loan debt *crisis*. It is easy to discuss these issues in an abstract fashion, far away from the innate human suffering. However, it must be constantly reminded that behind every economic decision, there are individuals who are directly impacted. Thus, there must be a concerted effort to strive for humane and ethical economic policies especially in the realm of fundamental human needs such as education.

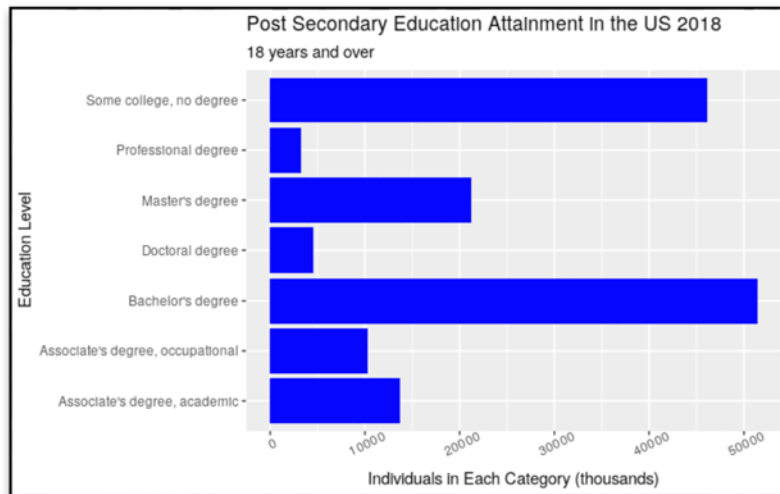


Figure 1

Post-secondary education has become an essential part of becoming financially-stable. According to the Federal Reserve's 2019 report on the Economic Wellbeing of U.S. Households, 87% of those with a bachelor's degree are considered to be, "at least okay financially" (Economic Wellbeing of U.S. Households, 2019). Ironically, in recent decades, attaining a post-secondary degree has become a catalyzing factor for financial instability. In the United States, there is over \$1.6 trillion dollars in student loan debt shared amongst 45 million individuals (Warren, 2020). The prospect of debt weighs heavily on the minds of those wishing to pursue a degree. A Harvard survey found that 70% of those polled stated that their ability to afford college played an important role in deciding whether to even consider pursuing an education ("Student Debt Viewed as Major Problem; Financial Considerations Important Factor for Most Millennials When Considering Whether to Pursue College", 2014). Not only does the cost of college impact a student's decision to go to school, it can also be the reason they never finish. Figure 1 illustrates the distribution of post-secondary education in the United States as of 2018 ("Educational Attainment of the Population 18 Years and Over, by Age, Sex, Race, and Hispanic Origin", 2018). While the largest category of Americans have attained a Bachelor's degree, the second largest category are those who have completed some college, but have not completed their degree or certificate.

The reason so many have not completed their education is answered in a 2008 study conducted by Public Agenda (a non-profit run by the Bill and Melinda Gates Foundation). The study found that, "Those who dropped out are almost twice as likely to cite problems juggling work and school as their main problem as they are to blame tuition bills (54 percent to 31 percent)" (Public Agenda, 2008). While this study is older, it reflects the circumstance of many of those who are currently affected by the loan debt crisis. To add to this, a 2019 survey from the Pew Research Foundation found that a third of adults between the ages of 18-29 had outstanding debt directly tied to their own education not including other forms of debt (e.g. credit card etc.) (Cilluffo, 2019). What these findings show is that the current system has burdened the up and coming workforce with inordinate sums of debt.

In addition to this, an article from the Bureau of Labor Statistics (BLS) stated that, “Over four decades, workers with a bachelor’s degree earned on average 56 percent more and workers with an associate’s degree averaged 21 percent more than high school graduates” (Karageorge, 2014). What this shows is that over time, it will become economically unviable to not have some form of post-secondary education. This economy requires more advanced skills and technical ability to land jobs that pay enough to live comfortably (Karageorge, 2014). If the trend from the BLS holds, the proportion of low-income earners without post-secondary education will increase, making it more difficult for them to pursue an education given the recent rise in tuition. American citizens are now tasked with two difficult decisions; either they choose not to get an education and risk not finding a decent paying job, they could or get an education and risk accruing large amounts of debt.

Understanding the Current System

Before discussing the factors behind the increase in student debt, it is necessary to understand the system as it operates today. The current Federal student loan system consists of two main types of student loans: Direct Subsidized and Direct Unsubsidized. Direct Subsidized loans are made available to students based on financial need and do not accrue interest while the borrower is in school. Under the current policy, the Federal government pays the interest accrued during the student’s educational period. These loans are only available to qualifying undergraduate students. On the other hand, Direct Unsubsidized loans are available to all post-secondary students. However, these loans do accrue interest while the borrower is in school. Two additional Federal loan types are: Direct PLUS and Direct Consolidation. Direct PLUS loans are granted to graduate/professional students or parents of undergraduate students to help cover educational expenses. Direct Consolidation loans give the borrower the ability to consolidate all of their debt to one loan servicer. These federal loans have low interest rates and students do not typically have to begin making payments until 6 months after finishing school. Private loans are also available to student borrowers but typically have higher interest rates and are unsubsidized (*Federal Student Aid, 2020*).

Borrowers are fully responsible for beginning their federal loan payments 6 months after completion of school. This 6-month period is known as the grace period. After the grace period, the loan must be paid per the loan repayment plan agreed upon by the borrower. If the borrower cannot make their agreed upon loan payments, the loan goes into default (*Federal Student Aid, 2020*). Currently, there are government programs available to help borrowers who are struggling to make payments. These programs are income based and only apply to federal loans. There are eight different government programs available. They range from Standard Repayment plans to *discretionary income*-based repayment plans. Among these programs there is a common theme: if a borrower uses an income-based repayment plan to lower monthly payments, they will end up paying more over time due to accrued interest. In some cases, the borrower will end up paying twice as much interest and will be paying off their student loans for two and a half times longer. Below is a data table comparing a Standard Repayment plan and an Income Based Repayment (IBR) plan. The data below shows the tradeoff that must be made if a government IBR plan is used (*Federal Student Aid, 2020*).

Loan.Categories	Standard.Decade.Repayment.Plan	Income.Based.Repayment.Plan
Federal Loan Amount	\$29,800	\$29,800
Loan Term	10 Years	25 Years (Approx.)
Loan Interest Rate	4.53%	4.53%
Monthly Payment	\$309.27	\$101.00 (Inc. Annually)
Annual Income	NA	\$45,000
Family Size	NA	4
Annula Income Growth Rate (US Average)	NA	4.44%
Paid Interest	\$7,312.83	\$15,949

Table 1

As for forgiveness programs, there are options available for special cases. An example of one program available is called the Public Service Loan Forgiveness (PSLF) program. To qualify, you must make 120 months of successful loan payments and work full-time for a public service employer. These employers include: government organizations, and certain non-profit groups. Also, certain teachers qualify for loan forgiveness programs. Loan forgiveness due to death, bankruptcy, school closures, etc. are possible in specific situations (*Federal Student Aid, 2020*).

Finally, under the current system, there are private loans. These do not qualify for government programs and the borrower is completely responsible for paying off these loans. Private loans typically have higher interest rates that can be both variable and fixed. In the end these loans are riskier and more expensive than federal direct loans.

The Factors in the Rising Cost of College

The increase in the disbursements of loans has much to do with the dramatic increase of

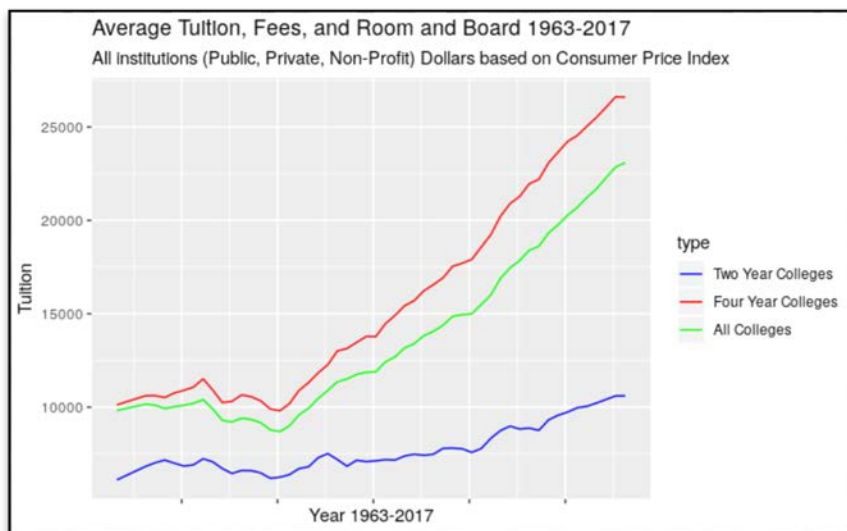


Figure 2

college tuition and fees (Figure 2). A study conducted by the National Bureau of Economic Research (NBER) found that the cost of net-tuition has increased by 106% from 1987-2010 in real US Dollars (Gordon & Hedlund, 2016). The reason for this rise is still contested with theories informed by different economic and political persuasions. This makes the problem of increasing tuition difficult to diagnose. Given the breadth of this subject, we will focus on the two most

common theories cited as causing the dramatic increase in tuition. They are as follows: the Bennett Hypothesis and the reduction in public funding. The theories raised by economists are unique to the competitive framework of the current system. This fact lends itself to the idea that in order to truly address the student loan debt crisis, deep systemic change will be required. Before moving forward, it must be noted this paper focuses on policies affecting public college since much more can be done to address state funded institutions using policy when compared to their private counterparts.

Modernizing the Bennett Hypothesis

The Bennett Hypothesis has existed for over three decades. In a New York Times op-ed from 1987, then Secretary of Education William Bennett asserted that when access to federal financial aid increases, tuition costs also increase. Explicitly stated, the Bennett Hypothesis predicts that for every \$1 increase in student aid, tuition is increased by \$1 (Gordon & Hedlund, 2016). This hypothesis insinuates that in order to reduce tuition, the federal government should reduce financial aid. Since its postulation in 1987, many studies have tested this hypothesis.

There are many studies both crediting and discrediting the hypothesis, and in light of this criticism, economist Andrew Gillin proposed the Bennett Hypothesis 2.0 in a paper for the Center for College Affordability and Productivity (CCAP). In it, he assesses the merits and pitfalls of the Bennett Hypothesis and comes to a more comprehensive solution using it as a framework. A common critique of the original hypothesis states it is too general and cannot be applied to every institution or situation (Weissmann, 2012). Gillin's paper proves useful as a salient response to this critique.

Gillin's argument against what he calls the "Original Bennett Hypothesis" is that the existing evidence does not confirm Bennett's original assertion. According to Bennett's model, if the college's supply curve is vertical--meaning a college has reached maximum student capacity--the tuition should increase a dollar for every new federal aid dollar. The assumption that colleges are at or close to maximum student capacity is indeed true. This said, there is little evidence to suggest that there is a 1 to 1 relationship between a rise in tuition costs and increases in federal aid (Gillin, 2012). Here, Gillin makes an important distinction between low income students and higher income students. His paper shows that as tuition rises, the demand curve for lower income students becomes horizontal (i.e. elastic or extremely sensitive to changes in price) (Gillin, 2012). A lower income student will not entertain the possibility of school without aid, and therefore, a college has nothing to gain from them. From this, Gillin observes that Bennett's Hypothesis does not work for lower income students as an increase in tuition would not be likely. This said, Gillin states if grants are delivered to higher income households, tuition is more likely to rise.

Addressing the Underfunded Argument

Another factor attributed to the increase in tuition is the reduction of state funding for public institutions. Public colleges and universities are primarily funded by the states that they reside in. Funding at the state level is more focused on the operational level of a school while federal money is allocated towards student aid (Urahn & Conroy, 2015). This is not to say that states provide no student aid, it is just to say that there must be a distinction made between the purpose of federal and state funding. The Underfunded Argument posits that cuts in operational funding of higher education shifts the loss of revenue on to the student by increasing tuition and other fees.

In recent years, data shows that the 2008 recession led to funding cuts to colleges and universities leading to an increase in tuition. A study conducted by the United States Government Accountability Office (GAO) observed that between 2003 and 2012, overall State funding of public colleges decreased by 9% accompanied by an 8% increase in tuition costs (Emrey-Arras, 2014). The study attributes this recent decrease in funding to the 2008 subprime mortgage crisis. It can be extrapolated that when state funding is decreased, colleges are forced to find other sources of revenue to make up the difference. In this case, the revenue gap is shifted on the students.

A more recent study from the Center on Budget and Policy Priorities (CBPP) looks at the lingering effects of the great recession from 2008-2017. This study shows that from 2008 to 2017, states higher education budgets are \$9 billion less than their 2008 budgets. On a per capita level, this is equivalent to spending 16% less per student in 2017 compared to 2008 (Mitchell, Leachman & Masterson, 2017). Even post-recession, states refused to increase spending on higher education. This has led to a further increase in tuition. The study goes on to say that from 2008 to 2017 tuition rates have increased by an astounding 35% nationwide in four-year public colleges (Mitchell, Leachman & Masterson, 2017). It must also be noted that the study mentions that while federal student aid has risen over this time period, it has done little to help the problem of rising tuition.

When looking at the evidence, there appears to be little disagreement that these funding cuts have led to a direct increase in tuition. This issue is only exacerbated by the fact that enrollment continues to rise as mentioned in both the GAO and the CBPP study. As more students enter the system, it becomes apparent that there must be some initiative to properly fund these schools. If not addressed, the burden of cost will continue to fall on the shoulders of students. Even though federal student aid has increased, as shown by Andrew Gillin's Bennett Hypothesis 2.0, the increased aid will not help, much less solve the problem. Given the situation, it becomes clear that more drastic measures must be implemented in order to fix the problem.

Macroeconomic Effects of Student Loan Debt Forgiveness

Here the authors would like to note that it would be irresponsible not to address the current COVID-19 pandemic. This ongoing catastrophe has rattled the state of the economy. If there was ever a time to address the student loan debt crisis, it would be now. Mass student loan debt is not only an issue for individuals, it also puts a strain on the economy as a whole. Naturally, debt reduces an individual's discretionary income. With so many citizens in debt, a reduction in discretionary income leads to a series of ramifications that cascade through the national economy. The benefits surrounding the cancellation of debt have been studied and yield promising results. In a 2018 study, researchers found that forgiveness of all Federal loans would double as an economic stimulus. Specifically, they project that canceling federal student loan debt would increase the GDP by \$22 billion annually (Fullwiler, Kelton, Ruetschlin & Steinbaum, 2018). This can be attributed to higher spending in the economy. If citizens no longer have to spend their income paying down debt, instead, they can spend their money on economically stimulating activities such as going out, buying a new home, starting a family, or becoming an entrepreneur. As a result, the researchers estimated that 1.2-1.5 million jobs would be created every year (Fullwiler, Kelton, Ruetschlin & Steinbaum, 2018).

Amid the recent COVID-19 pandemic, in an open letter to Senate Majority Leader Mitch McConnell, Senator Elizabeth Warren has proposed an immediate payment freeze for student loan debt holders. In addition, she has also requested a forgiveness plan for at least \$10,000 for every student loan debt holder. The reason behind this move is to not only relieve financial pressure from citizens facing this crisis but also to protect the economy from further downfall. Senator Warren writes, "We must push an economic stimulus package that puts the livelihoods of vulnerable families as the top priority" (Warren, 2020). It is clear from this letter that protecting those struggling under the burden of student loan debt is an essential part of ensuring the economy's stability. Based on the findings from the 2018 study referenced above, a freeze on student loans would indeed stimulate the economy especially in the midst of an international health crisis.

As we navigate this crisis, it is important to look at existing proposals that address the student loan debt crisis. Current proposals provide a necessary framework that incite discussion. It is more pragmatic to build upon existing plans than to create a new one. As we are in the midst

of a presidential primary, many proposals have come up to address this crisis. Below we discuss the most prominent policy recommendations.

Donald Trump's Policy

Donald Trump's policy on student loans greatly reflects the current system as it is now. The above section titled *Understanding our Current System* succinctly describes how the federal government currently deals with these types of loans. However, we know from prior statements that he has proposed some small changes. First and foremost, he has considered simplifying the multitude of loan repayment programs into a single program. He also plans to set the discretionary income percentage to 12.5%, and forgive all student loans between 5 & 10 years earlier (Friedman, 2019). He has also proposed discharging student loans due to bankruptcy (Friedman, 2019). Of the more controversial proposals, Trump has considered eliminating the PSLF (Public Service Loan Forgiveness) program (Farrington, 2020). This would eliminate a loan forgiveness program for those working at government jobs and non-profits.

Bernie Sanders' Proposal

Democratic presidential candidate Senator Bernie Sanders has proposed a history-altering plan to confront the student loan crisis. His views on the student loan debt is most known for the promise to, "Cancel all student loan debt for the some 45 million Americans who owe about \$1.6 trillion..." (Sanders, 2020). However, this is just the beginning to his educational plan. Senator Sanders plans to pass the College for All Act which would provide a minimum of \$48 billion a year to make all public four-year colleges and universities tuition-free. This funding would also go to aid other schools such as tribal colleges and community colleges. The final key point Senator Sanders promises is to invest \$1.3 billion annually into private, historically black colleges and minority serving schools (Sanders, 2020). To be able to pay for all of these proposals, Bernie Sanders plans to place three separate taxes on Wall Street speculators (Sanders, 2020).

The proposed taxes come from a paper written by Robert Pollin, James Heintz, and Thomas Herndon titled *The Revenue Potential of a Financial Transaction Tax for US Financial Markets*. This paper outlines that \$220 billion per year could be raised by adding a 0.5% tax on stock transactions, 0.1% tax on bond transactions and a 0.005% tax on derivative trades (Pollin et al., 2017). To give a reference to how small these percentages are, a 0.5% tax is equivalent to 50 cents for every \$100 of stocks traded.

To ensure that the student loan debt never returns to this crisis point again, Senator Sanders has promised to make a few more changes to the finances of higher education. To start, student loan interest rates range from 4.45% to 7% as of the 2017-2018 school year (Fay, 2020). Senator Sanders believes that the federal government should not be profiting off of students and plans to put a cap of 1.88% on interest rates (Sanders, 2020). Another proposal that Senator Sanders makes is to triple the funding for the Work-Study Program to allow it to benefit an additional 1.4 million students (Sanders, 2020). To help low-income students, he plans to expand the Pell Grants and, "Require participating states and tribes to cover the full cost of obtaining a degree for low-income students (normally those with a family income of less than \$25,000) by covering any gap that may still exist after we eliminate tuition, fees, and grants." (Sanders, 2020).

Joe Biden's Proposal

Former Vice President Joe Biden is taking a more gradual approach to student loan debt. Essentially, he is planning to cut monthly loan payments in half to make it easier for college graduates to make their payments. More specifically, he is lowering the rate of payment for the income-driven student loan repayment system. With our current Loan Repayment Systems, borrowers pay 10%-15% of their discretionary income towards their loan (US Department of Education, 2020). Biden's system would cut that amount to 5% (Biden, 2020). He also proposes

to completely forgive all loan debt after 20 years of payment (Biden, 2020). If the borrower makes under \$25,000 per year, they would not be responsible for monthly federal loan payments until their income rises above this level (Biden, 2020).

Biden plans to pay for this new program by increasing taxes in two specific areas. First, he proposes to eliminate the *step-up in basis tax* loophole (Biden, 2020). This loophole allows users to get out of paying a capital gains tax by creating a trust for their heirs (Kenton, 2020). Second, he will limit itemized tax deductions to 28% (Biden, 2020). Biden claims that this will raise \$750 billion over the next 10 years (Biden, 2020).

Job and Career Research

The policies mentioned above are informed by research and legislation developed by notable individuals who dedicate their careers to higher education. Two of these important figures are Dr. Michael B. Paulsen and Representative Pramila Jayapal. They are at the forefront of educational reform and expansion. Described below are their ideas and policies on higher education.

Dr. Michael B. Paulsen

Biography

Michael B. Paulsen is widely recognized for his extensive research contributions to the economics of higher education and is a retired professor of Higher Education & Student affairs at the University of Iowa. He attained a bachelor's degree from St. Ambrose University and a master's degree in economics from the University of Wisconsin-Milwaukee. He then completed his Ph.D. at the University of Iowa. Prior to teaching at the University of Iowa, Dr. Paulson was a part of higher education programs at the University of Alabama, the University of Illinois, and the University of New Orleans ("Dr. Michael B. Paulsen | iae.education.uiowa.edu", 2020).

Outside of teaching, Dr. Paulsen has also contributed to other organizations and been recognized for his work through various achievements. The Iowa Academy of Education sums up his efforts by saying, "Professor Paulsen was on the Board of Directors for the Association for the Study of Higher Education (ASHE), served as Chair of the Budget for ASHE, and served on the Executive Council of the American Educational Research Association's Division J." ("Dr. Michael B. Paulsen | iae.education.uiowa.edu", 2020). Due to his extensive work within scholarly publications, Dr. Paulsen was one of the top 20 cited individuals for the core journals of higher education. Dr. Paulsen was also the recipient of the Research Achievement Award in 2015 for ASHE ("ASHE Research Achievement Award", 2020). On top of all of these achievements, he received the Collegiate Teaching Award in 2017 from the University of Iowa's College of Education.

Career

Throughout Dr. Paulsen's career, he has played a vital role in the publication of numerous academic books, journals, and articles. One of his most notable is his role as a Series Editor in the annually published volumes, since 1985, of *Higher Education: Handbook of Theory and Research*. Dr. Paulsen has been an editor on a multitude of scholarly pieces that break down and examine almost every part of the economics behind higher education. The impact of his writings can be put into perspective with the fact that just his 77 articles on Google Scholarly alone have been cited 7869 times as of March 25, 2020 (Paulsen, 2020). The work done by researchers, like Dr. Paulsen, are the reason the average public can now see this crisis in plain view. Without people like him, it would be near impossible to be able to lay out a plan to overcome our broken higher education system.

Representative Pramila Jayapal Biography

Pramila Jayapal is a U.S Representative for Washington's 7th congressional district and a strong advocate of ensuring access to higher education for all. She was born in India and came to the United States by herself at the age of 16 to attend an American university ("About Me - Congresswoman Pramila Jayapal", 2020). Representative Jayapal earned her bachelor's degree at Georgetown University and went on to earn a Master of Business Administration (MBA) at Northwestern University. In 2014, Representative Jayapal was elected to the Washington State Senate for District 37. Then, in 2017, she was elected as the U.S. Representative for Washington's 7th congressional district.

Career

As Senator Bernie Sanders, Representative Ilhan Omar, and Representative Pramila Jayapal introduced the College for All act, Representative Jayapal stated, "There is a crisis in higher education at a time when a postsecondary degree is more important than ever" (Forrest, 2020). Representative Pramila has been passionate about advocating for reforms that consider the ideals of individual students and believes that all students should have an opportunity to get a higher education ("Education — Pramila for Congress", 2020). In 2016 as State Senator, along with Representative Gerry Pollet and Senator David Frockt, she introduced the Washington Promise program that proposed two years of free community college for all Washingtonians ("Jayapal/Frockt 'Washington Promise' introduce in Legislature", 2016). Representative Jayapal has continued her fight for students' rights with the introduction of the Students Not Profits Act in 2019 with Senator Sherrod Brown. This act would remove subsidies to predatory for-profit colleges and protect students ("JAYAPAL & BROWN INTRODUCE BICAMERAL BILL TO PROTECT STUDENTS FROM PREDATORY FOR-PROFIT COLLEGES - Congresswoman Pramila Jayapal", 2019). One of the largest contributions she made to higher education was authoring the College for All Act, which Senator Bernie Sanders is promising to pass if elected president ("About Me - Congresswoman Pramila Jayapal", 2020; Sanders, 2020).

Mathematical Tools

The solution to the student loan debt crisis is twofold. The first aspect is the student loan debt itself. This aspect of the crisis is the most acute and must be dealt with immediately. The second aspect is fully funding public higher education to make college tuition free at the point of service.

Aspect I: The Acute Loan Debt Crisis

Forgiving \$1.6 trillion of student loan debt requires an adjustment in tax policy. In order to raise enough revenue to pay off remaining principals, the team employed two taxation models to construct a cost-benefit analysis. The team focused on ensuring that additional taxation would meet the funding threshold without putting unnecessary pressure on working families.

Value Added Tax

Value added tax (VAT) is used in over 150 countries around the world--especially European countries. The system is generally used in lieu of a sales tax system. The principle behind a value added tax is that a tax is added after each step in an item's production, manufacturing, distribution, and retailing process. During each step in the above process, value is added to the item. Thus, a *value added tax* is imposed. Below is a basic example of a 10% VAT on an item.

10% VAT Example

key	Producer	Manufacturer	Distributor	Retailer	VAT.Gov.SUM
Good Sold at	\$5.00	\$8.00	\$15.00	\$32.00	NA
VAT 10%	\$0.50	\$0.80	\$1.50	\$3.20	NA
Total Sale USD	\$5.50	\$8.80	\$16.50	\$35.20	NA
Output VAT	\$0.50	\$0.80	\$1.50	\$3.20	NA
Input VAT	NA	\$0.50	\$0.80	\$1.50	NA
Amount Paid to Government (Output - Input)	\$0.50	\$0.30	\$0.70	\$1.70	\$3.20

Table 2

The tax on an item is distributed among each phase of development before it reaches the consumer. The higher the profit margin on an item, the higher the VAT will be. The consumer ends up paying the full VAT which is comparable to a sales tax. However, with a VAT system, the retailer is not solely responsible for paying the “sales” tax back to the government. This incentivizes all levels of the market to add fair values to their items so that they do not have to pay more tax.

Financial Transaction Tax

Financial transaction taxes (FTT) are taxes levied against the transaction of financial holdings such as stocks and bonds (Giralt, 2018). In theory, an FTT would place a fractional tax on each of these numerous transactions, and as time progresses, these small figures will add up to a substantial amount of revenue. In many European countries, these types of taxes became quite popular following the 2008 subprime mortgage crisis (Giralt, 2018). Bernie Sanders proposed a model already tailored to the current US economy making it the most useful in this situation.

Transaction.Type	Percent
Stocks	0.5%
Bonds	0.1%
Derivatives	0.005%

Table 3

Aspect II: Regression and Predictive Modeling

The US economy is a dynamic system, and its many markets behave in different ways. The markets targeted by proposed taxes discussed above will change with time. The team needed to estimate how fast and to what degree these markets would change. In order to do this, the team employed methods from *Regression Analysis*. Regression analysis is a branch in statistics which focuses on uncovering patterns in related data. Specifically, regression analysis looks at the relationship between an independent variable[s] (input data) and a dependent variable (output data). If discovered, emergent patterns can be used to predict short-term future behavior of a given system.

Linear Regression and R² Correlation Coefficients

The most common method in regression is the straight-line (linear) model. The purpose behind a linear regression model is to be able to see the trend within a set of data points. The

method is used to find a *best-fit* line that most accurately shows the relationship between the independent (x) and dependent (y) variables.

$$m = \frac{\sum_{i=1}^n [(x_i - \bar{x})(y_i - \bar{y})]}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

$$b = \underline{y} - m\underline{x}$$

To be able to tell the accuracy of the line, R² correlation coefficients are used. The R² correlation ranges from -1 to 1 and gives a numerical value for how well the linear regression line fits the data. For example, if a linear regression line has an R² correlation of 1, that means all of the data points within the given set fall on the linear regression line. If the value is -1, the line is still accurate but the relationship between independent and dependent variables are inverse. The team used this method to make short-term predictions of the consumer market and the increase of total higher education tuition. Both markets displayed strong linear correlations with time.

$$R^2 = \left[\frac{\sum_{i=1}^n [(x_i - \bar{x})(y_i - \bar{y})]}{n(\sigma_x * \sigma_y)} \right]^2$$

Thesis Defense

Cost Benefit Analysis

Joe Biden’s Proposal Analysis

Joe Biden’s plan to reduce the strain on students involves modifying the current system. He will cut monthly payments by at least 50% by lowering the discretionary income amount from 10-15% to 5%. He plans to forgive an individual’s loan after 20 years and does not require payments if their salary is less than \$25,000. Additionally, he wants to make two year community colleges tuition free (Biden, 2020).

He plans to pay for part of this by eliminating the *step-up in basis* tax loophole. According to the US Department of Treasury’s prediction for the fiscal years of 2018-2027, there will be a total of \$416.3 billion dollars of potential tax revenue lost through the step-up in basis loophole. Below is a portion from their income tax expenditures document showing the basis tax loopholes predicted amount (Tax Expenditures, 2017).

ESTIMATES OF TOTAL INCOME TAX EXPENDITURES FOR FISCAL YEARS 2017-2027												
(in millions of dollars)												
	Total from corporations and individuals											
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2018-27
(coal)												
72 Capital gains exclusion of small corporation stock	790	1,020	1,240	1,400	1,520	1,630	1,730	1,830	1,900	1,980	2,050	16,300
73 Step-up basis of capital gains at death	37,919	38,719	39,569	40,169	40,569	41,249	41,869	42,629	43,239	43,829	44,549	416,300
74 Carryover basis of capital gains on gifts	5,190	4,840	4,670	4,560	4,530	4,530	4,560	4,640	4,700	4,730	4,780	46,540
75 Ordinary income treatment of loss from small business corporation stock sale	70	80	80	80	80	80	90	90	90	100	100	870

Table 4

To pay for the rest of his plan, Joe Biden will limit itemized tax deductions to 28% of their total amount (Biden, 2020). The Congressional Budget Office predicted that between 2017 and 2026, a total of \$171.5 billion dollars in tax revenue could be raised by using this new tax law (Congressional Budget Office, 2016). Below is a table showing the results of the Congressional Budget Office’s study.

Billions of Dollars	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2017-2021	2017-2026
Change in Revenues												
Limit the tax benefits of itemized deductions to 28 percent of their total value	7.2	14.9	15.8	16.6	17.4	18.2	19.0	19.9	20.7	21.6	71.9	171.5
Limit the tax value of itemized deductions to 6 percent of AGI	5.2	10.6	11.2	11.6	11.9	12.5	13.2	13.8	14.3	14.9	50.5	119.2
Eliminate all itemized deductions	93.2	193.8	206.4	216.7	227.0	237.0	247.5	258.7	270.4	281.1	937.1	2,231.8

Table 5

Biden’s model predicts a \$750 billion revenue gain over the next 10 years--assuming he starts from the upcoming election year (Biden, 2020). The information provided above serves as an example of how much potential revenue is available. Joe Biden’s plan predicts a longer time frame than the one shown. Although his plan would help many students suffering from expensive monthly payments, there are some serious drawbacks. First and foremost, his plan does nothing to eliminate the \$1.6 trillion in student loan debt that has already accumulated. In fact, under his proposal, the total loan debt would continue to increase since many students would still need to borrow money for school.

Financial Transaction Tax Analysis (Bernie Sanders’ Proposal)

The financial transaction tax (FTT) outlined within Bernie Sanders’ proposal would consist of a 0.5% tax on stock transactions, a 0.1% tax on bond transactions, and a 0.005% tax on the notional value of all derivative trades. In the paper *The Revenue Potential of a Financial Transaction Tax for U.S. Financial Markets*, the authors make an extremely conservative estimate that this FTT would produce \$220 billion a year (Pollin et al., 2017). This plan also includes a caveat that individuals with a salary of less than \$50,000 or \$75,000 for joint-filers will not pay this tax.

The actual amount of funding that this FTT would generate a year can be broken down into the three taxes. In 2018, the total value of stocks traded was \$33.027 trillion ("Stocks traded, total value (current US\$) - United States | Data", 2020). If the proposed tax of 0.5% was implemented, this would generate \$165.135 billion annually. According to the Securities Industry and Financial Markets Association (SIFMA) in 2018, between municipal and treasury bond trades, there was approximately \$201.48 trillion traded in bonds throughout the year which would generate \$201.48 billion per year with a 0.1% tax ("Statistics", 2020). The team conducted an interview with Dr. Thomas Herndon, co-author of *The Revenue Potential of a Financial Transaction Tax for U.S. Financial Markets*, who commented on how it is functionally impossible to get an accurate value of the yearly derivatives change (Herndon, 2020). The research paper used for Senator Sanders’s plan estimated the derivative trade in 2015 was \$1,525 trillion (Pollin et al., 2017). Implementing the 0.005% tax on that value would yield \$76.25 billion. The combination of all of these would produce \$442.865 billion per year. However, that is assuming that every person pays it and implementing this tax would not affect the market.

When proposing a tax on any form of transaction, one must always assume that there will be a drop in trades by the people who do not want to pay this tax. To be able to have a grasp of how much the FTT would affect trading, we can look at the experience France had. In April of 2012, France implemented a similar tax and saw an initial drop of trades of almost 20% (Pollin et

al., 2017). However, this was a short term decrease and overtime the market reabsorbed this loss. To be on the conservative side, the \$220 billion a year figure from the research paper includes a 50% drop in trades as a result of this FTT. Even though it can be reasonably assumed that the trades will not drop 50%, using this value allows us to account for a decrease in the stock market from other outside circumstances. Taking this extremely conservative value for yearly funds allows one to know that, even during the economic downturn we are seeing during COVID-19, the \$220 billion a year is still easily achievable. Since France also saw that the market absorbed the initial decrease in trades, one can also assume that this value will increase as the market returns to stable conditions.

To account for the individuals and families under the \$50,000 salary or \$75,000 net-income for joint-filers, the authors once again used a conservative value. If the average household exempt from these taxes had a stock/bond portfolio of \$300,000 and traded five times that amount every year, each household would trade \$1.5 million annually. If taxed with the proposed FTT, that bracket of individuals would raise \$12 billion annually (Pollin et al., 2017). To be conservative, \$20 billion will be used to ensure that our timelines will be met.

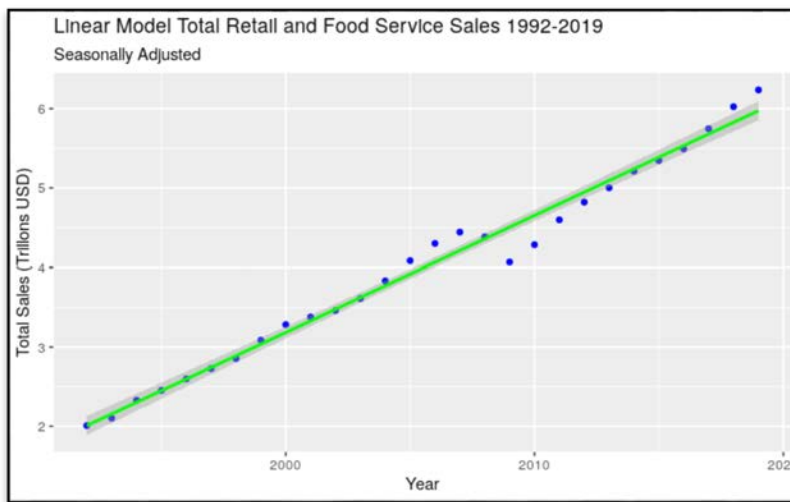
When taking all of this into account, using the stock/bond data from 2018 and the derivative data from 2015, the FTT tax proposed in this paper will generate a minimum of \$211.4325 billion dollars a year. Starting with the \$422.865 billion, \$20 billion is subtracted to account for the tax that would have been generated by individuals and households below the salary Senator Sanders proposes. Next, the \$422.865 billion is multiplied by 0.5, to account for a drop in trading when implemented, leaving the annual funds generated being \$211.4325 billion. It is important to keep in mind that this number is excessively conservative and will likely increase as time goes on. Even if there is a 50% drop in trade when the tax begins, drawing from France's experience, the market will eventually absorb this. Resulting in the actual revenue generated being closer to the \$422.865 billion.

Value Added Tax Model

To pay off the nearly \$1.6 trillion in student loan debt, the team proposes a modest value added tax on retail goods in tandem with Senator Sanders' proposed FTT. This value added tax would be implemented in addition to state and local sales taxes. Figure 3 illustrates the total retail and food service sales in the United States for the past 27 years. A linear regression analysis shows that this data is strongly linearly correlated--possessing an R^2 correlation coefficient of 0.98. It must be noted that the slight valley seen in 2008-2009 is a result of the subprime mortgage crisis. The team also conducted a regression analysis of the data following the crisis. The team observed that the slope of the regression line became steeper following the crash in order to

correct for the drop. The retail sales seem to increase steadily and appear to correct given enough time. It is difficult to assess how these sales will behave in the context of the COVID-19 pandemic,

Figure 3: Regression Line: $f(x) = 0.14685x - 290.52$



but these sales are due to naturally adjust back to this historical trend. This model has a strong enough correlation to predict the future retail sales and can provide a basis for determining the revenue raised by a VAT.

Rise in College Tuition

Using data from the National Center of Education Statistics (NCES), the team developed a regression model to predict the short term rise in tuition/fees of public institutions. Proposals such as Bernie Sanders’ College for All plan estimates that tuition free public college will cost approximately \$70 billion. This figure is not a static number. Total tuition has risen at linear rate over the past 7 years. According to the model our team produced, the reported increase in total

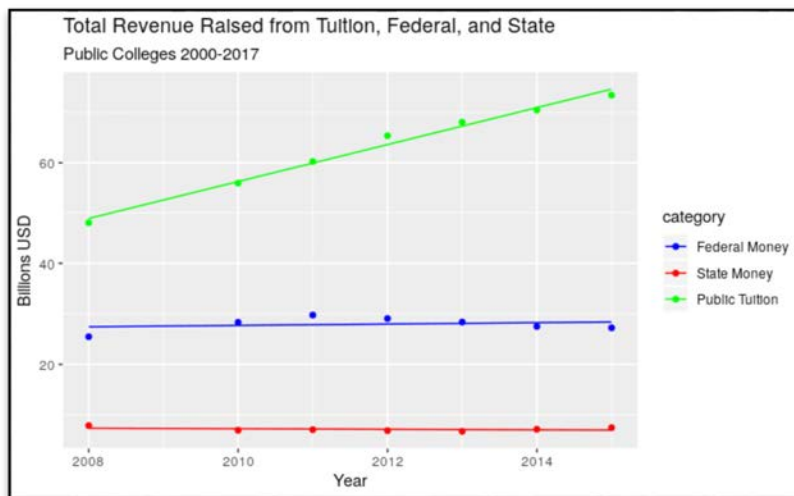


Figure 4

tuition yields a R² correlation coefficient of 0.99. With this in mind, the amount of money the federal government will have to allocate to ensure public college is free will increase gradually every year. It must be noted that some existing models reduce the federal funding amount in relation to state funding. This said, the current COVID-19 pandemic and the subsequent stock market crash, must be taken into consideration. In this time of extreme uncertainty, it is necessary to overestimate the required funding. Past

evidence strongly suggests that economic downturns result in budgetary cuts in higher education. Specifically, past evidence has suggested that State governments will reduce aid to higher education (Emrey-Arras, 2014). For this reason, the team opted not to deduct potential State

revenue from the model as there is no guarantee that this funding will continue at the necessary rate.

Conclusion

Based on the above models, the following can be extrapolated. Figure 5 illustrates three projections plotted against the \$1.6 trillion student loan debt. The model the team developed assumes that at the time of implementation, this plan will freeze all debt payments and hold the \$1.6 trillion debt as a static balance. The model shows the effects of Bernie Sanders’ proposed FTT supplemented by the team’s proposed VAT. Since the state of the economy is highly volatile due to the COVID-19 pandemic, the team has proposed three VAT models to varying degrees.

It should be noted that VAT is a regressive model (Tax Policy Center, 2020). The Tax Policy Center’s article *How Could We Improve the Federal Tax System* states, “A value-added tax (VAT) is a tax on consumption. Poorer households spend a larger proportion of their income. A VAT is therefore regressive...” (Tax Policy Center, 2020). However, a federal VAT could be altered in two specific ways to suit the economy at any given time. First, the VAT percentage could be lowered if need be. Secondly, a tax-credit system could be implemented for the federal VAT if the strain on low-income citizens becomes too high. This would allow for tax refunds on items purchased by low-income families. A VAT on goods such as food, medicine, and living essentials could be refunded at the end of the year.

With this in mind, the following model shows the effect of a supplemental VAT at 2%, 1%, and 0.5%. This model includes a deduction to account for annual tuition-free public college. If implemented in 2021 combined with an FTT, a 2% VAT (illustrated in green) would pay off student loans by 2027; a 1% VAT (illustrated in blue) suggests student loans would be paid off by 2030; a 0.5% VAT (illustrated in purple) suggests student loans would be paid off by 2032.

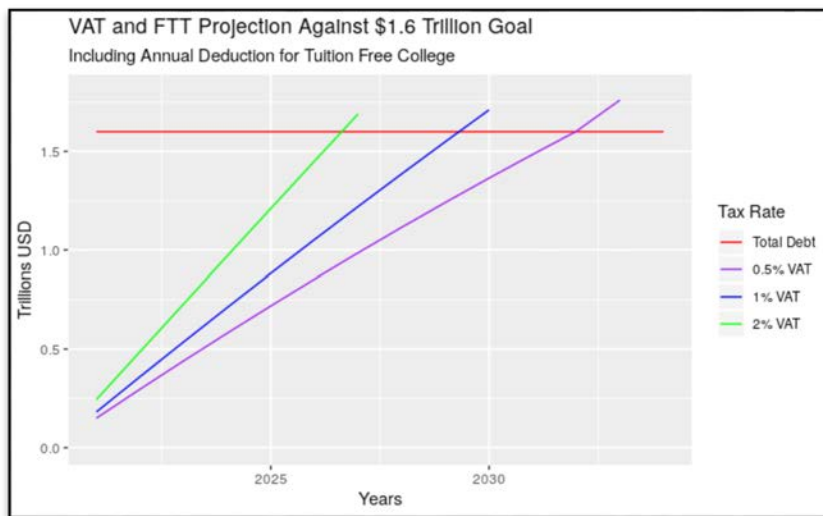


Figure 5

a 0.5% VAT (illustrated in purple) suggests student loans would be paid off by 2032.

The proposed VAT would contain a sunset provision, so that after the student loan debt has been paid back, the tax would no longer affect retail sales. Public tuition would continue to be funded by Senator Sanders’ modest FTT. If the trend in rising tuition costs holds, the conservative estimate for the FTT would cover the cost of tuition for the next three decades

before needing adjustment (see appendix A). This said, it is likely the model will change over time due to unforeseen factors. Fortunately, this uncertainty can be addressed by excess revenue from FTT. The proposed FTT raises more than is currently necessary to pay for tuition and will increase as the stock market inevitably grows. This money can be placed in a reserve that can be used to supplement later years which do not raise enough revenue for tuition. This said, the reserve amount varies depending on the VAT supplement. This is due to the fact that while the revenue is allocated to paying off student loan debt, no money will be applied towards this reserve. The date at which the reserve begins is dependent upon the implemented VAT. Figure 1 in Appendix A models the growth of this reserve using the conservative \$211 billion FTT revenue estimate.

The team would urge immediate implementation of this proposal as COVID-19 spreads. With the instability of markets and many citizens losing their jobs, debt relief is of paramount importance. Not only does this proposal provide individual relief, mass debt forgiveness and free college would stimulate the economy. Since the projections used are conservative, the team believes that these models are both timely and realistic within the context of the given crisis.

Addressing Concerns

The team has raised some important questions regarding how the proposed ideas will affect the current system. Since the plan given by the team only covers the cost of tuition, how will students pay for room and board? The answer lies in the current Pell Grant system. Students who cannot afford room and board even after having free tuition, will be eligible to apply for a Pell Grant. In 2017, the federal government issued \$30 billion in Pell grants (Mulhere, 2017). Also, more than \$7.4 billion dollars of private scholarships/fellowships are given every year to qualifying students (Kantrowitz 2019). This money is no longer needed to help with tuition and could be used to fund student housing and dining. Federal and private student loans will still be available under the current system for paying for private schools and any leftover room and board costs not covered by the Pell Grants. These loans will have fixed, low interest rates and fair repayment plans. Students are solely responsible for paying any loans taken out after the start of the \$1.6 trillion debt pay off.

Future Study

While researching this topic, questions were raised about the role that higher education plays in our society. One of the most glaring issues still unaddressed are the underlying symptoms of rising tuition costs. The team suggests that further research should be conducted into assessing the competitive model of higher education. Economists such as Andrew Gillin and Howard Bowen point out that the structure of higher education does not always focus on the quality of education. Instead, metrics such as prestige and excellence drive up costs and artificially increase tuition. In today's economic landscape, postsecondary education is no longer a luxury. It has become a necessary aspect in becoming financially stable in the United States. Based on this reality, it is our suggestion that colleges put their focus on effectively educating the future students. Our study has heavily focused on developing a system that ensures every American citizen has the opportunity to attend college and receive an education, and we hope that research in this area continues.

Acknowledgements

We would like to thank Senator Amy Klobuchar for taking the time to answer the list of questions we had. We know it's a chaotic time right now during the COVID-19 pandemic and greatly appreciate her response.

We also like to show our gratitude to Dr. Thomas Herndon for allowing us to interview him. His expertise in economics and contributions to *The Revenue Potential of a Financial Transaction Tax for U.S. Financial Markets* helped us immensely.

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Appendix A: Additional Data

	Education	total
1	Associate's degree, academic	13761
2	Associate's degree, occupational	10341
3	Bachelor's degree	51406
4	Doctoral degree	4487
5	Master's degree	21280
6	Professional degree	3202
7	Some college, no degree	46175

Data use in **figure 1** sourced from the United States Census Bureau. Educational Attainment in the United States: 2018.

Source:

Table 1. Educational Attainment of the Population 18 Years and Over, by Age, Sex, Race, and Hispanic Origin.

14 Year Projected Tuition Increase Billions USD (R²=0.99)

Year	Projeted.Tuition.Increase
2021	96.73266
2022	100.40992
2023	104.08718
2024	107.76444
2025	111.44170
2026	115.11896
2027	118.79622
2028	122.47348
2029	126.15074
2030	129.82800
2031	133.50526
2032	137.18252
2033	140.85978
2034	144.53704

14 Year Projected VAT in Trillions USD (R²= 0.98)

Year	Total	VAT.0.5percent	VAT.1percent	VAT.2percent
2021	6.26154	0.03130770	0.0626154	0.1252308
2022	6.40839	0.03204195	0.0640839	0.1281678
2023	6.55524	0.03277620	0.0655524	0.1311048
2024	6.70209	0.03351045	0.0670209	0.1340418
2025	6.84894	0.03424470	0.0684894	0.1369788
2026	6.99579	0.03497895	0.0699579	0.1399158
2027	7.14264	0.03571320	0.0714264	0.1428528
2028	7.28949	0.03644745	0.0728949	0.1457898
2029	7.43634	0.03718170	0.0743634	0.1487268
2030	7.58319	0.03791595	0.0758319	0.1516638
2031	7.73004	0.03865020	0.0773004	0.1546008
2032	7.87689	0.03938445	0.0787689	0.1575378
2033	8.02374	0.04011870	0.0802374	0.1604748
2034	8.17059	0.04085295	0.0817059	0.1634118

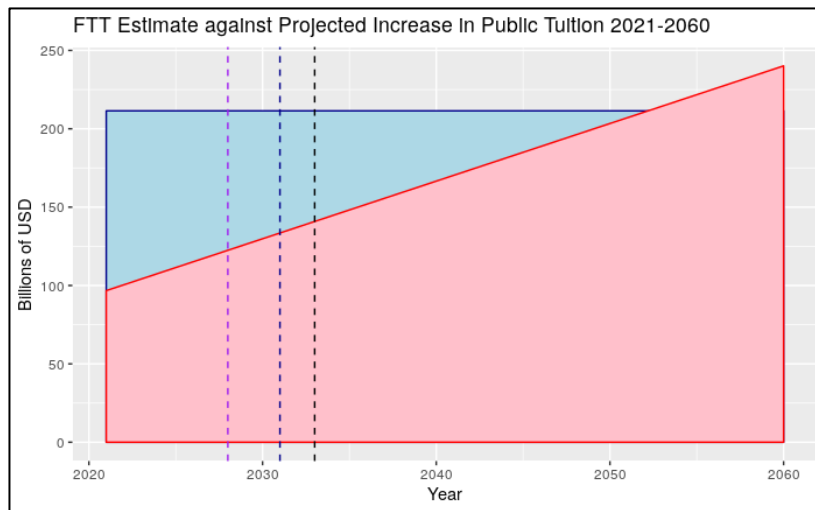
Projected Annual Average Tuition in Public Colleges and Universities in USD

year	tuition.projected
2020	7502.819
2021	7741.271
2022	7984.729
2023	8233.192
2024	8486.660
2025	8745.133
2026	9008.612
2027	9277.095
2028	9550.584
2029	9829.078
2030	10112.577
2031	10401.081

Accumulated VAT at 2%,1%,0.5% Plus FTT Minus Public Tuition Trillions USD

Year	VAT.FTT.Minus.Tuition2	VAT.FTT.Minus.Tuition1	VAT.FTT.Minus.Tuition0.5
2021	0.2436079	0.1809925	0.1496848
2022	0.4864755	0.3597762	0.2964266
2023	0.7286029	0.5363512	0.4402254
2024	0.9699900	0.7107174	0.5810811
2025	1.2106369	0.8828749	0.7189939
2026	1.4505435	1.0528236	0.8539636
2027	1.6897098	1.2205635	0.9859904
2028	1.9281359	1.3860947	1.1150741
2029	2.1658217	1.5494171	1.2412148
2030	2.4027673	1.7105308	1.3644125
2031	2.6389726	1.8694357	1.4846672
2032	2.8744376	2.0261318	1.6019789
2033	3.1532895	2.2247463	1.7604747
2034	3.4314012	2.4211521	1.9160275

Figure 1



$$\int_{2028}^{2052} 211.4325 - (3.677x - 7335.0098)dx = \$1088.6952 \text{ billion}$$

$$\int_{2031}^{2052} 211.4325 - (3.677x - 7335.0098)dx = \$836.7828 \text{ billion}$$

$$\int_{2033}^{2052} 211.4325 - (3.677x - 7335.0098)dx = \$687.2262 \text{ billion}$$

Appendix B: Selected Code Snippets

Census Data Cleaning:

```
library(dplyr)

Edu<-table_1_1 %>%
  head(15)%>%
  filter(...1=="18 years and over")%>%
  select(...1,`Some college, no degree`,`Associate's degree, occupational`,
          `Associate's degree, academic`,`Bachelor's degree`,`Master's degree`,
          `Professional degree`,`Doctoral degree`)%>%
  gather(key=Education,value=Individuals,`Some college, no degree`,
          `Associate's degree, occupational`,`Associate's degree, academic`,
          `Bachelor's degree`,`Master's degree`,`Professional degree`,`Doctoral degree`)%>%
  group_by(Education)%>%
  summarize(total=sum(Individuals))

library(grid)
library(gridExtra)
grid.table(Edu)

ggplot(data=Edu)+geom_bar(mapping = aes(x=Education,y=total),stat="identity",fill="Blue")+
  theme(axis.text.x=element_text(angle=25))+labs(x="Education Level",y="Individuals in Each Category (thousands)",title="Post
Secondary Education Attainment in the US 2018",subtitle = "18 years and over")+coord_flip()
```

Total Average Tuition Public, Private, For Profit Data Cleaning:

```
AllColleges<-tabn330_10 %>%
  head(64)%>%
  filter(!is.na(...1) & ...1 != "1" & ...1 != "All institutions")%>%
  mutate(...1=as.Date(...1,"%Y"))%>%
  select(...1,`All insti-tutions...2`)

AllColleges

ggplot(data=AllColleges,aes(x=...1,y=`All insti-tutions...2`))+geom_line(color="Red")+labs(x="Year
1963-2017",y="Tuition",title="Average Tuition, Fees, and Room and Board 1963-2017", subtitle="All institutions (Public,
Private, Non-Profit) Dollars based on Consumer Price Index")+ theme(axis.text.x=element_blank())
```

Annual Total Tuition Public Tuition Data Clean:

```
# Clean data from Education Statistics
# Total Tuition per year
# Select range|
revenueSource<- tabn333_10[1:7,3:5]%>%
  filter(!is.na(...3)) %>%
  mutate(tuition = as.double(...3)/1000000) %>%
  mutate(year = 2009:2015) %>%
  mutate(year = ifelse(year == 2009, 2008,year))%>%
  mutate(federal.money = as.double(...4)/1000000)%>%
  mutate(state.money = as.double(...5)/1000000)%>%
  select(year,tuition,federal.money,state.money) %>%
  gather(key=category,value=money,tuition,federal.money,state.money)
```

VAT Projection Calculation:

```
# Convert VAT Data to trillions USD
VATData2<-Value_Added_Tax_Data_Sheet2 %>%
  mutate(Total=`Total` (Trillions)`/1000000) %>%
  select(Year,Total)

# Linear Model for Growth of retail market
LinearProjection<-function(x){
  return((0.14685*x) - 290.52231)
}

# Years
Year<-c(2021,2022,2023,2024,2025,2026,2027,2028,2029,2030,2031,2032,2033,2034)

# Annual Projection
Total<-c(LinearProjection(2021),LinearProjection(2022),LinearProjection(2023),LinearProjection(2024),LinearProjection(2025),LinearProjection(2026),LinearProjection(2027),LinearProjection(2028),LinearProjection(2029),LinearProjection(2030),LinearProjection(2031),LinearProjection(2032),LinearProjection(2033),LinearProjection(2034))

# Calculate Taxes at different Rates| rates
VAT1<-data.frame(Year,Total)%>%
  mutate(VAT.0.5percent = (Total * 0.005))%>%
  mutate(VAT.1percent = (Total * 0.01))%>%
  mutate(VAT.2percent = (Total * 0.02))
```

Calculated Tax Policies accounting for Tuition Increase

```
# Load tidyverse library
library(tidyverse)

VAT.FTT<-VAT1%>%
  cbind(TP14$Projected.Tuition.Increase)%>%
  # Calculate VAT 2% + FTT
  mutate(VAT.plus.FTT.2 = VAT.2percent + 0.2114325)%>%
  # Calculate VAT 1% + FTT
  mutate(VAT.plus.FTT.1 = VAT.1percent + 0.2114325) %>%
  # Calculate VAT 0.5% + FTT
  mutate(VAT.plus.FTT.0.5 = VAT.0.5percent + 0.2114325) %>%
  # Convert Projected Tuition to Trillions USD
  # Remove from Tax revenue|
  mutate(VAT.FTT.Minus.Tuition2 = VAT.plus.FTT.2 - (TP12$Projected.Tuition.Increase/1000))%>%
  mutate(VAT.FTT.Minus.Tuition1 = VAT.plus.FTT.1 - (TP12$Projected.Tuition.Increase/1000)) %>%
  mutate(VAT.FTT.Minus.Tuition0.5 = VAT.plus.FTT.0.5 - (TP12$Projected.Tuition.Increase/1000)) %>%
  select(Year,
         VAT.FTT.Minus.Tuition2,
         VAT.FTT.Minus.Tuition1,
         VAT.FTT.Minus.Tuition0.5)
```

Calculate Running Total of Revenue

```
# Calculate the running total of tax revenue
# 14 year projection
for(i in 1:14){
  if(VAT.FTT$VAT.FTT.Minus.Tuition2[1] == VAT.FTT$VAT.FTT.Minus.Tuition2[i])
  {
    VAT.FTT$VAT.FTT.Minus.Tuition2[i] = VAT.FTT$VAT.FTT.Minus.Tuition2[i]
    VAT.FTT$VAT.FTT.Minus.Tuition1[i] = VAT.FTT$VAT.FTT.Minus.Tuition1[i]
    VAT.FTT$VAT.FTT.Minus.Tuition0.5[i] = VAT.FTT$VAT.FTT.Minus.Tuition0.5[i]
  }else{
    VAT.FTT$VAT.FTT.Minus.Tuition2[i] = VAT.FTT$VAT.FTT.Minus.Tuition2[i] + VAT.FTT$VAT.FTT.Minus.Tuition2[i-1]
    VAT.FTT$VAT.FTT.Minus.Tuition1[i] = VAT.FTT$VAT.FTT.Minus.Tuition1[i] + VAT.FTT$VAT.FTT.Minus.Tuition1[i-1]
    VAT.FTT$VAT.FTT.Minus.Tuition0.5[i] = VAT.FTT$VAT.FTT.Minus.Tuition0.5[i] +
    VAT.FTT$VAT.FTT.Minus.Tuition0.5[i-1]
  }
}
}
```

Appendix C: Notes on Programming Tools

The R language and RMarkdown software were used to conduct the statistical analyses seen in this paper. R is a versatile programming tool with many packages. Below are listed the packages used:

R Version: 3.5.2 “Eggshell Igloo”

formattable : used to generate the tables in this paper

tidyverse : large data manipulation package use to wrangle public education data

ggplot2 : used to generate the graphics and charts in this paper

dplyr : data cleaning tools

In addition, an existing linear regression tool written by a team member was used to find the equations of the regression lines used in this analysis. This tool was written in Python3 in 2019 and proved useful in this project. Source code is included below:

Appendix C: Notes on Programming Tools

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```
#
# Program Title: Linear Regression
# Date Created: 29 October, 2019
#

#
#
# INTRODUCTION
# -----
#
# This program is designed to create a simple linear regression model for a series of (x,y)
coordinates
# A regression line is a linear function that best fits a data set when plotted on a cartesian graph
#
# Data Source: This program is designed to import the (x,y) coordinates from a comma
delimited .dat file
# This programs default uses a test file named Regression.dat
#
# NOTES ABOUT GRAPHICS
# -----
#
# This program utilizes the graphics module by John Zelle
# Program renders a 650x650 pixel window
# Program graphs the (x,y) coordinates, error bars, and regression lines in black
# Error bars are labeled in red with its y value
# The x,y axis will be labeled by increments of 5 in black
#
# FORMULAS USED
# -----
#
# The regression line will take the standard form  $y = mx + b$  in  $R^2$ 
# Where 'm' denotes the slope
# Where 'b' denotes the y intercept
# Where 'x' denotes the independent variable
# Where 'y' denotes the dependent variable
#
# The  $R^2$  correlation coefficient exists in the range  $-1 \leq R^2 \leq 1$ 
# When  $R^2 == +1$  this indicates a strong positive correlation
# When  $R^2 == -1$  this indicates a strong negative correlation
# When  $R^2 == 0$  this indicates no correlation
#  $R^2$  value is an indicator of the 'Goodness to fit' of a linear function to a scatter plot
#
# Formula used for calculating standard deviation (stdv)
# Where 'x_bar' denotes the mean of x coordinates of data set
```

```

# Where 'n' denotes the size of the dataset
#
# stdv_x = sqrt( $\sum(xi-x\_bar)^2/n$ )
# For stdv_y, replace xi and x_bar with y
#
# Formula used for calculating R**2
# R**2 =  $\{(1/n)*\sum[xi-x\_bar]*[yi-y\_bar]/(stdv\_x*stdv\_y)\}^2$ 
#
# Formula used for calculating 'm' or slope:
# m =  $\sum [(xi - x\_bar)(yi - y\_bar)] / \sum [(xi - x\_bar)^2]$ 
#
# Formula used to find the 'y' intercept:
# b = y_bar -(m*x_bar)
#
# TESTING
# -----
#
# To make sure the program works properly the following should be outputted:
# Regression Line: y = 1.34 x + 11.43
# R**2 Coefficient: 0.56
# Suggested chart size: 35x35
#
#

import math
# graphics module by John Zelle
import graphics

# GRAPHICS FUNCTION
# -----

def main(x,y,b,m,range_axis, errorList):
    """Please note that since datasets vary in scale, in the future,
    I would like to give the user more control over the display.
    Currently, the only power they have is setting the axis range.
    Elements such as title, axis padding, spacing, etc. are all
    proportional to the entered "range_axis".

    Formal Parameters:
    x == x points
    y == y points
    b == y intercept of regression line
    m == slope of regression line

```

```

range_axis == the max range of x and y axis
errorList == a list containing the y values that lie on regress line""

# max_x and max_y are used to make the x and y axis
max_x = range_axis
max_y = range_axis
# regress variable is the y coordinate of the regression line
regress = ((range_axis/2)*m) + b

# x and y axis denoted by vertical lines
y_axis = graphics.Line(graphics.Point(0,0),graphics.Point(0,range_axis))
y_axis.setArrow('last')

x_axis = graphics.Line(graphics.Point(0,0),graphics.Point(range_axis,0))
x_axis.setArrow('last')

# Plot the regression line
regress_line = graphics.Line(graphics.Point(0,b),graphics.Point((range_axis/2), regress))
regress_line.setFill(graphics.color_rgb(0,0,0))

# set the color of x and y axis
x_axis.setFill(graphics.color_rgb(0,0,0))
y_axis.setFill(graphics.color_rgb(0,0,0))

# Set the size of the window
win = graphics.GraphWin('Regression Plot', 700,700)

# Set the coordinate range
win.setCoords(-range_axis/4,-
range_axis/4,range_axis+(range_axis/4),range_axis+(range_axis/4))
win.setBackground(graphics.color_rgb(255,255,255))

i = 0
while len(x) > i: # This loop plots data points

    k = x[i] # store x value at index i
    z = y[i] # store y value at index i
    data = graphics.Point(k, z) # store as point
    data.setFill(graphics.color_rgb(0,0,0)) # set point color
    data.draw(win) # draw the point on the window

    i = i + 1

```

```

i = 0
while i < range_axis: # Loop sets dash mark on y axis

    y_dash = graphics.Line(graphics.Point(0,i),graphics.Point(-
range_axis/(range_axis*4),i))
    y_dash.setFill(graphics.color_rgb(0,0,0))
    y_dash.draw(win)
    i = i + 1

i = 0
while i < range_axis: # Loop sets dash mark on x axis

    x_dash = graphics.Line(graphics.Point(i,0),graphics.Point(i,-
range_axis/(range_axis*4)))
    x_dash.setFill(graphics.color_rgb(0,0,0))
    x_dash.draw(win)
    i = i + 1

i = 0
while i < len(y):      # Plots the error bars from points to line

    err_line = graphics.Line(graphics.Point(x[i],y[i]),graphics.Point(x[i],errorList[i]))
    err_line.setFill(graphics.color_rgb(0,0,0))
    # iterates over the y values and compares them to the y values of the regression
line
    if y[i] <= errorList[i]: # Graphs the error lable above the regression line if y point is
above the line
        err_lable = graphics.Text(graphics.Point(x[i],y[i] -
range_axis/(range_axis*2)), str(y[i]))
        err_lable.setSize(7)
        err_lable.setFill(graphics.color_rgb(255,0,0))
        err_lable.draw(win)
    else: # Graphs the error lable above the regression line if y point is below the line
        err_lable =
graphics.Text(graphics.Point(x[i],y[i]+range_axis/(range_axis*2)), str(y[i]))
        err_lable.setSize(7)
        err_lable.setFill(graphics.color_rgb(255,0,0))
        err_lable.draw(win)

    err_line.draw(win)
    i = i + 1

i = 0
while i < range_axis: # Lables the x axis counting by 5

```

```

        if i/5 == int(i/5):
            x_inc = graphics.Text(graphics.Point(i, -range_axis/50), str(i))
            x_inc.setSize(9)
            x_inc.draw(win)
            i = i + 1
        else: # if i is not divisible by 5, we skip the lable
            i = i + 1

i = 0
while i < range_axis: # Lables the y axis counting by 5
    if i/5 == int(i/5):
        y_inc = graphics.Text(graphics.Point(-range_axis/50, i), str(i))
        y_inc.setSize(9)
        y_inc.draw(win)
        i = i + 1
    else: # if i is not divisible by 5, we skip the lable
        i = i + 1

# style of x axis lable
x_axisLable = graphics.Text(graphics.Point(range_axis + 1, 0), 'x')
x_axisLable.setStyle('italic')
x_axisLable.setFace('times roman')
x_axisLable.setSize(14)

# style of y axis lable
y_axisLable = graphics.Text(graphics.Point(0, range_axis + 1), 'y')
y_axisLable.setStyle('italic')
y_axisLable.setFace('times roman')
y_axisLable.setSize(14)

# Title of graph
title_graphic =
graphics.Text(graphics.Point((range_axis/2),range_axis+(range_axis/8)), 'Linear Regression
Model')

key_graphic = graphics.Text(graphics.Point(range_axis/2, -range_axis/8), '* Error Lables
indicate y values of inputted data (labeled in red)\
\n* Graph scale based on user input (rescale if window does not fit data)')
key_graphic.draw(win)

# Draw above to the window
title_graphic.draw(win)
y_axisLable.draw(win)
x_axisLable.draw(win)

```

```

x_axis.draw(win)
y_axis.draw(win)
regress_line.draw(win)

#Closes window and exits programs
win.getMouse()
win.close()

# FUNCTIONS
# -----

def programWelcome():
    """Welcomes user to program and informs them of program requirements """

    print('Welcome to my linear regression program')
    print(format('-', '-<40'))
    print('Please make sure the data set you would like analyzed has the following: ')
    print( '1. (x,y) coordinates are comma delimited \n2. File is in same directory as program
\n3. File has .dat extension')
    print(format('-', '-<40'), '\n')

def meanBar(list_value):
    """ Calculates the x_bar or y_bar (mean) of given list
    Formal Parameters:
    list_value == list that you want to get the mean of"""

    var_bar = sum(list_value)/len(list_value)
    return var_bar

def stDev(list_value, mean):
    """ Finds the Standard Deviation of any inputted list
    Formal Parameters:
    list_value == list of values to be calculated
    mean == the mean of the list being calculated"""

    n = len(list_value)
    dev = [((a - mean)**2)/n for a in list_value]
    stdev = math.sqrt(sum(dev))
    return stdev

def slope(list_value1, list_value2, mean1, mean2):
    """Find the slope (m) of Regression line
    Formal Parameters:
    list_value1 == x values

```

```
list_value2 == y values
mean1 == x bar
mean2 == y bar"""
```

```
a = [(k - mean1) for k in list_value1]
b = [(k - mean2) for k in list_value2]
c = []
```

```
i = 0
while i < len(a):

    z = a[i] * b[i]
    c.append(z)
    i = i + 1
```

```
sum1 = sum(c)
d = [(k - mean1)**2 for k in list_value1]
sum2 = sum(d)
slope = sum1 / sum2
```

```
return slope
```

```
def rCorr(list_value1,list_value2,mean1,mean2,stDev1,stDev2):
```

```
    """ Finds the R**2 Correlation Coefficient
    Formal Parameters:
    list_value1 == x points
    list_value2 == y points
    mean1 == mean of x values
    mean2 == mean of y values
    stDev1 == standard deviation of x values
    stDev2 == standard deviation of y values"""
```

```
n = len(list_value1)
a = [(k - mean1) for k in list_value1]
b = [(k - mean2) for k in list_value2]
c = []
```

```
i = 0
while i < len(a):

    z = a[i] * b[i]
    c.append(z)
    i = i + 1
```

```

    c = [k/(stDev1*stDev2) for k in c ]
    sum1 = sum(c)

    Rsqr = ((1/n)*sum1)**2
    return Rsqr

def y_intercept(x_bar,y_bar,slope):
    """ Returns the y intercept of regression line
    Formal Parameters:
    x_bar == mean of x values
    y_bar == mean of y values
    slope == m value of regression line"""
    y_intercept = y_bar -(x_bar*slope)
    return y_intercept

def errorPoints(x_points,y_intercept,slope):
    """Makes a list of the y values that lie on the regression line that
    correspond with the x values
    Formal Parameters:
    x_points == x values of dataset
    y_intercept == b value of the regression line
    slope == m value of the regression line"""
    y_points = []

    i = 0
    while i < len(x_points):
        y = (x_points[i]*slope) + y_intercept
        y_points.append(y)
        i = i + 1

    return y_points

# EXTRACTING AND FORMATTING DATA
# -----

# Display the program welcome informs user about program use and parameters
programWelcome()

# We assign a variable with the external .dat file containing (x,y) coordinates
# Set the argument to 'r' since we will need to read the data
regression_data = input('Please input file name: ')
valid = False
while not valid:
    try:

```

```
        regression_data = open(regression_data)
        valid = True
    except IOError:
        print('The file could not be found. Make sure it is in the right directory or is spelled
correctly.')
        regression_data = input('\n Please input file name: ')

# Below are two empty lists that will contain (x,y)
# This list will hold the 'x' values
x_values = []
# This list will hold the 'y' values
y_values = []
# empty string is used to determine when the program should stop reading the .dat file
empty_str= ""
# boolean flag used to break while loop
end_of_file = False

# while loop will iterate through all the data file until end_of_file is True
while not end_of_file:
    # program will read the .dat file line by line
    # .dat file is is formatted as follows:
    # x,y
    xy_line = regression_data.readline()

    # When the the readline() has nothing to read, it will break the loop.
    # A list containing only x values will be printed
    # A list containing only y values will be printed
    if xy_line == empty_str:

        end_of_file = True

    else:
        # xy_line will hold both (x,y) coordinates and store them as a list with a length of
        # Both (x,y) coordinates are held as string values
        # We will store these independent values in all_values
        all_values = xy_line.strip().split(',')

        # Here, we iterate over all_values
        # Each line is held in a list with len of 2
        # Thus index values are [0] and [1] (we are in R^2)
        # Note that we convert from string to float value
        for k in all_values:
            #if index is [0] it is stored as an 'x' value
```

```

        if k == all_values[0]:
            x_values.append(float(k))
        # if index is [1] it is stored as an 'y' value
        else:
            y_values.append(float(k))

#REGRESSION CALCULATION
#-----

# x_bar is the mean of all 'x' values
# formula (1/n)*Σx
x_bar = meanBar(x_values)

# y_bar is the mean of all 'y' values
# formula (1/n)*Σy
y_bar = meanBar(y_values)

m = slope(x_values, y_values, x_bar, y_bar)

stdev_x = stDev(x_values, x_bar)
stdev_y = stDev(y_values, y_bar)

# Calculate the R^2 correlation coefficient
R = rCorr(x_values, y_values, x_bar, y_bar, stdev_x, stdev_y)

# Calculate the y intercept
b = y_intercept(x_bar, y_bar, m)

# Calculate all of the y values on the line to be used to plot error bars
errorList = errorPoints(x_values, b, m)

# USER DISPLAY
# -----
# Ask user if they would like to continue with program or go back and edit data
proceed = input('Would you like to proceed? [y/n] ')
# Boolean flag to kill loops
boolean = True

while boolean == True:
    if proceed == 'y':

        #Display the regression line in y = mx + b form and R^2 correlation coefficient
        print('\n Below is the regression line in y = mx + b format (rounded to 2 decimal
places) :\n ')

```

```

print('y = ',format(m, '.5f'),'x + ',format(b, '.5f'))
print('With an R^2 correlation coefficient', format(R, '.2f'))
boolean = False
# Ask user if they would like to see a regression chart
graphic = input('\n Would you like to see a graphic? [y/n] ')
boolean_2 = True # New boolean flag to break following loops

while boolean_2 == True:

    if graphic == 'y':
        print('The maximum x value is ',max(x_values),'The maximum y
value is ',max(y_values))
        # ask user to set the range of the x,y plot using the largest value
in dataset
        print('For the best view, set the range to the largest number in
your dataset')
        range_axis = float(input('Please set the range of the x,y plot (e.g 5
yields a 5 x 5 chart): '))
        # Call the 'main' function to display the chart
        main(x_values,y_values, b,m, range_axis, errorList)
        boolean_2 == False
    # Exit the program
    elif graphic == 'n':
        boolean_2 = False
        print('See you around!')

    else:
        print("That is not a valid option")
        graphic = input('\n Would you like to see a graphic? [y/n]')

elif proceed == 'n': # Tells user to reformat data and try again
    print('Your reformat your data and try again')
    boolean = False

else: # if user fails to input [y/n] ask again
    print('Sorry ',proceed, 'could not be understood')
    proceed = input('Would you like to proceed? [y/n] ')

```