ESSAYS ON THE MARKET FOR HIGHER EDUCATION AND PUBLIC POLICIES

by

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ABSTRACT

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My dissertation analyzes the government provision of education. The first chapter evaluates how state performance-based funding affects student outcomes and other intermediate measures. I find significant increases to completion rates, retention rates and student's future income attributed to these programs. Further, the improvements increase with the amount of state funding allocated based on college performance. My second chapter uses a quantitative equilibrium model of the market for higher education to evaluate the impact of performance-based federal financial aid. The model reveals that basing a rating system entirely on one measure may lead to minor increases in the incentivized area and considerable decreases in other areas. My final chapter develops a majority voting model with both K-12 and post-secondary education to gain insight into how the education budget is allocated in the presence of heterogeneous agents with conflicting preferences. The model predicts an inverted U-shape relationship between income inequality and the education fund allocation within a state. This prediction is confirmed by the data.

Keywords: Public Economics, Higher Education, Education Finance, Incentivized Compensation.

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PREFACE

I want to thank my thesis committee members—Professor Daniele Coen-Pirani, Marla Ripoll, Daniel Berkowitz, and Dennis Epple—for their time and feedback. Their guidance has positively contributed to my development as an economist.

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1.0 INTRODUCTION

A common theme in my research is the study of incentivized compensation schemes. I also have broader theoretical and empirical research related to the impact public finance has on public organizations. I employ structural models, their quantitative versions, and empirical strategies to study these topics.

My first chapter titled "Grading Colleges: An Empirical Analysis of State College Performance-Based Funding," studies the impact of tying state public college funding to specific college outcomes, a practice utilized in more than 30 states. Despite the widespread use, the effectiveness of these policies is still an open issue. I analyze the impact of performance-based funding on college outcomes using a triple-difference model along with a unique dataset I construct containing all state performance-based funding implementations. I find that adopting performance funding and allocating a larger portion of public funds based on performance funding significantly increases both the completion and retention rates. Selection of students, seen through an increase in the average SAT score, are driving these results. However, there is evidence that complicated performance-based funding programs lead to colleges shifting spending away from instruction towards administration, potentially to remain in compliance with the new funding program. I also find that the measures chosen to allocate funding differentially affect outcomes, with access and progression having the largest effects.

The federal government is also considering adopting performance-based funding, with a number of current proposals suggesting that the federal Pell Grant be tied to school outcome measures. My second chapter, “Access, Affordability, and Outcomes: Evaluating Rating-Based College Aid,” considers how a performance-based federal aid system would change the decisions of colleges and students. Since these changes have not yet been made and a change to federal aid would effect both public and private colleges, empirical analysis can not evaluate a federal performance-based funding program. Therefore, I build a structural model of the market for higher education to simulate a performance-based federal aid system. The model yields three main results. First, a performance-based system that is based entirely on either access, affordability, or student outcomes, would lead to minor a increase in the incentivized area and considerable decreases in the other two areas. Second, I show that performance-based federal aid can increase the overall welfare of the students. Third, performance-based systems based on access or affordability can be used to remove the incentive for colleges to respond to increases in federal aid by raising tuition.

In my third chapter, “Allocating Education Funds Between Different Levels of Education: A Majority Voting Result,” I explore why states spend different proportions of their education budgets on college education. I find empirical evidence that differences in income distribution across states are an important determinant of funding. To explore this relation, I build a majority voting model with two complementary levels of education: a compulsory lower level and a partially-funded higher level. The model reveals intuition about why differences in the income distribution of state residents could lead to different allocations of the education budget.

Educational funding has assumed a larger portion of state, federal, and household budgets over time. In my research, I employ both structural and empirical techniques to explore this topic of public finance. Since each technique has its own limitations and advantages, using both methods allows me to gain a more complete understanding of the problem at hand. My research investigates how changing public policies change incentives, an important consideration that could inform policy discussions in the United States and many other countries.

2.0 GRADING COLLEGES: AN EMPIRICAL ANALYSIS OF STATE COLLEGE PERFORMANCE-BASED FUNDING

2.1 INTRODUCTION

In the public sector, the reliance on performance-based measures in the budgeting process has become increasingly common. This movement towards public accountability is a response to criticism that public organizations, compared to private organizations, are less effective and responsive to external interests [Rabovsky, 2012]. By allocating public funds based on performance, the government creates a direct incentive for public organizations to improve efficiency and performance. Allocating spending based on outcomes also improves the efficiency of government spending since funds are allocated to more efficient organizations [Dougherty and Reddy, 2011].

In state governments' financing of higher education, performance based funding (PBF) plays an important role. PBF has been utilized as a tool to address concern about the overall poor performance of American public colleges. When compared to other international institutions, American colleges are ranked poorly in measures of student success.[1] To push colleges towards better outcomes, many states have experimented with basing public

[1] According to a report by National Student Clearinghouse [2012], under 60 percent of United State's first-time degree seeking students who begin at a four-year public university complete their degree within six years, making the United States college completion rate and college attainment rate lower than those of many advanced economies.

college appropriations on college outputs. Since 1979, thirty-four states have used performance measures to allocate some portion of either four-year or two-year college funding. This movement towards college accountability extends beyond state governments. Recently, the federal government has advocated changing the Pell Grant program to tie federal college aid to the performance of colleges.[2] Despite widespread use, the effectiveness of PBF is still an open issue, partially due to the fact that PBF adoption is not a random event. Further, it is not clear which PBF characteristics are most effective at improving college performance.

In this paper, I utilize a unique dataset I constructed containing all implementations of state PBF along with college-level data to examine the effect of state PBF on four-year college outcomes. I estimate the effect of PBF on the incentivized outcomes often used by states as performance measures. I differentiate funding programs based on the amount of funding available to estimate of how allocating funding based on PBF metrics affects outcomes. I also explore how colleges respond to PBF by utilizing data on student labor market outcomes, college admission decisions, and college spending decisions. Examining this data allows me to observe if colleges are increasing education quality to improve incentivized outcomes or if standards are being changed in response to PBF. In addition, I explore the differential effects of different PBF programs by using information on the specific performance measure used by states to allocate PBF.

In my main specification, I address possible endogeneity issues by using a triple-difference model which controls for state specific trends and nationwide public-college trends. State specific trends, common among states who adopt PBF, are controlled for by comparing the effect of PBF on public colleges to private colleges in the same state. Since PBF changes do not directly affect the funding that private colleges receive from the government, I am able to use private colleges as a control for state-level trends that are

[2] The details of the proposal are outlined in The White House [2013]

common across both types of colleges in states that adopt PBF. Nationwide public-college trends are accounted for by using states that do not adopt PBF as a control for the states that do implement PBF.

I find that implementation of PBF increased the average completion rate by 1.18 percentage points and the average retention rate by 0.87 percentage points. The size of these changes are large in reference to the average 2013 public college completion rate of 48.87% and retention rate of 73.43%. The results are greatly affected by the amount of funding allocated based on performance measures. As states distribute a larger percentage of appropriations based on performance outcomes, colleges further increase their completion and retention rates. Using PBF to distribute an additional $1,000 per in-state full-time equivalent (FTE) public college student further increases the average completion rate by 0.46 percentage points and the average first year retention rate by 0.47 percentage points. I also demonstrate that PBF has a significant effect on student's labor market outcomes. Using PBF to distribute an additional $1,000 per in-state full-time equivalent (FTE) public college student increases student's 2014 median earnings by $1,351 and mean earnings by $671.

I conclude that PBF leads to increased admission standards. Specifically, every year PBF is in effect the average SAT score at public college increases by 1.2 points. This result suggests colleges decide to limit enrollment to high ability students to improve outcomes. I also find PBF causes some unexpected consequences. By examining spending decisions, I find that colleges subject to PBF decrease the amount they spend on instruction by 167 dollars per FTE student. At the same time, colleges increase the amount they spend on administration by 139 dollars per FTE student. These results suggest that the increased administrative responsibility that colleges face leads to colleges decreasing the amount spent on instruction in order to remain in compliance with new performance reporting requirements. Taken together, an increase in the average SAT score combined with a decrease in instruction spending suggests colleges are improving performance through student selection instead of improvements in academic performance.

In addition, allocating funding based on different performance measures has different results. I classify PBF into different categories based on whether funding was tied to research, access, completion, progression, or efficiency. I find that allocating more funding based on the progression and access categories result in the largest changes to incentivized outcomes. Further, these improvements are not only seen in the category which performance funding is attached. Access and progression-based funding programs lead to increases in completion, progression, and efficiency. I also find that increased spending based on access or progression reduce the research measure, suggesting that the goal of improving research output is at odds with the goals of improving completion, progression, and efficiency. The increases to student's future income seem to be driven by programs relying on completion and efficiency-based performance measures.

Digging deeper, I find that colleges respond differently to each category of performance measures. Specifically, the improvements to SAT score are associated with PBF programs that base funding on access and progression. In response to these programs, colleges become more selective and allocate funding towards providing more institutional grants to high ability students. The decrease in instructional expenditure is associated with programs that base funding on completion, research, and efficiency. When PBF programs base funding on these combined measures, in an effort to increase efficiency and reduce waste, colleges decrease the instructional budget.

The problem of incentivizing public colleges to improve the outcomes government values mirrors the multi-task principal-agent problem described in Holmstrom and Milgrom [1991]. Public colleges are optimizing an objective function that is related but distinct from the government's objective of improving the educational quality provided. Public colleges use money received from the government on a variety of tasks in pursuit of maximizing their own goal. Performance funding attempts to push public organizations towards tasks which most improve educational quality by basing college appropriations on a measure which improves with educational quality, such as the completion rate. However under a principal-agent setup with multidimensional incentives, if one of the public college's available tasks will improve the reported measure while having a limited effect on educational quality, the public college may decide to employ this task in order to increase their appropriations. This type of action is referred to as "performance padding" or "window dressing" in Lambert [2001] and Feltham and Xie [1994]. Under PBF, some examples of performance padding are weakening standards or limiting admission to high achieving students, both improve the measure used to allocate funding but not educational quality. On the other hand, increased spending on academic focused programs is an example of a task that may improve educational quality and the incentivized measure.

Previous literature has mainly focused on the primary question of whether PBF programs are effective at improving incentivized measures, though a consensus on the effectiveness has not been reached. Further, there are few comprehensive studies that examine the overall effect of PBF. Shin [2010] finds limited evidence that PBF improves graduation rates. Rabovsky [2012] finds evidence that PBF has changed the spending profile of colleges, resulting in an increase in spending on education related expenses and a decrease in research related expenses. Other studies have focused on specific implementations of PBF, for example Hillman et al. [2015] studies Washington community college PBF, Sanford and Hunter [2011] analyzes PBF used in Tennessee, and Umbricht et al. [2015] researches Indiana PBF programs.

I advance this line of research in several ways. First, I use college-level data to examine the effect on a number of incentivized outcomes. Due to data availability, previous studies limited their analysis by examining how PBF impacts the number of degrees granted, which is not the focus of many PBF programs and contains little information on outcomes such as college access, progression, and efficiency. Second, I control for state-level trends and public-college trends which may have been the catalyst of PBF adoption. Without accounting for these trends, endogeneity may mask the true effect of PBF. Third, to analyze the differential effects of distinct PBF implementations, I construct a new dataset of all PBF programs. This dataset contains information on the incentivized performance outcomes, the percent of funding allocated based on each outcome, and the total amount of funding allocated based on performance. Finally, I examine not only how PBF changes incentivized outcomes but also how PBF changes labor outcomes and college decisions. When colleges are judged based on outcomes such as completion measures, there are concerns that colleges might engage in performance padding and pass students through who otherwise would have failed. Examining only outcomes tied to funding shows the combined effect of lowered standards along with any actual improvements. Information on actual improvements can be learned from analyzing colleges' responses in areas which are not directly incentivized and by seeing how these changes affect labor outcomes.

Other than papers which evaluate the impact of state PBF, this paper is related to the public accountability research which analyzes the use of public funds to improve the outcomes of public organizations. There are a number of papers which discuss different accountability programs attached to education funding. Svoboda [2016] uses a general equilibrium model to simulate how a federal performance-based college aid program would change decisions of students and colleges. I find colleges would engage in performance padding by observing that federal performance-based college aid can lead to minor increases in the incentivized areas at the expense of considerable decreases to other non-incentivized areas. At the primary and secondary education level, Lavy [2009] explores the effect on students outcomes of offering individual monetary incentives to math and English teachers. My paper is also related to the broader lines of research which study the effect of monetary incentives on publicly provided programs other than education. For example, Pham et al. [2007] and Lindenauer et al. [2007], among others, explore the effect on patient outcomes of payment schemes which link medical care quality to Medicare reimbursements. The success of spending based Medicare reimbursements implemented by the Affordable Care Act have been examined by a number of papers including Nyweide et al. [2015] and Liu et al. [2016].

The rest of the paper is structured as follows. Section 2.2 describes the different state PBF programs and the construction of the PBF dataset. Section 2.3 describes the college-level data. Section 2.4 explores the effect of performance funding on incentivized outcomes. Section 2.5 considers how PBF changes labor market outcomes and college decisions. Section 2.6 examines the differential effect of different PBF implementations. Section 4.6 concludes.

2.2 STATE PERFORMANCE-BASED FUNDING

College PBF varies the amount of state appropriations a public college receives based on measurable outcomes.[3] When implemented, this method replaces or supplements either a funding formula based on educational inputs, such as the number of full-time students or number of enrolled credit hours, or a base-plus method of college funding [SRI International, 2012].[4]

The proponents of PBF argue that a performance-based system can potentially impact

[3]In this research, I limit my analysis to transparent performance funding processes which explicitly state how outcomes are evaluated and rewarded. These funding processes differ from performance-based budgeting where performance measures are reported to the state legislature as part of the budget process. Under performance-based budgeting, if measures are used to allocate money to colleges based on outcomes, the method of allocation is not announced.

[4]Under base-plus funding, the amount of state college funding is equal to last years funding, the base, plus or minus some adjustment. This adjustment can be tied to enrollment, legislative budget, or other state specific factors.

colleges in two ways ([Dougherty and Hong, 2006] and [Dougherty and Reddy, 2011]). First, by explicitly defining how funding is allocated to colleges, the government is informing colleges of the outcomes that the government values. Public colleges may then change their actions in order to align their priorities with the state government. Second, by tying funding to outcomes, colleges will change their actions to maximize the amount of performance funding they receive. PBF supplies colleges with information on government preferences and provides a financial incentive to achieve certain goals.

Arguments against PBF include the possibility that colleges' preferences are already aligned with the preferences of the government and therefore knowledge of government preferences won't affect colleges' decisions. In addition, measures used to allocate performance funding such as completion and retention rates are highly related to the student's ability and effort. Year-over-year these measures are volatile. When funding is tied to volatile measures, it results in an unsteady income stream which can negatively impact programs designed to improve student outcomes. Another concern is that the programs are often complicated. Many resources have to be spent by the government and the colleges to determine how much funding should be allocated to each college. Further, these programs are often short lived. If a program will be only in effect for a few years, it is not in the best interest of a colleges to make changes in pursuit of a temporary reward. Finally, some believe a PBF system will incentivize colleges to lower their standards in order to game the system and receive a high amount of PBF. For example, a college may revise their degree requirements in order to raise their completion rates.[5]

Just as there is no consensus on PBF's effectiveness, among those in favor of PBF there is no consensus on what form of PBF is the best. Some disagree on what aspects of college performance are most important to the state while others disagree on which performance measures to use and how much public funding should be allocated through

[5] A discussion of each of these points is presented in Dougherty and Reddy [2011].

PBF. These concerns have resulted in different states enacting very different programs. For example, North Dakota in 2014 instituted PBF that allocated all college funding based only on course completion. In contrast, in 2014 Minnesota allocated only 5% of funding based on progress towards a wide variety of goals, ranging from increasing the number of degrees to decreasing administrative cost.

This paper aims to answer whether PBF changes colleges outcomes and further explore which characteristics of PBF are most effective. To answer these questions, a comprehensive dataset of all performance-based initiatives is needed. The dataset must contain information on when each state's PBF was in effect, the outcomes that performance funding incentivized, the total amount of performance funding available, and the amount of funding tied to each outcome. Though there are a number of datasets which list PBF implementation years, none of these datasets contain information on the other three items.

Since this data is not available, I construct a complete dataset of PBF characteristics. First, I gather an aggregated list of performance funding implementations. I obtain information about current PBF programs from the National Conference of State Legislatures. This group maintains a list of state budgets, state legislation, and other official state government releases that describe in detail the PBF programs currently being implemented or being developed. From these documents, I am able to determine how long all current PBF programs were in effect. To obtain historical information, I combine data from a number of papers which examined PBF. These studies include Burke and Serban [1998], Burke and Minassians [2002], Dougherty and Reddy [2011], Rabovsky [2012], Rutherford and Rabovsky [2014], and Tandberg and Hillman [2014]. While aggregating information, I ran into a number of inconsistencies about when exactly PBF was active. To clear up these discrepancies, primary sources are consulted. I find that many inconsistencies arise from labeling performance-based *budgeting* as performance-based *funding* while other discrepancies arise when a PBF initiative is passed but later repealed before it comes into effect.

Table 2.1: Summary of Performance Funding for Four-Year Institutions

State	Performance Funding Years in Operation	State	Performance Funding Years in Operation
Arizona	2013-	Nevada	2015-
Arkansas	1996, 2014-	New Jersey	2000-02
Colorado	1995-98, 2001-03	New Mexico	2013-
Florida	1997-00	North Dakota	2014-
Illinois	2013-	Ohio	1998-
Indiana	2004-	Oklahoma	2002-
Kansas	2006-	Oregon	2012-
Kentucky	1997-98, 2008	Pennsylvania*	2001-
Louisiana	2011-	South Carolina	1997-2004
Maine	2014-	South Dakota	2000-2003, 2013
Michigan	2013-	Tennessee	1993-
Minnesota	1996-97, 2008-09, 2012-	Texas	2009-2011
Mississippi	2014-	Utah	2014-
Missouri	1994-2001, 2014-	Virginia	2007-
Montana	2015-	Washington	1998-99

*PA performance funding is only in effect for the 14 Pennsylvania State System of Higher Education colleges.

Finally, some of these studies rely on inaccurate survey data.

Once I have a list of PBF implementations, I gather data on how each state allocated funding. Specifically, I am interested in determining which outcomes were used to allocate funding. I group all outcomes into five categories: completion, access, progression, efficiency, and research. The rest of the paper only considers performance funding in which one or more outcome measures are contained within these five categories. Other measures

Table 2.2: Performance Funding Characteristics 2001-2013

	PBF Adoptions	PBF Terminations		Incentivized Outcome	Funding Percent
Number	14	8	**Completion**	81%	38%
	PBF Amount	**Real PBF Per FTE**	**Progression**	63%	24%
Average	82,873,370	418	**Research**	44%	15%
Median	6,542,330	71	**Access**	56%	15%
Std. Dev.	230,608,300	1,129	**Efficiency**	24%	8%

This table presents data information restricted to years 2001-2013. Pennsylvania is excluded from all numbers. PBF Amount is the total amount of state funding which will be distributed to all public colleges based on performance outcomes. Real PBF per FTE is performance funding amount adjusted to 2013 dollars using a higher-education price index divided by the total number of public full-time equivalent students in that state. Incentivized Outcome is the percent of performance funding programs which base funding on each outcome category and Funding Percent measures the average percent of funding attached to each outcome.

tied to funding are not considered performance measures.[6] Only a very small portion of PBF programs relied on measures that did not fit into these five categories.

I further gather information on how much total performance funding was available and how much funding was tied to each outcome measure. Information about the amount of money tied to the performance funding program is available in each state's budget. The outcomes tied to funding and the relative importance of each outcome is determined by consulting legislation and state funding websites. In many cases, these sources detail the exact performance funding formula. In other cases, the law that implements PBF specifies the outcomes which will be considered without specifying the exact weight placed on each outcome. In these scenarios, the percent of funding attached to each outcome is determined based on the proportion of outcomes in each category.

Table 2.1 displays information on each states' four-year college PBF programs. This

[6]Some examples of excluded measures include student satisfaction survey results and program accreditation.

table reveals that 30 states either currently utilize or in the past have utilized PBF. Of these states, 11 have started and subsequently terminated a PBF program, and 6 of these 11 states implemented a different form of PBF after terminating performance funding and returning to another funding strategy. When a state did implement PBF, the state's specific implementation of PBF was not constant over time. Law makers frequently changed the amount of funding associated with PBF, the measures used to allocate funding, and the relative importance of each measure. The online appendix includes a brief summary of each state's PBF programs, including information on how the programs changed over time.[7]

Characteristics of the PBF programs are summarized in Table 2.2. Completion had the largest amount of performance money attached to it, with 38% of all performance funding being allocated based on completion, and was most often used by states as a performance measure, used 81% of the time. Efficiency is on the other end of the spectrum, accounting for the least amount of money, with only 8% of all performance funding being allocated based on research, and being chosen by states as a performance metric least often, used 24% of the time. Overall, the amount of performance funding per FTE public college student is relatively small; the average performance funding program only dedicated $418 per FTE public college student.

Further information about the categories used to allocated funding is summarize in Table 2.3. Panel A of this table shows what percent of all PBF years used pairwise combinations of performance categories to allocate funding. The results reveal that PBF programs often relied on multiple measures. Panel B shows the pairwise correlation between the amount of real performance-based funding per state FTE public college student, allocated based on each category. The high correlations reveal that completion, research, and efficiency often had similar levels of funding distributed based on these outcomes.

[7] The online appendix is located at goo.gl/7UyIkS

Table 2.3: PBF Category Usage and Funding Amount Correlation

Panel A: Performance Funding Category Usage					
	Completion	Progression	Research	Access	Efficiency
Completion	81%				
Progression	52%	63%			
Research	35%	19%	44%		
Access	48%	26%	31%	56%	
Efficiency	21%	15%	20%	19%	24%

Panel B: Real Performance Funding Amount Per State FTE Correlation					
	Completion	Progression	Research	Access	Efficiency
Completion	1				
Progression	0.424***	1			
Research	0.926***	0.226**	1		
Access	0.008	-0.132	0.094	1	
Efficiency	0.791***	0.198	0.824***	-0.035	1

This table shows the correlation between the characteristics of PBF programs. PBF programs in effect between 2001 and 2013 are considered. Pennsylvania is excluded from this analysis. Panel A presents the percent of PBF programs which rely on both pairwise measures to allocate PBF. Panel B presents the pairwise correlation between the amount of real performance funding per FTE allocated based on each category. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

2.3 DATA

2.3.1 Population Sample

I utilize college-level data from the Integrated Postsecondary Education Database System (IPEDS). Due to limited variable availability in earlier years, I restrict the sample to information on years between 2001 and 2013.[8] Since the vast majority of state funding

[8]Information on the SAT score of the colleges is only available starting in 2001. If this control variable is not used, completion rate availability would still limit the sample to information on years between 1997 and 2013.

Table 2.4: Summary Statistics

	Total			Public			Private		
	Obs	**Mean**	**St Dev**	**Obs**	**Mean**	**St Dev**	**Obs**	**Mean**	**St Dev**
				Incentivized Outcomes					
Completion Percent	16,366	52.35	18.67	5,674	45.76	16.58	10,692	55.85	18.77
Federal Grants/ FTE	15,809	2,650	13,770	5,856	2,823	9,029	9,953	2,548	15,912
Full-time Retention Percent	12,271	73.61	13.07	4,250	72.96	11.47	8,021	73.96	13.83
Bachelor Degrees/1000 FTE	16,841	175.75	61.52	5,860	165.25	51.44	10,981	181.35	65.58
				Control Variables					
State Approp($000s)/FTE	16,836	2.90	5.06	5,780	8.33	5.42	11,056	0.06	0.43
Unemployment Percent	16,922	6.40	2.08	5,866	6.36	2.09	11,056	6.42	2.07
SAT Average	14,126	1,063	128	5,148	1,035	105	8,978	1,079	137
				2014 Labor Market Variables					
Average Income	11,849	37,470	16,465	4,214	35,923	13,275	7,635	38,325	17,929
Median Income	11,849	33,232	12,655	4,214	32,157	11,488	7,635	33,826	13,218
Median Income w/o 0s	11,849	35,677	13,209	4,214	34,549	11,994	7,635	36,301	13,795
Proportion 1st Quintile	11,849	0.0916	0.0341	4,214	0.0942	0.0293	7,635	0.0902	0.0364
Proportion 2nd Quintile	11,849	0.1486	0.0562	4,214	0.1529	0.0509	7,635	0.1463	0.0587
Proportion 3rd Quintile	11,849	0.1845	0.0554	4,214	0.1956	0.0510	7,635	0.1784	0.0567
Proportion 4th Quintile	11,849	0.2510	0.0582	4,214	0.2555	0.0467	7,635	0.2485	0.0636
Proportion 5th Quintile	11,849	0.3243	0.1302	4,214	0.3018	0.1149	7,635	0.3367	0.1364
				Admission Variables					
FTE Count	16,922	6,129	10,314	5,866	12,310	14,852	11,056	2,849	3,845
Admissions	13,821	1,202	1,552	4,842	2,133	2,034	8,979	700	871
Admission Rate	12,714	0.28	0.12	4,448	0.30	0.10	8,266	0.27	0.12
New Undergraduates	15,305	1,609	2,761	5,301	3,309	4,028	10,004	708	852
In-state Tuition ($)	16,711	16,324	11,104	5,842	4,516	2,405	10,869	22,671	8,439
Out-of-state Tuition ($)	16,711	19,433	8,669	5,842	13,402	5,165	10,869	22,675	8,435
				Spending by Category					
Total Spending/FTE	16,891	25,089	39,270	5,865	21,860	25,879	11,026	26,807	44,696
Instruction/FTE	16,862	9,366	8,135	5,852	8,130	4,942	11,010	10,023	9,335
Research/FTE	9,063	4,600	29,100	5,375	3,343	12,400	3,688	6,431	43,030
Public Service/FTE	9,924	1,214	5,018	5,665	1,283	2,283	4,259	1,122	7,192
Student Support/FTE	16,756	5,300	5,857	5,864	3,708	4,887	10,892	6,157	6,149
Inst. Support & Ops /FTE	15,997	6,540	9,426	5,856	4,302	3,183	10,141	7,832	11,391
College Grants/FTE	7,971	1,559	1,694	5,829	1,362	1,048	2,142	2,097	2,701

This table displays summary statistics for all colleges, public colleges, and private colleges. The first panel displays variables often tied to funding, the second panel displays control variables, the third panel displays information on 2014 income variables, the forth panel displays measurements associated with various admission decisions, and the fifth panel displays information on the amount of spending broken into different categories. Inst. Support & Ops is an abbreviation for institutional support and operations. All variables labeled with "/FTE" are dollar amounts per full-time equivalent student. All dollar amounts are transformed to 2013 terms using a higher-education price index.

is distributed to public colleges, I am interested in identifying the effect of PBF on four-year American public colleges. To control for state-level trends, I also use information on four-year non-profit private colleges. I restrict my sample to four-year colleges located in the 50 states. Military institutions, tribal colleges, medical schools, law schools, schools of art, theological seminaries, and other specialized institutions are excluded. The state of Pennsylvania is excluded due to the unique performance funding setup in that state. In Pennsylvania, only colleges under the Pennsylvania State System of Higher Education are subject to PBF. This program excludes the largest public colleges. Since not all public colleges are impacted by the performance program, the estimation technique I employ is not valid for this state. All results are qualitatively the same if Pennsylvania colleges are included. The final sample consists of 442 public colleges and 853 private colleges.

2.3.2 Incentivized Outcomes

I first examine the impact of performance funding on incentivized outcome variables which are often tied to government funding. Specifically, I examine the impact on completion, research, progression, and efficiency. The six-year graduation rate is used to measure completion. The amount of outside research funding is measured by the dollar amount of federal grants net Pell obtained by each college divided by the number of FTE students. These amounts are converted to 2013 dollars using a higher education price index. Federal grants are competitive and large amounts of federal grant money is interpreted to mean large research progress. Progression is measured by the first year retention rate. Data on the retention rate is only available since 2004. Efficiency is measured by bachelor degrees per 1,000 FTE students.

2.3.3 Labor Market Outcomes

Data on students' labor market outcomes was gathered in Chetty et al. [2017]. By using data from federal tax returns and the Department of Education spanning years 1996-2014, the authors create a dataset that associates student's 2014 earnings to their birth cohort for each college. Each student in the data is assigned to a specific college-birth cohort bucket based on their year of birth and the college attended most often between ages 19 and 22. The dataset contains information at the college level by birth cohorts between 1980 and 1991. Colleges are identified by their OPEID, the office of postsecondary education identification. In each college-birth cohort bucket, aggregate information on students' 2014 income is computed. Specifically, the average income, median income, median income excluding zero income observations, and percent of students in each income quintile relative to all other people in the same birth cohort is computed.

To associate college level information with labor market information, I map OPEID to the IPEDS distinct identification system. This presents some challenges since the OPEID associates information on students who attend "branch campuses" into the main campus. The IPEDS database system instead has separate entries for every branch campus. Therefore, IPEDS college level data is transformed to follow the OPEID system and subsequently incorporated into the student labor market dataset. I attribute college-level information describing the college 19 years after the student's birth year to each college-birth cohort bucket. Information on colleges 19 years after the student birth corresponds to college level characteristics present when most students were entering freshman. Results have also been run attributing college level characteristics 18 and 20 years after student birth year to each college-birth cohort bucket. The results in each case were qualitatively the same.

2.3.4 College Decisions

I also explore the effect on college decision variables which are not incentivized. These variables represent adjustments college can choose to implement in response to PBF.

I examine how admission decisions change following implementation of PBF. I consider changes to the number of admissions, the admission rate, the number of new undergraduates, the average in-state tuition, and the average out-of-state tuition. The average tuition amounts are converted to 2013 dollars using the higher-education price index. I also consider changes to the SAT score and FTE student number. I would prefer to use the average SAT score of the incoming class, however the SAT score for this subpopulation is not contained in the IPEDS database. I examine the year-over-year difference in SAT instead of the level measure to obtain more information about the incoming students. The year-over-year change should be highly related to the SAT score for new students. To determine if a college is contracting or expanding, the year-over-year change is also used when analyzing the number of FTE students.

I utilize information on how much the college spends on different areas. All spending amounts are adjusted to 2013 dollars using the higher-education price index and divided by the number of FTE students. I consider total spending and separately consider spending on expenses related to instruction, research, public service, student support, institutional support and operations, and grants given to students by the college. The public service category consists of expenses for activities that provide non-instructional services beneficial to individuals and groups external to the institution. Student support is the sum of the categories labeled student service and academic support in the IPEDS database. Student service consists of expenses for admissions, registrar activities, and activities whose primary purpose is to contribute to students emotional and physical well-being and to their development outside the context of the formal instruction. Academic support includes expenses of activities and services that support the institution's primary missions of instruction, research, and public service. Institutional support and operations is the sum of the categories labeled institutional support and operations in the IPEDS database. Institutional support contains the expenses of the day-to-day operational support of the institution including general administrative services, central executive-level activities concerned with management and long range planning, legal and fiscal operations, space management, employee personnel and records, logistical services such as purchasing and printing, and public relations and development. Operations consists of expenses relating to service and maintenance of campus grounds and facilities used for educational and general purposes. Institutional grants is equal to the amount of scholarships and fellowships given by the college to students.

2.3.5 Performance Funding Variables

From the dataset described in Section 2.2, a performance funding dummy variable is created. This variables takes on a value of 1 when performance funding is in effect and 0 when performance funding is not in effect. Further, I consider how much funding is allocated through performance funding. The funding variable is equal to the total amount of performance funding available divided by the total number of FTE public college students in that state. Performance funding amounts are converted to 2013 dollars using the higher-education price index. Finally, I construct variables equal to the amount of performance funding allocated based on a specific category. These variables are equal to the total amount of performance funding multiplied by the funding percent for each of the five outcome categories.

2.3.6 Covariates

In each of my models, I include covariates which are known to affect college outcomes. Measures of the state support of the college, students characteristics, and state economic conditions are included. State appropriations per FTE, contained in the IPEDS database, is used to measure state support. State appropriations are converted to 2013 dollars using the higher-education price index. State economic conditions are measured by the annual unemployment rate of the state, obtained from the Bureau of Labor Statistics. To control for student ability, the average SAT score of students is used. The inclusion of college fixed effects makes inclusion of any time invariant college level characteristics unnecessary. Table 2.4 summarizes key information for each of the variables.

2.4 EFFECT OF PBF ON INCENTIVIZED OUTCOMES

2.4.1 Methodology

In this section, I explore the effect of PBF on incentivized outcomes. Since funding is attached to improving certain outcomes, if colleges are responding to these incentives these outcomes should improve. I consider how outcomes change in response to any PBF program and also differentiate programs based on their performance funding amount.

2.4.1.1 Effect of Any PBF Program Assignment of PBF is not random and college outcomes may influence when lawmakers decide to adopt PBF. I employ a triple-difference model to help deal with the endogeneity problem due to potential non-random adoption. I account for two possible sources of endogeneity, one relating to trends among all public colleges and another relating to trends in states who adopt performance funding.

The first source of endogeneity arises because PBF could potentially be adopted in response to an overall decrease in public college performance. However, this decrease could be due to nationwide trends. Changing tastes of students could change the composition of students who decide to attend public colleges. If nationwide, public college outcomes started to deteriorate and then subsequently improved, passage of PBF when outcomes are at their worst could result in the improvement incorrectly being attributed to PBF. To deal with this issue, I account for nationwide public college trends by comparing the effect of PBF on public colleges in states with PBF to states that have not adopted PBF.

The second source of endogeneity arises if state-level trends affect the adoption of PBF. Suppose colleges in a state had unusually bad outcomes for a few years and then returned to normal levels a few years later. If the government of this state reacted to the bad outcomes by implementing PBF, it would appear that PBF had a large effect on outcomes. However, if the real reason these outcomes changed was due to cohort effects, it would be wrong to attribute the improvement to PBF. To deal with this issue, I account for state specific trends common among states who adopt PBF by comparing the effect of PBF on public colleges to private colleges in the same state. According to Hillman and Weichman [2016], the median four-year public college student attends a college located 18 miles from their home and the median four-year private college student attends a college located 46 miles from their home. This suggests that the majority of students in both public and private colleges are in-state students, hence both types of colleges are subject to the same cohort effects and other statewide trends. When contrasting the improvements in public colleges to that of private colleges, private colleges act as a control. Using private colleges in this way is possible since PBF changes do not affect the funding that private colleges receive from the government. Therefore, differential improvements to outcomes seen in public colleges can be attributed to PBF.

The triple-difference model that controls for both sources of endogeneity takes on the following form:

$$Y_{i,s,t} = \beta_0 + \beta_1 G_i \cdot E_{s,t} + \beta_2 E_{s,t} + G_i \cdot \delta_t^G + \delta_i + \delta_t + \beta_3 X_{i,t} + \varepsilon_{i,s,t}, \tag{2.1}$$

where $Y_{i,s,t}$ denotes the outcome of interest for college i, located in state s, in year t. $E_{s,t}$ is an indicator which takes on a value of 1 if PBF is in effect in state s at time t and 0 otherwise. G_i is an indicator equal to 1 if college i is public. The vector of covariates introduced in Section 2.3 is denoted by $X_{i,t}$. δ_i are college-level fixed effects, δ_t are year fixed effects, and δ_t^G are public college specific year fixed effects. $\varepsilon_{i,t}$ is the error term.

The triple-difference setup utilizes three layers of difference: difference between public and private colleges, difference between states who adopt PBF and states who do not, and difference before and after PBF is adopted. Because the performance funding programs are enacted at different time periods, the variable $E_{s,t}$ is used to indicate when PBF is in effect at time t for state s. This term is identical to the interaction term of post and treatment that is traditionally included. The inclusion of college-level fixed effects account for the public-private term, G_i, and the treatment indicator. The time fixed effects account for the post indicator.

College-level fixed effects are included to control for time invariant college level differences which may impact outcomes, such as location, public status, and Carnegie Classification of Institutions of Higher Education.[9] Year fixed effects are included to control for time variant factors which affect all colleges, such as yearly changes in federal college aid programs. In addition to the overall year fixed effects, the regression includes separate year fixed effects for public colleges. Inclusion of two types of year fixed effects control for any separate nationwide trends that may be occurring in either public or private colleges.

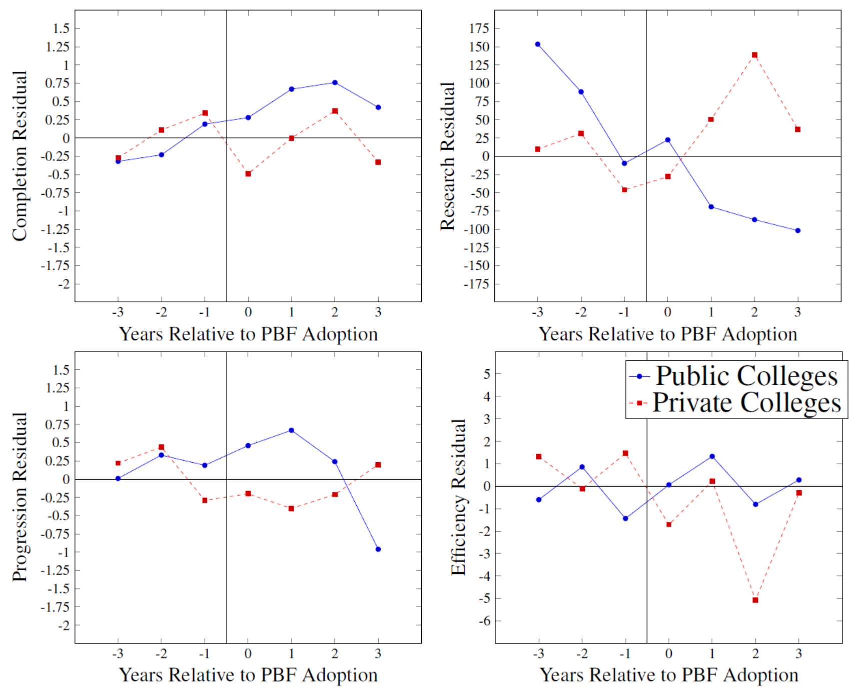
[9]Carnegie Classification of Institutions of Higher Education sorts colleges into categories of roughly comparable institutions.

The coefficient of interest, β_1, estimates the impact of performance funding on public colleges. In addition to controlling for public-college trends, endogeneity is controlled for by accounting for state-level trends common among states that adopt PBF. State-level trends occurring after the adoption of PBF that affect both public and private colleges are controlled for through inclusion of the term $E_{s,t}$. Due to this term, effects common to both types of college do not effect the estimate of β_1 and instead are seen in the coefficient β_2.

The identification of β_1 does not solely come from the adoption of PBF programs. In practice, some states see multiple funding transitions, from non-performance-based funding to performance-based funding and from performance-based funding to back to non-performance-based funding. This means β_1 is identified by changes in outcomes that occur following states' adoption of PBF and also through states' abolishment of PBF. In my sample, there are 14 adoptions and 8 terminations of PBF. In the next estimation strategy, I analyze the differential effect of funding amount. Since the funding amount associated with each PBF program changes often, concerns about limited variation are addressed by including performance funding amount.

To support the usage of a triple-difference model, Figure 2.1 shows four parallel trend graphs. These graphs provide an opportunity to test the validity of the assumption of similar trends in advance of PBF adoption. The variable on the x-axis is the number of years relative to the year PBF was adopted. Year 0 is normalized to be the year PBF first went into effect. On the y-axis the graphs plot the average residual, obtained from running the regression specified in Equation (2.1) without the term $G_i \cdot E_{s,t}$, for each of the four incentivized outcomes. Before enactment of PBF, the movements of the public and private lines for completion, research, and progression mirror each other. The year-to-year movements for efficiency are not as close as the other three outcome variables, but the overall trends before enactment are similar. These similar patterns suggest that the parallel trend assumption is valid in this situation. Once the performance funding program

Figure 2.1: College Trend In Incentivized Outcomes Relative to PBF Adoption



Notes: Year 0 is normalized to be the year PBF first went into effect. Other years values are in reference to this adoption year. The y-axis refers to the average residual, obtained from running the regression specified in Equation (2.1) without the term $G_i \cdot E_{s,t}$, for each of the four incentivized outcomes.

is enacted, public colleges see a large increase in completion and progression. These differences disappear as time passes. The temporary nature of these effects may be due to the fact that some states abolish PBF and return to other funding methods. In addition, since some PBF implementations occurred relatively recently there is not information on the effect of outcomes many years after PBF was implemented. The compositional change that occurs when these states drop out of the sample may also contribute to the decrease observed a couple of years after PBF is adopted. The gap in amount of research spending grows following PBF adoption, with public college spending decreasing while private college spending increases. The public college efficiency measure does not change much following the PBF adoption.

As a robustness check, I run the following regression separately for private and public colleges:

$$Y_{i,t} = \beta_0 + \beta_1 E_{s,t} + \beta_3 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t}. \tag{2.2}$$

Private colleges receive relatively little state funding and are not directly affected by funding changes. In Equation (2.2), the coefficient β_1 reveals the average effect of PBF in reference to colleges in states without PBF. Identification in this model comes from the differential timing of performance funding adoption and termination. If the change in outcomes is actually due to the change in public college funding, then in a regression run on a sample of only on private colleges the estimate of β_1 should not be significant. On the other hand since public colleges are affected, then in a regression run on a sample of only public colleges the estimate of β_1 should be significant.

2.4.1.2 Performance Funding Amount The amount of state college appropriations tied to performance measures varies widely between states. In 2014, Ohio allocated 50% of their college appropriations based on performance outcomes while Maine only allocated 5% of their college appropriations based on performance outcomes. If colleges are adapting their policies due to the financial incentive imposed by PBF, then reforms in states with more PBF would have a larger impact than reforms in states with less PBF.

To account for the impact of states allocating different amounts of funding based on performance measures, I modify the triple-difference setup. Instead of using an indicator for PBF, I measure PBF "intensity" by using information on the per student dollar amount of PBF. The new regression formula corresponding to this generalized triple different strategy is now given by:

$$Y_{i,s,t} = \beta_0 + \beta_1 G_i \cdot F_{s,t} + \beta_2 F_{s,t} + G_i \cdot \delta_t^G + \delta_i + \delta_t + \beta_3 X_{i,t} + \varepsilon_{i,s,t}, \tag{2.3}$$

where $F_{s,t}$ denotes the per student amount of performance funding available in state s at time t.

The coefficient of interest in Equation (2.3) is β_1. Under this specification β_1 reveals information on how distributing more college funding through a PBF program impacts outcomes. This parameter is identified through adoption and termination of PBF programs and also through changes in the amount of performance funding available. In every PBF implementation, the amount of performance funding available changes every year.

2.4.2 Results

2.4.2.1 Effect of Any PBF Program Table 2.5 presents estimates of the effect of PBF on college outcomes. This table reports statistics corresponding to the triple-difference regression outlined in Equation (2.1). The table displays estimates of how PBF affects all colleges, how PBF differentially affects public colleges, and how the covariates impact outcomes.

The estimates suggest that PBF leads to public colleges seeing an increase in completion and progression. Column 1 reveals that public colleges subject to PBF increase their average completion rate by approximately 1.18 percentage points, relative to private colleges in states with performance funding. Considering the average four-year public college had a completion rate of only 48.87 percent in 2013, this corresponds to a 2.4% increase. Column 3 estimates that PBF increases the average first year retention rate by 0.87 percentage points in public colleges, compared to private colleges, or a relative 1.2% (0.87 /

Table 2.5: The Effect of Performance Funding on College Outcomes

	(1) Completion	(2) Research	(3) Progression	(4) Efficiency
Public * PBF Indicator	1.177*	-42.17	0.871*	1.997
	(0.652)	(114.3)	(0.510)	(2.065)
PBF Indicator	-0.376	11.33	-0.0751	-0.239
	(0.409)	(86.28)	(0.334)	(1.719)
Unemployment Percent	0.0511	34.57	-0.0165	0.102
	(0.125)	(27.22)	(0.0750)	(0.453)
State Appropriations	-0.239	4.263	-0.245**	1.664***
	(0.147)	(54.13)	(0.120)	(0.557)
Average SAT Score	0.0152***	2.213***	0.0189***	0.0208*
	(0.00319)	(0.678)	(0.00369)	(0.0106)
Observations	13,936	13,350	10,550	14,044
Number of Colleges	1,191	1,172	1,180	1,195
College and Year FE	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2004-2013	2001-2013

Robust standard errors clustered at the state level in parentheses. State appropriations measures the total amount of funding allocated to that college per FTE student. This variable is measured in thousands of 2013 dollars per FTE student. *** p<0.01, ** p<0.05, * p<0.1

73.43) increase. The results suggest performance funding does not have much of an effect on the efficiency outcome.

Research is not affected by the performance funding changes. In fact, the sign of the coefficient associated with research is the opposite of what is expected. The limited effect on research could be explained by the fact that research is not often chosen as an incentivized outcome and when it is chosen a relatively small amount of performance funding is attached to research. Another possibility, is that research does not fit in well with the other outcomes. Completion, progression, and efficiency are all related and improving any one of these outcomes would help the other outcomes. Since performance funding programs often attach funding to multiple outcomes, colleges may be choosing to spend their resources raising the three connected outcomes to improve multiple measures.

As a robustness check, the regression outlined in Equation (2.2) includes only public colleges or only private colleges. Results of these regressions are presented in Table 2.6. The outcomes of completion and progression are improved in the public college regression when performance funding is in effect while no private college outcomes are affected by performance funding. Though efficiency is not significantly related to public college outcomes, the p-value of 0.103 is close to significance. The results of this exercise are consistent with the results found in the triple-difference regressions, presented in Table 2.5. This further validates the choice of private colleges as a comparison group.

2.4.2.2 Performance Funding Amount Table 2.7 presents the regression estimates for the specification which includes the amount of performance funding, outlined in Equation (2.3). In each column, the table reports estimates of how the amount of performance funding affects all college outcomes and the differential impact of this variable on public colleges. The control variables of state appropriation per FTE, unemployment rate, and average SAT score are included in all four regressions.

Allocating more funding based on performance measures increases completion and progression. Increasing the amount of performance funding by $1,220, or one standard deviation for states with performance funding, results in a 0.55 and 0.57 percentage point increase to the completion and retention rates, respectively.

Since the control variable of state appropriations per FTE is included, the estimate of PBF per state FTE is not masking an income effect. By including a control for total amount of government appropriations, the results instead are to be interpreted as the effect of allocating more public appropriations through PBF while keeping the total amount of

Table 2.6: The Effect of Performance Funding on Public and Private Colleges

	(1) Completion	(2) Research	(3) Retention	(4) Degree/FTE
PBF Indicator	0.843**	-50.46	0.814*	2.176
	(0.370)	(83.73)	(0.409)	(1.308)
State Appropriations	-0.245*	-28.10	-0.248*	1.664***
	(0.143)	(56.44)	(0.125)	(0.391)
Unemployment Percent	0.188	-46.06	-0.00369	1.483***
	(0.173)	(29.87)	(0.172)	(0.484)
Average SAT Score	0.0168***	2.963***	0.0159***	0.0336*
	(0.00402)	(1.073)	(0.00458)	(0.0172)
Observations	5,012	5,066	3,786	5,066
Number of Colleges	417	419	418	419
College and Year FE	Yes	Yes	Yes	Yes
College Type	Public	Public	Public	Public
Sample	2001-2013	2001-2013	2004-2013	2001-2013
	(5) Completion	(6) Research	(7) Retention	(8) Degree/FTE
PBF Indicator	-0.414	18.40	-0.0764	-0.588
	(0.403)	(92.29)	(0.324)	(1.742)
State Appropriations	0.297	461.9**	0.0198	5.798
	(0.316)	(172.1)	(0.399)	(5.502)
Unemployment Percent	-0.0323	89.15*	-0.0235	-0.738
	(0.146)	(45.05)	(0.122)	(0.638)
Average SAT Score	0.0147***	1.954**	0.0199***	0.0165
	(0.00458)	(0.831)	(0.00494)	(0.0122)
Observations	8,924	8,284	6,764	8,978
Number of Colleges	774	753	762	776
College and Year FE	Yes	Yes	Yes	Yes
College Type	Private	Private	Private	Private
Sample	2001-2013	2001-2013	2004-2013	2001-2013

Robust standard errors clustered at the state level in parentheses. State appropriations measures the total amount of funding allocated to that college per FTE student. This variable is measured in thousands of 2013 dollars per FTE student. *** p<0.01, ** p<0.05, * p<0.1

Table 2.7: The Effect of Performance Funding Amount on College Outcomes

	(1) Completion	(2) Research	(3) Progression	(4) Efficiency
Public * PBF Amount	0.461***	-2.364	0.472**	0.570
	(0.169)	(27.19)	(0.178)	(0.645)
PBF Amount	-0.110**	-8.801	-0.168***	-0.297
	(0.0479)	(35.74)	(0.0492)	(0.358)
Observations	13,936	13,350	10,550	14,044
Number of Colleges	1,191	1,172	1,180	1,195
College and Year FE	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2004-2013	2001-2013

Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2013 dollars per state FTE student. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

state funding constant. The results estimate the effect of distributing state funding based on outcome measures instead of through the usual distribution methods.

These results suggest it is possible to see large improvements in outcomes without spending more money, but instead changing how appropriations are distributed. If the average state allocated all of their college appropriation based on outcome measures, the point estimates suggest that the completion rate in the average public college would increase 4.72% and the first year retention rate would increase 2.63%. These increases would cut the public-private completion gap in half and result in the average public college having a higher first year retention rate than the average private college.

2.5 EFFECT OF PBF ON NON-INCENTIVIZED OUTCOMES

2.5.1 Methodology

In the previous sections, I present evidence that the incentivized outcomes are improved under PBF. However, these results do not reveal how these improvements are realized. Since these incentivized outcomes are tied to funding there is an incentive to engage in "performance padding" or "window dressing." To explore whether the improvements observed are the result of these undesirable actions or instead due to real improvements, I consider non-incentivized outcomes. Specifically, I examine changes to college policies in order to identify the channel though which the incentivized outcomes are being improved. Further, student's labor market outcomes are used to find the effect PBF on student's future earnings.

2.5.1.1 Performance-Based Funding Channel If changes in incentivized outcomes are not attributable to "performance padding" then this effect should be accompanied with changes in college policies. College policy changes are the mechanisms that colleges can use to achieve an improvement to incentivized outcomes. I examine two possible channels that colleges could utilize to improve incentivized outcomes: changes in college spending or changes in student selection.

If a college were to try to change spending in order to increase the incentivized outcomes, this would likely be seen in either an increase in spending related to instruction or student support. Increasing instruction spending could increase outcomes by lowering the class size or hiring more qualified teachers. On the other hand, increasing student support spending could increase outcomes by investing in programs that target struggling students.

Colleges may also attempt to increase the incentivized outcomes by changing the type of student that attends their college. Colleges can change their student composition by changing admission or tuition rates. Tuition rates can also be changed for specific students through the use of institutional grants. Changes in the average ability of students can be observed through the average SAT score. When examining the average SAT score, data restricted to entering students is not available. In place of information about entering students, I use measures of the change in average SAT over consecutive years. The change should be highly correlated with information about new students. The change is also used to examine how the number of FTE students responds to implementation of PBF.

To identify the response to PBF, I repeat the analysis outlined in Equation (2.3). I separately analyze the effect of PBF on various admission and spending variable identified in Section 2.3.

2.5.1.2 Labor Market Outcomes One way to assess the impact of PBF policies is to examine data on student's labor market outcomes. Using data on student's 2014 wages I can see if the use of PBF results in any change to student's lifetime earnings. Future labor market outcomes have the advantage of not being directly related to state funding. Therefore, there is not an incentive to game the system in order to increase labor market measures.

Two possible ways that student's future income could be affected by implementation of PBF are either due to increased education quality or alternatively due to increased probability of college completion. If students are subject to a higher quality of education then they may find higher paying jobs or be promoted quicker once they do find a job. This change would positively impact the majority of students. Alternatively, PBF could just result in a higher chance of college graduation. These students who otherwise would not have graduated should experience higher earnings because of PBF.

To identify the response of labor market variables to PBF, I repeat the analysis outlined in Equation (2.3). I examine the impact on measures of mean income, median income, and other measures of the 2014 income distribution.

2.5.2 Results

2.5.2.1 Performance-Based Funding Channel Table 2.8 analyzes how college spending responds to PBF. Each dependent variable measures the spending per FTE student converted to 2013 dollars. Out of all the spending categories, only spending on instruction and institutional support are significantly affected by changes in the amount of performance funding. For every $1,000 increase in state performance funding per FTE student, spending on instruction decreases by $167 per FTE student while institutional support and operations spending increases by $139 per FTE student.

The results suggest that colleges are not changing spending decisions to improve the incentivized outcomes in the way predicted. Instead of increasing spending on instruction, colleges are moving spending from instruction towards general administrative services and operations. A possible rationalization of this response is due to budgetary issues. If budgets were tight, it is possible that instruction expenses are being cut in order pay for increased institutional expenses that arise because of PBF. A common complaint relating to PBF is the high resource costs associated with the program. In order to gather and report all necessary statistics, colleges need to spend more resources on administration related activities. To stay in compliance with PBF and ensure the college maximizes the performance money received, colleges are choosing to increase the amount spent on administration.

The effect of PBF amount on college admission and tuition decisions is summarized in Table 2.9. The variables labeled with “Diff” measure the difference between years. Information on institutional grants is displayed in the last column of Table 2.8.

The only evidence of selection is seen in an increase to the average SAT score. The

Table 2.8: The Effect of Performance Funding on College Spending per FTE

	(1) Total Education & General	(2) Instruction	(3) Research	(4) Public Service	(5) Student Support	(6) Institutional Support & Operations	(7) Institutional Grants
Public * PBF Amount	-10.15	-167.4***	-126.7	-16.91	13.09	138.5***	17.97
	(81.15)	(21.74)	(106.3)	(15.57)	(72.68)	(29.29)	(43.14)
Observations	14,044	14,044	7,989	8,555	13,986	13,460	6,774
College, Year, and Public by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013

Table 2.9: The Effect of Performance Funding on Admission Decisions

	(1) SAT Diff	(2) FTE Diff	(3) Admissions	(4) Admission Rate	(5) New Undergraduates	(6) Tuition In-State	(7) Tuition Out-of-State
Public * PBF Amount	1.197**	19.48	41.36	0.00320	56.57	-75.17	175.0
	(0.467)	(33.80)	(25.12)	(0.00370)	(63.43)	(131.3)	(270.9)
Observations	12,684	14,039	12,775	11,787	13,017	14,001	14,001
College, Year, and Public by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013

Tables 2.8 and 2.9: Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2013 dollars per state FTE student. *** p<0.01, ** p<0.05, * p<0.1

average SAT of the college increases 1.2 points each year PBF is in effect, for every $1,000 increase in performance funding. Though the number is small, since the dependent variable is the change in SAT score, this effect corresponds to an increase in the average SAT score of the whole college each year PBF is in effect. If new students are only one forth of the total student body, then this implies that every year PBF is in effect, for every $1,000 of performance funding, the average new first year student has an SAT score that is about 5 points higher than the average of the students being replaced. In addition, the difference in average SAT score between public and private colleges is only 40 points. This improvement in student quality could explain some of the improvements seen to the completion and retention rates.

Table 2.10 further explores the impact of performance based funding on lagged measures of the average SAT score. Since the SAT measure is the college-wide average, changes in admission standards following implementation of PBF may not be seen immediately through the SAT measure. There should be an affect on lagged measures of the college-wide average SAT score should since these measures contain a larger percentage of students who were subject to potential admission policy changes. The table reveals this intuition is true. The first column, corresponding to the average SAT score has a small point estimate and is not statistically significant. However, as the lag on the SAT measure increases, both the point estimate and statistical significance rise sharply. The last column reveals in the 3rd year following the PBF increase, the average SAT score of public colleges increases by 6.24 points for every $1,000 increase in funding.

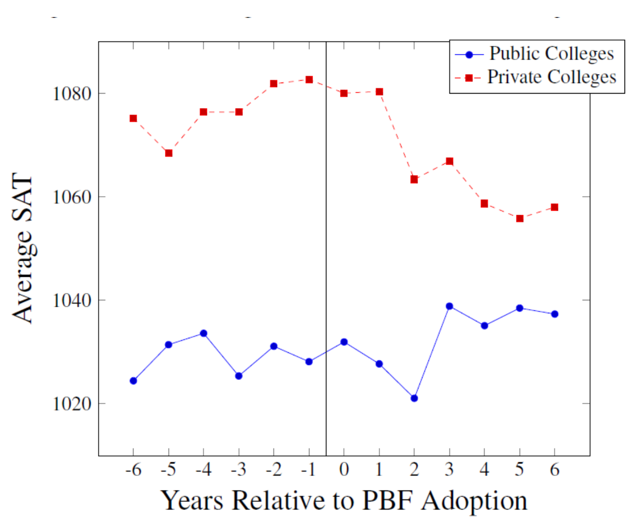
Figure 2.2 graphs the average SAT scores of public and private colleges in PBF states, relative to the adoption of PBF. The graph reveals two main points. First, the average SAT score of public colleges does not increase immediately following adoption of PBF. Instead, as seen in the regressions, it takes a few years for PBF to result in an increase in the average SAT scores. Second, the increase in average SAT scores in public colleges

Table 2.10: The Effect of Performance Funding on Lagged SAT Measures

	(1) Average SAT	(2) 1 - Year Lagged Average SAT	(3) 2 - Year Lagged Average SAT	(4) 3 - Year Lagged Average SAT
Public * PBF Amount	1.41	1.99*	2.37*	6.24***
	(1.31)	(1.04)	(1.22)	(1.15)
Observations	12,684	11,542	10,414	9,294
College and Year FE	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes
Sample	2002-2013	2002-2012	2002-2011	2002-2010

Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2013 dollars per state FTE student. Each regression includes a control for the 1 year lead average SAT score in place of the typical average SAT score used. *** p<0.01, ** p<0.05, * p<0.1

Figure 2.2: Student Average SAT Score Relative to PBF Adoption



does not perfectly coincide with a decrease in the average score in private colleges. If public colleges were increasing quality by attracting students who otherwise would have attended private college, you would expect the timing of the public college increase to coincide with the private college decrease. The graph reveals that there is a decrease in average SAT scores in private colleges but that decrease takes place before the public increase. In the year of the large private college SAT decrease, public colleges also see a decrease to average SAT scores, though the magnitude of the decrease is less. Therefore, it is possible that public colleges are receiving this increase by attracting talented students who would have otherwise attended an institution out of state or who would not have attended college.

Note the increase in SAT score is not accompanied with a decrease in the admission rate, changes to tuition, or changes in institutional grants. If colleges were taking measures to improve the SAT score, changes should also be seen in these measures. By examining differential programs it is clear that the lack of significance associated with these variables is due to different PBF measures resulting in different forms of student selection.[10]

2.5.2.2 Labor Market Outcomes Table 2.11 reveals that PBF programs have a very positive impact on the 2014 income of students who are starting their college career when the PBF is in effect. A $1,000 increase in state funding based on performance measures increases the 2014 mean income of students by $671. The median income increases by $1,351 or $1,231 if you do not include zero observations in the calculation.

Table 2.12 shows how the income distribution changes when the amount of performance funding increases. Due to an increase in performance funding, students are less likely to have incomes in the bottom three quintiles and more likely to have incomes in the

[10]The different forms of student selection associated with different performance measures are seen in Section 2.6.

Table 2.11: The Effect of Performance Funding on Mean and Median 2014 Income

	(1) Mean Income	(2) Median Income	(3) Median Income No Zeros
Public * PBF Amount	671.3**	1,351***	1,231***
	(309.1)	(287.2)	(262.9)
Observations	9,185	9,185	9,185
College and Year FE	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes
Sample	2001-2010	2001-2010	2001-2010

Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2014 dollars per state FTE student. ***$p<0.01$, **$p<0.05$, *$p<0.1$

top quintiles. This is evidence that changes made because of PBF are leading to students finding higher paying jobs or being promoted quicker after graduation.

The interpretation of these labor market results is tricky since the average ability of students in public colleges increases in response to PBF. Therefore, it is hard to say if the increase in labor market earnings is due to colleges changing their practices or simply due to public colleges enrolling more high ability students.

Table 2.12: The Effect of Performance Funding on 2014 Income Distribution

	(1) 1st Income Quintile	(2) 2nd Income Quintile	(3) 3rd Income Quintile	(4) 4th Income Quintile	(5) 5th Income Quintile
Public * PBF Amount	-0.00313*	-0.0177***	-0.00772***	0.0106***	0.0180***
	(0.00171)	(0.00151)	(0.00116)	(0.00342)	(0.00343)
Observations	9,185	9,185	9,185	9,185	9,185
College and Year FE	Yes	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes
Sample	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010

Each column shows the results from a regression on the percentage of students in each income quintile, calculated based on their income compared to others in the same age group. Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2014 dollars per state FTE student. ***p<0.01, **p<0.05, *p<0.1

2.6 DIFFERENTIAL EFFECTS

2.6.1 Methodology

Just as states allocate different amounts of funding based on performance indicators, different states have designed unique programs which tie funding to different college outcome measures. The response to PBF may depend on the outcome chosen to allocate funding. For example, completion-based funding programs should change incentives differently than access-based funding programs.

The dataset I constructed categorizes all outcomes used by states into the categories of completion, access, progression, efficiency, and research. To examine the differential effects of using different outcome measures to allocate funding, I can use information on the amount of funding associated with each outcome category. Now instead of having a variable, $F_{s,t}$, equal to the total amount of performance-based funding, I have five binary variables, $F_{s,t}^{k}$. Each variable $F_{s,t}^{k}$ corresponds to the amount of performance funding allocated based on performance measure k, where

$$k \in \{\text{completion}, \text{research}, \text{progression}, \text{efficiency}, \text{access}\}.$$

Using each of these five indicators, I rerun the regression specified in Equation (2.3) including all five indicators for each funding category. The new regression equation is given by:

$$Y_{i,s,t} = \beta_0 + \sum_{k} \beta_1^k G_i \cdot F_{s,t}^k + \sum_{k} \beta_2^k F_{s,t}^k + G_i \cdot \delta_t^G + \delta_i + \delta_t + \beta_3 X_{i,t} + \varepsilon_{i,s,t}. \tag{2.4}$$

In this regression, β_1^k reveals information on how distributing more performance-based funding based on outcome k impacts outcomes. This estimate is in reference to private colleges in states with the same type of PBF.

In this specification, multicollinearity between the performance funding variables may be present. It is incredibly rare for PBF to be implemented based on measures in only one category. The average PBF program uses 2.7 of the 5 distinct categories to allocate college appropriations. States only use one category to allocate all performance funding in under 10 percent of PBF implementations. The percentage of PBF programs using multiple indicators is summarized in Table 2.3.

To address the potential multicollinearity, Equation (2.4) uses the amount of funding attached to each outcome category instead of an indicator variable for each category. Though states often use many outcome categories to allocate funding, the amount of funding allocated based on each category is usually not the same. Therefore, the variance in the funding amount associated with each outcome is higher than the variance present in indicator variables.

Using information on funding amount does not completely remove the multicollinearity problem, but it does make the problem less severe. However, as seen in Table 2.3, the dollar amount of funding allocated based on categories of completion, research, and efficiency are very highly correlated. This suggests that multicollinearity may still be at play even when using information of funding amount. To address this correlation, I create a variable which is equal to the sum of the completion, research, and efficiency performance based funding. I then rerun the regression specified in Equation (2.4), replacing the completion, research, and efficiency terms with the new combined variable. Though these three performance funding categories are quite different from each other, they are often grouped together in states' implementation of PBF. Therefore, the estimates associated with this combined measure will reveal the effect of this common grouping.

I examine the differential effects on both the incentivized outcomes and the non-incentivized outcomes.

2.6.2 Results

2.6.2.1 Incentivized Outcomes Table 2.13 presents the regression which includes the amount of performance funding attached to each specific outcome category, as outlined in Equation (2.4). The funding measures are adjusted by their standard deviation to make the estimates easily comparable.

The results reveal that allocating more performance funding based on a research or retention causes the incentivized category to increase. Using this technique, I do not find evidence that the outcomes of completion and efficiency are responsive to PBF programs that allocate funding based on those measures. This lack of a result may be due to the high correlation between funding amounts.

To remove the issue of multicollinearity, I rerun the regression outlined in Equation

Table 2.13: Differential Effect of PBF Amount on College Outcomes

	(1) Completion	(2) Research	(3) Progression	(4) Efficiency
Public * Completion PBF Amount	0.142	19.59	0.642	1.174
	(0.986)	(152.9)	(0.658)	(4.284)
Public * Research PBF Amount	0.317	261.8 **	-2.179 ***	-0.607
	(1.395)	(102.8)	(0.598)	(5.210)
Public * Progression PBF Amount	0.606	-151.4 **	1.423 ***	4.979 **
	(0.404)	(72.37)	(0.274)	(2.433)
Public * Efficiency PBF Amount	-0.149	-406.5	2.068	-2.279
	(0.868)	(299.9)	(1.582)	(5.427)
Public * Access PBF Amount	0.831 **	-339.8 ***	1.712 ***	9.821 **
	(0.412)	(103.6)	(0.291)	(3.756)
Observations	13,936	13,350	10,550	14,044
Number of Colleges	1,191	1,172	1,180	1,195
College and Year FE	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2004-2013	2001-2013

Notes: Robust standard errors clustered at the state level in parenthesis. All PBF amounts are measures of the amount of performance funding available in 2013 dollars per state FTE student. The PBF amount variables are scaled by their standard deviations to make the coefficient estimates comparable. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

(2.4 using a combined measure of completion, research, and efficiency. The results of this exercise are reported in Table 2.14. The variables are again scaled by their standard deviations to make the estimates easily comparable. Now, all three different categories of PBF significantly improve some outcomes. Using more PBF based on the combined outcomes leads to a significant increase in the completion rate. In Table 2.13, none of the three of the categories used to create the combined category had a detectable impact on their own.

Interestingly, increasing the amount of performance funding based on progression and

Table 2.14: Differential Effect of PBF Amount on Outcomes with Combined Categories

	(1) Completion	(2) Research	(3) Progression	(4) Efficiency
Public * Combined PBF Amount	0.309***	18.66	-0.0389	-0.428
	(0.0685)	(14.12)	(0.0501)	(0.469)
Public * Progression PBF Amount	0.531*	-158.1**	1.499***	5.056*
	(0.298)	(74.95)	(0.187)	(2.603)
Public * Access PBF Amount	0.796*	-300.3***	1.392***	9.205**
	(0.427)	(95.20)	(0.273)	(4.237)
Observations	13,936	13,350	10,550	14,044
Number of Colleges	1,191	1,172	1,180	1,195
College and Year FE	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2004-2013	2001-2013

Notes: Robust standard errors clustered at the state level in parenthesis. All PBF amounts are measures of performance funding available in 2013 dollars per state FTE student. Combined PBF Amount is equal to the sum of completion, research, and efficiency PBF amounts. The PBF amount variables are scaled by their standard deviations to make the coefficient estimates comparable. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

access impacts multiple outcomes. I find progression and access funding is associated with increases to completion, progression, and efficiency. The response to progression and access-based performance funding appears to have spillover effects which improve variables other than the incentivized outcomes. This can be explained by identifying that completion, progression, and efficiency measures are linked. Improvements to any one of these measures should have an impact on the other two measures. Interestingly, the research outcome decreases as more funding is allocated based on measures of progression and access. These decreases seem to suggest that the goal of increasing research productivity is disjoint from the other three incentivized outcomes. This may due to college employees having to allocate their time between improving research outcomes and improving academic outcomes.

2.6.2.2 Performance-Based Funding Channel This section analyzes how colleges are improving performance, while focusing on the differential effect of using different measures of performance to allocate PBF. When examining the differential effect, to deal with multicollinearity, I again combine the measures of completion, research, and efficiency into one combined category.

Table 2.15 displays how performance funding based on a specific performance category affects spending decisions. Overall, the table reveals the shift in spending from instruction to institutional support, found in Section 2.5, does not characterize the response to all PBF programs. In fact this response seems to be isolated to the combined category. A one standard deviation increase in funding based on the combined category is associated with a \$146 per FTE student decrease in instruction and a \$119 per FTE student increase in institutional support. This same response is not observed for the progression or access-based funding programs. In fact, an increase in access funding is associated with a \$407 per FTE student decrease in student support.

By examining the differential effects, a relationship between student support and PBF is revealed. Increases to both access and combined measures result in increases to student support. Colleges could be increasing student support to help students who need extra help. This should result in an increase to completion related metrics.

The differential effect of PBF amount on college admission and tuition decisions is summarized in Table 2.16. Information on institutional grants is displayed in the last column of Table 2.15. When analyzing the response to PBF, the only admission related impact was seen through improvements to the SAT score. In addition, the increase in SAT score was not accompanied with a decrease in the admission rate, changes to tuition, or changes in institutional grants. The lack of evidence relating to other variables was surpri-

Table 2.15: The Differential Effect of Performance Funding on College Spending per FTE

	(1) Total Education & General	(2) Instruction	(3) Research	(4) Public Service	(5) Student Support	(6) Institutional Support & Operations	(7) Institutional Grants
Public * Combined PBF Amount	-8.234	-146.3***	-237.6***	-20.86***	73.78***	119.3***	10.70
	(81.27)	(22.31)	(22.12)	(7.471)	(13.57)	(15.58)	(13.26)
Public * Progression PBF Amount	348.5	39.35	43.17	36.03	28.38	-92.24	194.1***
	(500.7)	(133.7)	(76.44)	(24.77)	(76.91)	(79.27)	(65.44)
Public * Access PBF Amount	775.2	268.7	-21.74	133.3***	301.8**	-407.2***	517.0***
	(822.2)	(216.8)	(103.2)	(29.73)	(120.6)	(118.4)	(83.78)
Observations	14,044	14,044	7,989	8,555	13,986	13,460	6,774
College, Year, and Public by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013

Table 2.16: The Differential Effect of Performance Funding on Admission Decisions

	(1) SAT Diff	(2) FTE Diff	(3) Admissions	(4) Admission Rate	(5) New Undergraduates	(6) Tuition In-State	(7) Tuition Out-of-State
Public * Combined PBF Amount	0.469	-54.77**	26.10***	0.00780***	-31.99***	97.41**	500.0***
	(0.349)	(24.93)	(8.359)	(0.000418)	(10.12)	(42.40)	(49.16)
Public * Progression PBF Amount	1.447***	120.0***	38.00	-0.00733**	184.9***	-381.6***	-615.9***
	(0.193)	(10.79)	(29.71)	(0.00279)	(37.27)	(112.1)	(174.9)
Public * Access PBF Amount	1.233***	15.10	-70.89*	-0.00426	-47.54	-165.4*	-402.8**
	(0.281)	(43.18)	(36.07)	(0.00382)	(59.58)	(97.21)	(197.7)
Observations	12,684	14,039	12,775	11,787	13,017	14,001	14,001
College, Year, and Public by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013	2001-2013

Tables 2.15 and 2.16: Robust standard errors clustered at the state level in parenthesis. All PBF amounts are measures of performance funding available in 2013 dollars per state FTE student. Combined PBF Amount is equal to the sum of completion, research, and efficiency PBF amounts. The PBF amount variables are scaled by their standard deviations to make the coefficient estimates comparable. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

sing. However, by examining differential programs it is clear that the lack of significance is due to different PBF programs resulting in different forms of student selection.

Under the combined measure, student selection is observed through colleges choosing to decrease the total number of students. To achieve this goal, colleges increase the number of admissions, admissions rate, and tuition for in-state and out-of-state students. Though the amount of students admitted into the college increases, because of the increase in overall tuition, less students decide to attend. Since completion and retention rates are both percentage numbers, by decreasing the number of students, colleges are able to better focus their resources to improve these measures.

Under the progression and access measures, colleges do not decide to decrease the size of their student body but instead increase the quality of their student body. Colleges do this by following a three step process. First, colleges restrict admissions. Lowered admissions is seen by a 0.7% decrease in the admission rate for progression-based programs and a 71 student decrease in admittance under access-based programs. Second, colleges lower the tuition charged to both in-state and out-of-state students to increase the likelihood that high ability students matriculate. Under progression-based programs tuition decreases by $382 and $616 for in-state and out-of-state students, respectively. Under access-based programs tuition decreases by $165 and $403 for in-state and out-of-state students, respectively. Third, colleges use institutional grants to decrease tuition for high ability students. Progression-based programs lead to an increase in grants spending equal to $194 per FTE student and access-based programs lead to an increase in grant spending $517 per FTE student. The end result of this process is a higher quality student body. Every year progression-based programs were in effect, the average SAT score increased 1.4 points while every year access-based programs were in effect, the average SAT score increased 1.2 points.

Table 2.17: Differential Effect of Performance Funding on Mean and Median 2014 Income

	(1) Mean Income	(2) Median Income	(3) Median Income No Zeros
Public * Combined PBF Amount	3,731	4,755*	4,316**
	(3,059)	(2,556)	(2,098)
Public * Progression PBF Amount	257.6	453.5	519.8
	(540.8)	(553.9)	(458.5)
Public * Access PBF Amount	-763.4	-1,358	-1,047
	(813.5)	(883.4)	(727.4)
Observations	8,943	8,943	8,943
College and Year FE	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes
Sample	2001-2010	2001-2010	2001-2010

Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2014 dollars per state FTE student. Combined PBF Amount is equal to the sum of completion, research, and efficiency PBF amounts. The PBF amount variables are scaled by their standard deviations to make the coefficient estimates comparable. ***p<0.01, **p<0.05, *p<0.1

2.6.2.3 Labor Market Outcomes Table 2.17 reveals the impact of different PBF programs on mean and median income. These results reveal that the combined performance measure seems to be driving the results seen in Table 2.11. A $1,000 increase in state funding based on the combined performance measures increases the median 2014 income by $4,755 or $4,316 if you do not include zero observations in the calculation. Further, the point estimate for mean income is also very high, however the results are noisy and the estimate is not statistically significant. Allocating funding based on progression or access-based measures do not seem to have an impact on 2014 mean or median income measures.

Table 2.18: Differential Effect of Performance Funding on 2014 Income Distribution

	(1) 1st Income Quintile	(2) 2nd Income Quintile	(3) 3rd Income Quintile	(4) 4th Income Quintile	(5) 5th Income Quintile
Public * Combined PBF Amount	0.00275	-0.0330*	-0.0211	0.00319	0.0482**
	(0.0142)	(0.0173)	(0.0126)	(0.0133)	(0.0229)
Public * Progression PBF Amount	-0.00393	-0.0110***	-0.00356	0.00579	0.0127**
	(0.00370)	(0.00409)	(0.00268)	(0.00417)	(0.00604)
Public * Access PBF Amount	0.000763	0.00997	0.00469	-0.0141*	-0.00129
	(0.00657)	(0.00671)	(0.00415)	(0.00759)	(0.00969)
Observations	8,943	8,943	8,943	8,943	8,943
College and Year FE	Yes	Yes	Yes	Yes	Yes
Public by Year FE	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes
Sample	2001-2010	2001-2010	2001-2010	2001-2010	2001-2010

Each column shows the results from a regression on the percentage of students in each income quintile, calculated based on their income compared to others in the same age group. Robust standard errors clustered at the state level in parentheses. PBF amount is a measure of the amount of performance funding available in thousands of 2014 dollars per state FTE student. Combined PBF Amount is equal to the sum of completion, research, and efficiency PBF amounts. The PBF amount variables are scaled by their standard deviations to make the coefficient estimates comparable. ***p<0.01, **p<0.05, *p<0.1

Table 2.18 shows how the income distribution responds to different performance-based funding programs. Allocating government funding based on the combined measure or progression result in a shift of the income distribution. Specifically, funding based on these measures result in less students earning in the bottom part of the distribution and more students earning in the top part of the distribution. This positive income shift is not observed with access-based performance funding.

2.7 CONCLUSION

This paper uses a unique dataset to examine the impact of performance-based funding on public colleges by utilizing triple-difference regressions which control for state-level and public-college level trends. I find evidence that PBF is effective at improving the completion and retention rates of colleges. Digging deeper, I find that completion and retention further increase with the amount of funding allocated based on performance measurements. These increases are not caused by an income effect, and the results reveal that increases to completion and progression can be achieved by simply changing the method of allocating public funds. If colleges were to completely allocate funding through performance measures, the difference in the completion rate between public and private colleges would be significantly reduced. I find that the retention and access measures are the most effective at improving many of the outcomes often incentivized at once. PBF programs that allocated funding based on completion, research, and efficiency were only effective at improving completion rates.

Changes in the incentivized outcomes appear to be partially due to colleges using performance padding to increase the incentivized measure without improving educational performance. Through examining intermediate outcomes, I find evidence that colleges are improving outcomes by attracting higher quality students. Every year PBF is in effect, the average SAT score of public colleges affected by PBF increases. This increase in average SAT score suggest increased effort to attract higher quality students.

There is some evidence that PBF results in better labor market outcomes for students. However, this result is hard to interpret since the composition of the student body also changes in response to PBF. The change in student composition means that I am unable to rule out that income increases are not due to increases in student ability.

Unexpected consequences arise due to the implementation of PBF. By examining the spending decisions of colleges, I find evidence that under PBF spending on instruction decreases while spending on institutional support increases. This result is driven by a subset of PBF programs who base funding on a combination of completion, research, and efficiency. Under these programs, in order to report all necessary statistics and comply with the state government, the administrative costs of the colleges increase. To pay for this increased administrative cost, colleges could choose to spend less on instruction. This finding suggests that some PBF programs may actually be hurting the educational quality students receive at public colleges.

This research has important policy implications since it helps inform the large number of states experimenting with PBF. I show that public colleges do produce better outcomes from PBF. By analyzing the differential effects, I find that the amount of performance funding and measures of performance used to allocate funding have a large impact on the improvements to outcomes. However, I also find some evidence that colleges have an incentive to use performance padding to increase the incentivized outcomes. The results here supplemented with a model of college and student choice such as in Svoboda [2016] can be utilized to design a program which maximizes the effect of PBF while limiting the incentives for performance padding. Together these techniques will allow policy makers to improve outcomes by observing what is effective and designing new programs while properly accounting for college and student responses.

3.0 ACCESS, AFFORDABILITY, AND OUTCOMES: EVALUATING RATING-BASED COLLEGE AID

3.1 INTRODUCTION

Colleges in the United States are facing increasing criticism of their performance in regards to access, affordability, and outcomes. Ellwood et al. [2000] presents evidence that the gap in college enrollment across income levels is widening over time, making college less accessible to the poor. Long [2004] and Turner [2012] observe that an increase in the federal support of colleges has not resulted in a large increase in affordability.[1] According to a report by National Student Clearinghouse [2012], under 60 percent of United States's first-time degree seeking students who begin at a four-year public university complete their degree within six years, making the United States college completion rate and college attainment rate lower than those of many advanced economies.

The poor performance of colleges has led to proposed reforms of the federal college financial aid system. One such proposal titled "The Presidents Plan to Make College

[1] These papers show that recent attempts to lower the cost of college, including increasing the maximum Pell Grant award and creating tax credits for those who attend college, have been met with an increase in tuition. According to College Board [2013], in the last twenty years, after adjusting for inflation, average grant aid and tax benefits at public four-year institutions have increased 180 percent. The same period saw net tuition and fees increase by 53 percent. The situation is similar for private nonprofit four-year universities, with aid having increased by 133 percent and tuition and fees by 23 percent.

More Affordable: A Better Bargain for the Middle Class," suggests tying the financial aid award a student receives to a college rating based on three areas: access, affordability, and outcomes.[2] Under this proposal, if a student attends a college with a high rating, she will receive more financial aid than if that same student attends a college with a low rating.

In this paper, I extend the model of higher education first developed in Epple et al. [2006] and Epple et al. [2016] by explicitly allowing for the possibility that a student drops out of college. Using college level data and the 1997 National Longitudinal Study of Youth, I create a quantitative version of this model which produces statistics that closely resemble the market for higher education under the current student federal aid system. I model a potential policy change which allows student federal aid to be tied to a rating determined by a college's performance. In the model, college performance is defined to be a function of the characteristics of the college and it's student body. This general setup is able to capture many different possible rating schemes. I explicitly consider ratings that tie the federal aid a student receives to measures of college access, affordability, and outcomes. I consider proposals based on one measure and proposals that take into account multiple measures of college performance. This simulated policy change makes it possible to evaluate how rating-based aid systems will impact the enrollment decisions of colleges and students. Further, I explore how introducing rating-based aid will affect college access, affordability, and outcomes.

I use a rich structural model of the market for higher education that incorporates the actions of both students and colleges. The model is characterized by two types of colleges, public and private, which compete against one another to attract students. Both types of colleges make decisions in order to maximize the educational quality they provide. Public colleges receive assistance from the state government but are not free to set their tuition. Private colleges do not receive this assistance and can use tuition discounts to attract de-

[2]More details on this proposal and other proposed federal reforms are outlined in Section 3.2.

sirable students. Students choose, from the colleges they have been admitted to, what college to attend after observing the educational quality and tuition at each college. Some students may choose to not attend any college and instead enter the labor force straight from high school. Low income students who attend college are awarded financial aid from the federal government. In the baseline scenario, the amount of aid students receive is equal to the amount they would receive under the current attendance-based federal aid system.

The model allows for the possibility that a student drops out of college. College non-completion is an important feature to include in a model of student choice since the average graduation rate in public universities in the United States is under 60 percent and the possibility of non-completion affects student's attendance decisions. If a student with a low probability of completion decides to attend college, it is very likely that she will have to drop out and be worse off than if she initially decided to not attend college. In my model, the completion rate of a student depends on the characteristics of each student and the quality of the college they attend. Colleges can change their average completion rate by altering enrollment decisions or by changing how much they spend on education. This feature of the model allows me to observe how the college completion rate responds to federal aid changes. Under the benchmark calibration, the model is able to replicate many of the main features of the data, including matching the college completion rate of different types of colleges.

Incorporating rating-based aid into the model yields three main findings. First, basing aid on any one measure can yield unintended consequences. When aid allocation is determined entirely by one of the three areas of focus, that area improves but this policy hurts the other two areas of focus. The magnitude of improvement is small compared to the magnitude of the deterioration. This result stems from the fact that actions taken in pursuit of one goal may be detrimental to a different goal. For example, consider a situation where colleges are trying to improve the average graduation rate. Since the likelihood of graduation is greater if the family income is higher [Light and Strayer, 2000], a college that wants to increase the average graduation rate may only admit high income students, resulting in a trade-off between increased completion and decreased access. In the same way, if the federal aid system puts too much emphasis on one goal, colleges will try to improve that one goal at the expense of the other less incentivized goals.

Second, introducing a rating-based system can result in overall welfare improvements when the rating is based heavily on the outcome ratings. In addition, an affordability-based rating system is effective at improving welfare for some segments of the population. When aid is based on the outcome rating, high income students benefit. When aid is based on the affordability rating, low income students benefit.

The third main result is related to how colleges respond to federal aid increases. Under rating-based aid where the rating is based on college completion, colleges react to an increase in federal aid by increasing tuition. This is similar to the response under the current attendance-based rating system. However, under the accessibility or outcome-based rating-based systems, the incentives introduced by the rating cancel out the incentives to raise tuition. As a result, colleges no longer choose to raise tuition in response to an increase in the maximum federal aid.

My research is related to several lines of literature. Besides Epple et al. [2006] and Epple et al. [2016], other papers also present models of the market for higher education. Chade et al. [2014] and Fu [2014] both study a model of college choice that includes uncertainty in college admission. The model I develop instead incorporates uncertainty in college completion into a structural model of the market for higher education. A number of papers present equilibrium models of higher education which look at the effect of policy changes on college non-completion. For example, Garriga and Keightley [2007] use an overlapping generations model to show education policies, including tuition subsidies, grant subsidies, and loan limit restrictions, affect college enrollment, time-to-degree, and dropout. Johnson [2013] uses a dynamic model of education, borrowing, and work decisions to explore how the removal of borrowing constraints affects college attendance and completion. Though these papers analyze a large variety of education policies, the federal performance-based aid programs that have been the subject of a number of proposals have not been considered.

The proposed change to federal aid is following several other changes in federal aid that share the common goal of increasing college affordability. Some of the previous interventions included increasing the maximum Pell Grant award for lower income families. Epple et al. [2016] shows that a blanket increase in the Pell Grant will result in universities increasing their tuition. The findings of their model are supported by the data presented in Turner [2012]. Turner [2012] uses yearly variation in the Pell Grant amount to show that an increase in the Pell Grant amount is passed through the colleges in the form of higher tuition.[3] These papers suggest that a blanket increase in the Pell Grant award will not improve the affordability of colleges. My paper explores how increase in federal aid will affect affordability under the current aid system and the new proposed rating-based aid system.

The rest of the paper is structured as follows. Section 3.2 reviews proposed changes to federal financial aid. Section 3.3 reviews the Epple et al. [2016] model, presents my extension, and defines the equilibrium. Section 3.4 discusses the optimal decisions of students and colleges. Section 3.5 incorporates federal funding into the model. In this section, the model is solved with the inclusion of attendance-based federal funding and the proposed rating-based federal funding. Section 3.6 makes functional form assumptions and calibrates the model. Section 3.7 simulates the proposed federal aid policies. Section

[3] Increases in federal aid leading to increases in tuition is also discussed in Singell and Stone [2006] and Rizzo and Ehrenberg [2004]

3.8 concludes.

3.2 POLICY REVIEW

Proposals to change federal funding follow funding changes made by state governments. As of 2014, more than half of all state governments base a portion of their college aid on college performance. These states vary the amount of funding based on a variety of performance indicators such as course completion, time to degree, transfer rates, number of degrees awarded, or number of low-income and minority graduates. Generally, the amount of performance-based aid is between 5 and 30 percent of the total state funding for higher education. Many of these performance-based funding programs begin as a small percent of total aid and increase overtime.[4]

In recent years, there have been many proposed reforms of federal college financial aid aimed at improving the performance of colleges. Many of these proposals suggest linking the amount of federal aid awarded to the college attended. The goals of these proposals are varied. Some design the modifications with the intent of raising the completion rate. A proposal by the Rethinking Student Aid Study Group [2008] suggests that the federal government provide direct funding to institutions based on their success in retaining and graduating low and moderate income students. A similar suggestion is made by The National Association of Student Financial Aid Administrators [2013]. Other proposals focus on increasing the affordability of college. Gillen [2011] suggests a modification of the

[4]For example, Arkansas instituted 5 percent performance-based funding during the 2012-2013 school year. This aid is scheduled to increase by 5 percent increments until capped at 25 percent during the 2017-2018 school year. Similarly, Maine instituted performance-based funding that was 5 percent of base funding in fiscal year 2014. This funding is scheduled to increase by 5 percent increments each year until 30 percent of base funding is allocated based on performance.

Pell Grant award which ties funding to the median cost of college instead of the cost of attendance at each college, in the belief that this would increase the price consciousness of students and incentivize colleges to keep tuition low.

A plan proposed by the Obama administration has the goal of simultaneously improving the colleges' outcomes, affordability, and accessibility for low income individuals.[5] This proposal combines many previously proposed federal aid reforms. The first stage of the proposal calls for the Department of Education to release ratings based on measures related to college outcomes, affordability, and accessibility for every college that receives federal financial aid. These ratings would be transparent and visible not only to the colleges, but also to potential students who are making college enrollment decisions. A number of measurements have been proposed for each of these criteria. The proposed outcome measures include the completion rate and measures of labor market success such as long-term median earnings, graduate school attendance, or percentage of students repaying their loans on time. Potential affordability measures include average tuition net institutional grant aid or net tuition paid by different income groups. Access measures include total enrollment of low to moderate income student, percentage of students receiving the Pell Grant, expected family contribution gap, and the number of first generation college students enrolled.

The federal financial aid students receive would be linked to these ratings. A student who attends a college with a higher rating will receive more financial aid than a student who attends a college with a lower rating. Tying aid to the ratings simultaneously encourages students to attend colleges that are better performing and encourages under-performing colleges to adopt practices to improve their rating.

This proposal was not well received by colleges. The push-back eventually led to the government altering the plan. The federal government instead decided to release a website

[5] The White House [2013] press release contains more information on the proposal.

that publishes information about all colleges.[6] Federal aid is not be tied to these college statistics; instead the website serves as a resource for students who are making college attendance decisions.

Though the original plan to tie college performance to federal aid was not implemented, performance-based funding is an important topic of interest to governments and is at the center of talk on education policy. As more states move to adopt performance funding and see success from these programs, the topic of federal performance funding is likely to be revisited in the future. In this paper, I simulate the effect of federal performance funding to better inform future changes to federal funding.

3.3 MODEL

To evaluate an introduction of rating-based federal funding I consider a structural model of the market for education. The setup of the model and baseline results presented in Sections 3.3, 3.4, and 3.5.1 closely follow the results presented in Epple et al. [2016]. In these sections, I briefly review the model while focusing discussion on the differences that arise due to my inclusion of the possibility of non-completion and other generalizations.[7]

In this section, I describe the decision problem of the potential students and the problem of each type of college. Then I introduce a government tax rate and define an equilibrium.

[6] The website is located at https://collegescorecard.ed.gov/

[7] For a more thorough discussion of the baseline model results, readers are encouraged to consult Epple et al. [2016].

3.3.1 Students

Students choose whether to attend college and, if they decide to go to college, what college to attend. Students are differentiated by their ability b and their before tax household income y.[8] The measure of potential students in the economy is assumed to be 1.

Assumption 1. *The joint cumulative distribution of income and ability, $F(b,y)$, is continuous with convex support $S \subset \mathbb{R}^2_+$ and density $f(b,y)$.*

Students choose from a set of options J, consisting of colleges that the student is admitted to and an outside option. The subscript j is used to refer to colleges and the subscript 0 is used to refer to the outside option. Students observe the level of education quality, $q(e_j, \theta_j)$, and the required tuition, $t_j(b,y)$, for all colleges that admit the student, where education quality is an increasing function of e_j, the per student expenditure on education, and θ_j, the mean ability level of the student body at college j. For convenience, I refer to $q(e_j, \theta_j)$ as q_j.

Assumption 2. *The outside option is available to all students at zero cost ($t_0 = 0$) and provides education quality q_0.*

Once a student enters college, the decision to complete is determined by a random draw. A student of type (b,y) who attends college j will receive a random draw that makes completing college the best decision with probability $c(q_j, b, y)$. Students are aware of these probabilities and this information influences their college decisions.

The completion rate is a function of the college quality, the student's ability and family income. It is assumed that students who have higher ability, higher family income, and

[8] In Epple et al. [2016] students are also differentiated by state of residence. To simplify the analysis, this feature is not included.

students who attend higher quality colleges are more likely to complete college. These assumptions are supported by the results observed in the data, presented in Section 3.6.

When students are making college attendance decisions, they are aware of the possibility that they will not complete college. For students with a low completion probability, the choice to attend college is risky, since there is a large probability that the student will have to drop out and pursue their outside option. When students drop out, they do not have their tuition refunded and are therefore worse off than students who initially decided to take the outside option. Students with a higher probability of completing college face a smaller risk.

The utility function of student i with ability b and income y, who attends college j, is given by a simple expected value over the probability that the student will complete college. Specifically the utility is:

$$U_{i,j}(b,y) = c(q_j,b,y) \cdot u(a(q_j,b),x_j) + (1 - c(q_j,b,y)) \cdot u(a(q_0,b),x_j) + \varepsilon_{i,j}$$
$$x_j = y - t_j(b,y) - \nu$$

In this function, $a(\cdot)$ is the achievement of the student, q_j is the education quality at college j, b is ability of the student, x_j is the remaining income, $t_j(b,y)$ is tuition for student of type (b,y) set by college j, ν is the non-tuition costs associated with attending college, $c(q_j,b,y)$ is the probability that student with ability b and income y graduates from college j, and $\varepsilon_{i,j}$ is the idiosyncratic preference shock for student i who attends college j.

The first two terms of the utility function are the weighted average of the utility that the student would receive if she graduated college j, $u(a(q_j,b),x_j)$, and the utility that the student would receive if she fails to complete college j, $u(a(q_0,b),x_j)$. The student is able to graduate with probability $c(q_j,b,y)$. The utility function is an increasing function of the student's achievement and remaining income. Achievement is an increasing function of the education quality received and the ability of the student. The idiosyncratic preference shock $\varepsilon_{i,j}$ is included to account for the unobservable factors that affect the college attendance decision.

Assumptions on the utility, achievement, completion, and college quality functions are summarized below.

Assumption 3. *$u(\cdot)$, $a(\cdot)$, $c(\cdot)$, $q(\cdot)$ are increasing in all arguments and are C^1.*

When solving the student's problem, I assume students follow Assumption 4.

Assumption 4. *When choosing, students take as given the admission policies, tuition levels, and the education quality of the colleges.*

Since there are many students at each college, it is reasonable to assume the actions of one student will not affect the decisions made by colleges.

3.3.2 Colleges

3.3.2.1 Public Colleges Public colleges decide what students to admit and how much to spend on educational expenditure. When making admittance decisions, public colleges are able to perfectly discriminate based on ability and income. The admission function is denoted by $\alpha_j(b,y)$. Once students are admitted, they choose the college to attend. This choice is given by the matriculation function $r_j(b,y;T,Q)$. In this function, T and Q refer to the vector of tuition and quality offers extended to a student of type (b,y).

Colleges maximize the sum of their students' "success". Success is a function of the student's achievement and completion probability, denoted as $o(a(q_j,b),c(q_j,b,y))$. This term can be thought of as the utility contribution that comes from attending college adjusted by the probability that a student completes. For brevity, $o(q_j,b,y)$ is used to refer to this function. The objective function of a public college is equal to

$$\int\int o(q_j, b, y)\alpha_j(b, y)r_j(b, y; T, Q)f(b, y)dbdy.$$

A public college can increase the realized value of their objective function by enrolling more students or by raising their education quality. To increase education quality, the college must increase either their average ability level or education spending.

Public colleges receive a subsidy of z_j per student from the state government. In addition to giving the subsidy, it is assumed that the state government sets tuition rates, $\hat{t}_j(y)$, that the public colleges must use. Tuition differentiation is included to match the empirical fact that the net tuition paid to public colleges increases with income. Further, I assume the tuition rates are set outside of the model.

Public colleges are constrained by the following budget constraint:

$$F + V(k_j) + k_j e_j = \int\int t_j(b, y)\alpha_j(b, y)r_j(b, y; T, Q)f(b, y)dbdy + k_j z_j.$$

Where k_j is the total number of students who attend college j.

The left hand side of this equation is the college's cost equal to the sum of the fixed cost of operating the college, F, the variable cost of operating a college, $V(k_j)$, and the total amount spent on education, $k_j e_j$. The right hand side of this equation is the revenue of a public college, equal to the sum of all tuition revenue collected plus the total subsidy received from the state government.

The next assumption limits the size of colleges.

Assumption 5. $V(\cdot)$ *is a twice differentiable, increasing, and convex function.*

3.3.2.2 Public College Optimization Problem The public college problem is summarized below

$$\max_{\theta_j, e_j, k_j, \alpha_j(b,y)} \int\int o(q_j, b, y)\alpha_j(b,y) r_j(b,y;T,Q) f(b,y) dbdy \quad \text{s.t.}$$

Identity Constraints:	$\theta_j = \frac{1}{k_j}\int\int b\alpha_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy$
	$k_j = \int\int \alpha_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy$
Budget Constraint:	$F + V(k_j) + k_j e_j = \int\int t_j(b,y)\alpha_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy + k_j z_j$
Exogenous Tuition:	$t_j(b,y) = \hat{t}_j(y)$
Feasibility Constraint:	$\alpha_j(b,y) \in [0,1] \ \forall\ (b,y)$

The following assumption is followed when solving the problem.

Assumption 6. *When setting policies, colleges take as given their competitors' admission policies, tuition levels, and educational quality.*

3.3.2.3 Private Colleges Private colleges solve a maximization problem that is similar to the problem public colleges face. The key differences arise due to their relationship with the state government.

Private colleges do not have an obligation to the community and their objective is assumed to be different than that of public colleges. Private colleges maximize the quality of their college.[9] Quality is given by the quality function discussed in 3.3.1. Private colleges do not receive a subsidy from state governments. In addition, they are able to set their own tuition for each possible type of student. Private colleges choose tuition levels and education expenditure in order to maximize quality.

The cost function for private colleges is identical to the cost function for public colleges; however, the revenue for private colleges is different. In place of the subsidy from

[9]A possible interpretation of this assumption is that private colleges want to maximize the prestige of their university.

the state government, private colleges receive endowment income D_j. This endowment is exogenously given and is not earmarked.

Private colleges are constrained by the following budget constraint:

$$F+V(k_j)+k_je_j=\int\int t_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy+D_j.$$

3.3.2.4 Private College Optimization Problem The decision problem for private colleges is similar to that of public colleges. The main difference is that private colleges also need to choose a tuition rate for each possible ability-income combination. In the absence of tuition caps, since private colleges can choose their tuition rate, there is always some tuition level that would make a private college want to admit a student. Therefore, instead of choosing whether to admit students, colleges choose a tuition level where they would want to admit students. This is the same as if $\alpha_j(b,y)$ was equal to one for all students (b,y). When tuition caps are instituted, this will no longer be true.

The private college maximization problem is summarized below

$$\max_{\theta_j,e_j,k_j,t_j(b,y)} q_j \quad \text{s.t.}$$

Identity Constraints: $\theta_j=\frac{1}{k_j}\int\int br_j(b,y;T,Q)f(b,y)dbdy$

$k_j=\int\int r_j(b,y;T,Q)f(b,y)dbdy$

Budget Constraint: $F+V(k_j)+k_je_j=\int\int t(b,y)r_j(b,y;T,Q)f(b,y)dbdy+D_j$

Assumption 6 also applies to private colleges.

3.3.3 State Budget Balance

I assume the state government operates a balanced budget. The state levies a uniform tax to pay for the subsidy given to public colleges. Assuming there are P public colleges indexed by $j = 1, 2, \ldots, P$, it follows that the uniform state tax, τ_s, must satisfy:

$$\tau_s \int \int y f(b, y) db dy = \sum_{j=1}^{P} z_j k_j$$

3.3.4 Definition of Equilibrium

Given (i) ability and income distribution, the utility function, and the completion functions; (ii) college fixed cost and variable cost function; (iii) the college quality function and public college objective function; (iv) the state subsidies, public tuition levels, and private endowments; (v) the number of public colleges and private colleges; and (vi) the quality of the outside option, an **equilibrium** consists of: (a) a collection of college characteristics (θ_j, e_j, k_j) for all colleges j; (b) an admission decision $\alpha_j(b, y)$ for all public colleges j; (c) a vector of tuitions $t_j(b, y)$ for all private colleges j; (d) a set of student choice probabilities $r_j(b, y; T, Q)$; and (e) a state tax rate τ_s that satisfies: (1) the public maximization problem for all public colleges, taking as given other colleges' charged tuition and quality; (2) the private maximization problem for all private colleges, taking as given other colleges' charged tuition and quality; (3) the utility maximization problem for all students (b, y), taking as given all college's charged tuition and quality; and (4) the government budget equation.

3.4 EQUILIBRIUM DECISIONS

3.4.1 Students

In order to analytically solve the model, the following assumptions about the student's achievement and utility function are made.

Assumption 7. *The student achievement function $a(q_j,b)$ and the utility index $u_j(\cdot)$ are given by:*

$$a(q_j,b) = q_j^{\omega_1} b^{\omega_2}, \quad u_j(a(q_j,b), y - t(b,y)) = \rho ln[(y - t(b,y))a(q_j,b)]$$

The random utility terms $\varepsilon_{i,j}$ are independent and identically distributed Type 1 Extreme Value random variables. [10]

The utility of student i who attends college j can be written as

$$U_{i,j}(b,y) = \rho ln[(y-t_j) q_j^{c(q_j,b,y)\cdot\omega_1} q_0^{(1-c(q_j,b,y))\cdot\omega_1} b^{\omega_2}] + \varepsilon_{i,j}.$$

From this utility and the assumption about $\varepsilon_{i,j}$, the matriculation function for each student (b,y) simplifies to

$$r_j(b,y;T,Q)) = \frac{(y-t_j)^{\rho} \frac{q_j}{q_0}^{c(q_j,b,y)\cdot\rho\cdot\omega_1}}{\sum_{k\in J}(y-t_k)^{\rho} \frac{q_k}{q_0}^{c(q_k,b,y)\cdot\rho\cdot\omega_1}}.$$

A college can increase the matriculation of a student with type (b,y) by either increasing quality or decreasing tuition. If a college decides to increase quality, an increase in matriculation comes from two sources. First, higher education quality increases the return to schooling for this college. Second, an increase in education quality increases the probability that any student will graduate. This makes the decision to attend college less risky and results in more students being willing to attend this college.

[10] This utility function is chosen to maintain comparability between the results presented here and those presented in Epple et al. [2016].

3.4.2 Public Colleges

The solution to the public college maximization problem yields the following admittance equation. The derivation of this equation is in Appendix A.1.1.

$$\alpha_j(b,y) = 1 \iff \frac{o(q_j,b,y)}{\lambda_j} + \hat{t}_j(y) + z_j > V'(k_j) + e_j + \frac{q_{\theta_j}}{q_{e_j}}(\theta_j - b). \tag{3.1}$$

This equation is the one state version of Proposition 2 described in Epple et al. [2016]. According to Equation (3.1), a public college will admit a student of type (b,y) if the marginal benefit of admitting this student is larger than this student's effective marginal cost. The marginal benefit, on the left side of the inequality, is equal to the sum of the increase to the success function, the tuition the student will pay and the subsidy from the state government. The effective marginal cost is equal to the increase in variable cost, the per student educational expenditure, and a cost component that differs based on the student's ability.

Since the effective marginal cost reappears many times in the equilibrium solution, I write it as $EMC_j(b,y)$.

$$EMC_j(b,y) \equiv V'(k_j) + e_j + \frac{q_{\theta_j}}{q_{e_j}}(\theta_j - b)$$

Note the effective marginal cost changes with the student's ability. If a student has ability b lower than the average ability θ_j, then admitting the student will lower the average ability of the college. This will hurt the rest of the students in the college and lower the value of the college's objective function. It is appropriate that this cost should be considered when deciding whether or not to admit a student. Likewise, if a student has ability b higher than the average ability θ_j, then admitting this student will raise the average ability of the college. The ability cost component will be negative, and admission decisions will favor these high ability students.

3.4.3 Private Colleges

The solution to the private college maximization problem yields the following implicit expression for the optimal tuition. The derivation is presented in Appendix A.1.2 .

$$r_j(b,y;T,Q) - EMC_j(b,y)\frac{\partial r_j(b,y;T,Q)}{\partial t_j(b,y)} = -t_j(b,y)\frac{\partial r_j(b,y;T,Q)}{\partial t_j(b,y)} \tag{3.2}$$

This equation is equivalent to Proposition 1 in Epple et al. [2016]. Private colleges set the marginal benefit from increasing tuition equal to the marginal cost. The marginal benefit of increasing tuition is equal to the increased revenue from students who are attending the college plus a decrease in the effective marginal cost derived from students changing attendance decisions due to the higher tuition. The marginal cost of increasing tuition is equal to the decrease in the amount of tuition collected from students who change attendance decisions.

Equation (3.2) can be solved to determine tuition for each type of student.

$$t_j(b,y) = EMC_j(b,y)\left[\frac{\rho(1-r_j(b,y;T,Q))}{\rho(1-r_j(b,y;T,Q))+1}\right] + y\left[\frac{1}{\rho(1-r_j(b,y;T,Q))+1}\right] \tag{3.3}$$

3.5 FEDERAL AID, TUITION CAPS AND NON-TUITION COSTS

3.5.1 Attendance-Based Federal Aid

In the baseline scenario, federal aid is attendance-based. It is assumed federal aid is given directly to students who exhibit financial need. The amount of aid depends on the expected family contribution, $EFC(y)$, and the tuition of the university. The expected family contribution is an increasing function of income. If tuition is higher than the students's expected contribution, the federal government provides aid, $\bar{A}_j(b,y)$, to the student up to some maximum aid level, $\bar{A}$.[11] Federal aid received by a student with ability and income (b,y) who attends university j can be summarized by the following equation.

$$\bar{A}_j(b,y) = min\{\bar{A}, max[t_j(b,y) - EFC(y), 0]\}$$

In this aid policy, the amount of aid received at two universities who charge the same tuition is exactly the same.

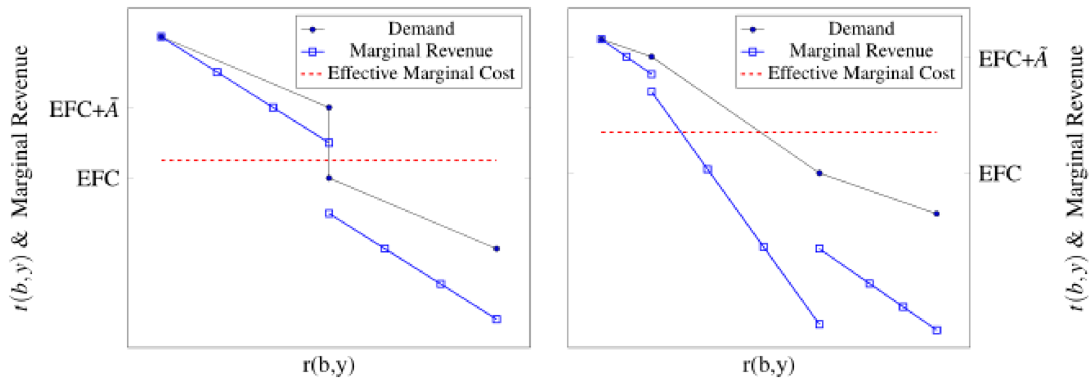
Since tuition is set exogenously for public colleges, the inclusion of federal aid does not directly change the practices of public colleges. The aid program indirectly affects public colleges by making public college cheaper for some students. The increase in affordability increases the matriculation at these colleges.

The inclusion of federal aid dramatically changes the tuition pricing for private colleges. This occurs since private colleges can exploit the aid formula to receive higher levels of tuition. The private colleges know that federal aid will be given to the students and will never set tuition to be anywhere in the range $t_j(b,y) \in (EFC(y), EFC(y) + \bar{A})$. For any tuition in this range, a small increase in tuition would not be seen by the students. Every increase in tuition would be met with a one-to-one increase in aid. Therefore, students would be indifferent between that tuition level and a small increase in tuition. At the same time, a small increase in tuition would be preferred by the college since it would result in the college receiving more tuition revenue. It follows that if tuition was set to be in-between $EFC(y)$ and $EFC(y) + \bar{A}$, the college would want to deviate from this pricing and increase tuition to $EFC(y) + \bar{A}$. This translates to a kinked demand curve, as illustrated in Figure 3.1.

The optimal tuition level is determined by comparing the effective marginal cost to the marginal revenue. If effective marginal cost equals marginal revenue to the left of the

[11]The federal government levies a tax τ_f to pay for the aid given to students. The tax is set such that the revenue raised is exactly equal to the aid given to students.

Figure 3.1: Demand for Student of Type (b, y)



(a) Attendance-Based Aid

(b) Rating-Based Aid

kink, full aid is given and tuition is determined by the upper portion of the demand curve. If marginal cost crosses in-between the two pieces of the marginal revenue curve, then it is optimal to game the system and set tuition such that the student is eligible for the maximum amount of aid. Finally, if marginal cost equals marginal revenue to the right of the kink, because of the discontinuity, one of two tuition levels could be optimal. Tuition is either set by the lower portion of the demand curve or the college sets tuition equal to the level where the student receives the maximum aid. The tuition that maximizes effective profit is the one that the college ultimately chooses to charge. Effective profit is equal to the difference between total revenue and total effective cost. All optimal tuition choices are presented in Appendix A.1.3.

3.5.2 Rating-Based Federal Aid

In this section, I modify the federal aid policy to tie aid to a college specific rating. This modification, along with the inclusion of endogenous completion rate, is the main contribution of this paper. This rating-based system will be used to simulate policy changes. More details of the optimization problems faced by colleges are outlined in Appendix A.2. The college specific rating is modeled to be general in order to explore the impact of the college ratings proposed in the White House's plan and many other types of potential ratings. Denote the rating of university j as Υ_j. This college specific rating is equal to the average rating $\upsilon(q_j, t_j(b,y), b, y)$ of the students who attend that college.

$$\Upsilon_j = \min\left(\frac{1}{k_j}\int\int \upsilon(q_j, t_j(b,y), b, y)\alpha_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy, 1\right)$$

To be compatible with the "Better Bargain Plan," the individual rating of a student can change with the quality of the college the student attends, the tuition charged to the student, and the student's type. The maximum rating a college can receive is 1.

The rating is related to the amount of aid a student will receive at college j. Specifically, a student who decides to attend a college with rating of Υ_j will receive federal aid equal to $\Upsilon_j^{\kappa}\tilde{A}_j(b,y)$,[12] where

$$\Upsilon_j^{\kappa}\tilde{A}_j(b,y) = \Upsilon_j^{\kappa} min\{\tilde{A}, max[t_j(b,y) - EFC(y), 0]\}.$$

The parameter κ dictates how important the rating is in determining the maximum aid amount. The exponent κ will be referred to as the rating intensity. When κ is zero, the rating does not affect the maximum aid amount. As κ increases, the rating's importance increases. The maximum aid is now denoted as $\tilde{A}$. The maximum aid is set to be higher in the rating-based system than under the attendance-based system. Since the maximum

[12] A proportional tax τ_f is levied to pay for all aid given by the federal government.

possible aid will be multiplied by this rating, it is necessary to increase the maximum possible aid to achieve a budget neutral policy change.

3.5.2.1 Modified Public College Solution Under the rating-based aid policy, the solution to the public college maximization problem is very similar to the solution under attendance-based federal aid. The admittance decision is now determined by the following statement

$$\alpha(b,y) = 1 \iff \frac{o(q_j,b)}{\lambda_j} + \hat{t}_j(y) + z_j > EMC_j(b,y) + \frac{\Psi_j}{\lambda_j}(\Upsilon_j - \upsilon(q_j,t_j(b,y),b,y)) \tag{3.4}$$

where Ψ_j is the Lagrange multiplier of the rating identity.[13] Appendix A.2 outlines the derivation of this equation.

Notice equation (3.4) is identical to equation (3.1), with the exception of the term $\frac{\Psi_j}{\lambda_j}(\Upsilon_j - \upsilon(q_j,t_j(b,y),b,y))$. This term adjusts the effective marginal cost of any student based on that student's impact on the rating. Admitting a student with a rating that is lower than the average rating Υ_j will lower the college's rating. A lower Υ_j results in less federal aid for students who decide to attend this college. On the other hand, admitting a student whose rating is higher than the average rating Υ_j will increase the college's rating. Increased aid makes it easier for the college to attract students. By increasing the rating, public colleges are decreasing the tuition students actually have to pay if they attend public college. A higher rating results in more federal aid for students who attend that college. This is the only method public colleges can use to change their effective tuition.

The logic behind this term mirrors the logic behind the term $\frac{q_{\theta_j}}{q_{e_j}}(\theta_j - b)$. The term $\frac{q_{\theta_j}}{q_{e_j}}(\theta_j - b)$ is equal to the cost (benefit) associated with admitting a student with ability

[13] If a college has a perfect rating, $\Psi_j = 0$ and this expression is exactly the same as under attendance-based aid

lower (higher) than the average ability of the college and $\frac{\Psi_j}{\lambda_j}(\Upsilon_j - \upsilon(q_j, t_j(b,y), b, y))$ is equal to the cost (benefit) associated with admitting a student with a rating lower (higher) than the average rating of the college.

3.5.2.2 Modified Private College Solution One major difference between this policy environment and the attendance-based aid is how federal aid responds to an increase in tuition when tuition is in between $EFC(y)$ and $EFC(y)+\tilde{A}$. Under the attendance-based aid system, if tuition started off in this range, an increase would be accompanied by a one-to-one increase in federal aid. Therefore, students were indifferent between all tuition levels in this range. It was optimal for colleges to manipulate this indifference and either set tuition such that a student type received no aid or they received the maximum amount of aid. In the new environment, this is no longer the case. With the policy change, if college j increases tuition by 1, the aid received by the student would only increase by Υ_j^{κ}. If $1-\Upsilon_j^{\kappa} > 0$, the student is no longer indifferent to any tuition levels in this range and colleges can not manipulate the aid formula in the same manner they previously could.

An example of the new demand, marginal revenue, and effective marginal cost curves is illustrated in Figure 3.1. The demand curve is no longer vertical between $EFC(y)$ and $EFC(y)+\tilde{A}$. This reflects the fact that once a student is eligible for aid, an increase in tuition will now be partially paid by the federal government until tuition reaches the maximum aid amount.

To determine the optimal tuition, I first find where the marginal revenue curve crosses the effective marginal cost. It is now possible for the marginal revenue to cross the effective marginal cost between the two kinks. Under rating-based aid, tuition may be set such that a student only receives a fraction of a college's maximum aid amount. All optimal tuition choices are presented in Appendix A.2.2.

3.5.3 Tuition Caps

For empirical reasons, tuition caps are introduced into both the attendance and rating-based scenarios. Tuition caps are assumed to be self imposed and determined outside of the model. In the data, tuition caps are interpreted as the sticker price of a college.

Assuming a tuition cap of T_j^c for each private college, the equilibrium is adjusted in the following way. Label $t_j^*(b,y)$ as the optimal tuition without considering a tuition cap. If the tuition cap is higher than the optimal tuition then the equilibrium tuition is not adjusted and $t_j(b,y) = t_j^*(b,y)$. If the cap is less than $t_j^*(b,y)$, the college can only charge a maximum of the tuition cap. However, with this limited tuition, admitting the student may no longer be beneficial to the college. A college determines if admitting the student is beneficial by comparing the effective marginal cost of the student to the tuition cap. If the tuition cap is larger than the effective marginal cost, then the student is admitted and $t_j(b,y) = T_j^c$. Otherwise, if the effective marginal cost is larger than the tuition cap, the student does not benefit the college and the student is not admitted.

3.6 QUANTITATIVE MODEL SPECIFICATIONS AND CALIBRATION

In this section, the remaining functional form assumptions are outlined, a number of parameters are set using the data, and the remaining parameters are calibrated. The parameters set a priori are summarized in Table 3.1 and the calibrated parameters are summarized in Table 3.2.

3.6.1 Functional Form Assumptions

The functional forms that have not yet been set are the objective function of the public colleges, the quality function, the variable cost function of colleges, and the completion function.

Public colleges are assumed to maximize an objective that is aligned with the students. The success function of the students is equal to

$$o(q_j, b, y) = q_j^{c(q_j,b,y)\omega_1} b^{c(q_j,b,y)\omega_2}.$$

This term, which appears in the student's utility function, is the achievement a student would receive if they were to complete college, adjusted by the completion probability of that student. The interpretation is that colleges want to provide a high level of education and graduate many students.

The education quality is assumed to follow the functional form

$$q(\theta_j, e_j) = \theta_j^{\gamma_1} e_j^{\gamma_2}.$$

The exponents on this function determine the relative importance of peer quality and education spending on education quality.

The college variable cost function is assumed to follow the form used in Epple et al. [2016]:

$$V(k) = v_1 k + v_2 k^2.$$

3.6.1.1 Income-Ability Distribution and Completion Function I estimate the joint student income and ability distribution, along with the completion function, using the Geocoded 1997 National Longitudinal Survey of Youth (NLSY97). The NLSY97 is a nationally representative sample of approximately 9,000 youths who were born between 1980 and 1984. The first round of the survey took place in 1997. Subsequent rounds of the survey have been conducted on an annual basis. Among other information, the public version of the NLSY97 collects data on the family income, ability, and education attainment of the survey participants. The restricted geocoded dataset contains additional information on the college attended by each respondent.

When estimating the student distribution, I limit the initial data set to students who have finished high school. Family income is set equal to the average family income when a student was 16 and 17. Those who are missing one of these years are assigned the family income of the remaining year. If an observation is missing for both years, family income from previous years is used. The income measure is then converted to 2011 dollars. The ability measure used is the percentile rank on the Armed Forces Qualification Test (AFQT). Since percentile alone does not reveal any information about the actual ability measure, I map the percentiles to student ability measures following the distribution used in Epple et al. [2016]. A lognormal distribution with a location parameter fits the family income data well. Once I have both the ability and income data, the correlation between income and ability is calculated. The results of these estimates are summarized in Table 3.1.

The NLSY97 is also used to estimate the completion function. A college's completion rate varies with family income, the ability of the student body, and college quality. To estimate how completion is related to each of these variables, the following probit regression is performed:

$$Prob(C_{i,j} = 1) = \Phi(\beta_0 + \beta_1 y_i + \beta_2 b_i + \beta_3 q_j) \tag{3.5}$$

Equation (3.5) is also the completion function functional form used in the model. $C_{i,j}$ takes on a value of one if the student i completed college j within six years and zero otherwise. Since the last available year of data is 2014, I restrict the sample to students that first attended college in 2008 or before. The independent variables y_i, b_i, and q_j represent the family income of student i, ability of student i, and the quality of college j. Family income and student ability are determined using the method described above. College quality is calculated following the function outlined in Section 3.6.1. I use the Delta Cost Project data set to obtain information on the average expenditure per student, e_j, and average SAT score, θ_j, for every college a student in my sample attends. Average expenditure is converted to 2011 dollars. The average SAT score is converted to average AFQT percentile using information from students in the NLSY97 who report both a AFQT score and an SAT score. This converted score is then transformed into average ability. This conversion ensures that individual student ability and average college ability are in the same units.

The parameter values of the completion function are reported in Table 3.1. The complete regression table is in Appendix A.4.

3.6.2 A Priori Parameters

The parameters set a priori fall into four categories: market variable, tuition limits, government aid, and quality parameters. All of these variables, with the exception of public tuition, are determined following the example of Epple et al. [2016].[14]

[14]Public tuition doesn't follow Epple et al. [2016] since that model does not include public tuition differentiated by family income.

Table 3.1: A Priori Parameters

Market Variables	
Number of Public Colleges	2
Number of Public Colleges	5
Tuition Limits($000s)	
Public Tuition By Income Quartile	7, 8, 9, 10
Private Tuition Caps	26, 28, 30, 32, 34
Government Aid($000s)	
Public Per-student Subsidy	6.6
Maximum Federal Aid	7.25
Quality Parameters	
γ_1	.85
γ_2	.14
Student Distribution	
Income Distribution	$ln(y+15,700) \sim N(10.952, 0.618)$
Ability Distribution	$ln(b) \sim N(1.0, 0.15)$
Ability-Income Correlation	0.3307
Completion Function Parameters	
β_0	-2.4060
β_1	.0014
β_2	.4118
β_3	.3502

3.6.2.1 Market Variables The total number of colleges is assumed to be seven. Of these, two are public and five are private. The public colleges are assumed to be exactly the same while the private colleges are differentiated by their endowments and tuition caps.

3.6.2.2 Tuition Limits Public college tuition is set so that tuition minus federal aid is in line with the net tuition levels observed in the data. The net tuition in the 2011-2012 school year for full-time public four-year institutions was $0 for the lowest income quartile, $2,325 for the second quartile, $6,417 for the third quartile, and was $8,346 for the forth quartile [College Board, 2014]. To match these net tuition values, gross tuition values of \$7,000, \$8,000, \$9,000, and \$10,000, respectively, are chosen. The private college tuition caps are set to match the sticker prices at private universities. According to Desrochers and Hurlbut [2014], the average sticker price at private research universities in 2011 was \$32,400. Using this as a guide, the private college tuition caps are set to be \$28,000, \$30,000, \$32,000, \$34,000, and \$36,000.

3.6.2.3 Government Aid The public college subsidy given by the state government is set to be equal to the average state subsidy. In 2011-2012, the average public subsidy given by state governments was \$6,600 per full time equivalent [College Board, 2014]. The maximum federal aid in the model is set to be a sum of a number of government aid programs. The maximum aid amount is based on a combination of the maximum Pell grant amount, the maximum work study reward, and the maximum amount given in subsidized federal loans. In the end, aid is determined by the following formula: Federal Aid = Grants + .33 Work Study+ .1 Loans. This formula yields a number close to \$7,250.

To approximate the expected family contribution formula, I use the 2011-2012 Expected Family Contribution Worksheet A to determine $EFC(y)$ for each student. I assume students make no income and are a part of a four member household with one student in college. I assume the contribution from assets is 7% when income is above \$50,000 and \$0 otherwise. Further, I assume the state allowance is equal to the median state allowance of 5% of income under \$15,000 and 4% of income above \$15,000.

3.6.2.4 Quality Parameters Following Epple et al. [2016], education quality parameters γ_1 and γ_2 are set to be 0.85 and 0.14, respectively. These variables are set to ensure the relative importance of education expenditure and student ability are comparable with financial aid regressions.

Table 3.2: Calibrated Values

Utility Parameters	
ρ	11.45
ω_1, ω_2	1.05,.85
ν ($000s)	3
q_0	2.45
Cost Function Parameters	
F ($000s)	.25
v_1, v_2	2, 40
D_3, D_4, D_5, D_6, D_7 ($000s)	.0048, .0070, .0103, .0186, .0754

3.6.3 Calibration and Baseline Results

A number of parameters are determined through calibration. The parameters ρ, ω_1, ω_2, q_0, ν, F, v_1, v_2, D_3, D_4, D_5, D_6, and D_7 are chosen such that (i) the average private tuition is $27,900, (ii) total enrollment of students is 42%, (iii) Share of private college enrollment is 33%, (iv) custodial costs are about 60% of all costs on average, and (v) endowment spending per student is equal to $155, $243, $386, $755, and $4,149 in each of the five private colleges.[15] The utility parameters $\rho, \omega_1, \omega_2, q_0, \nu$ are closely tied to the first three targets; cost parameters F, v_1, v_2 are tied to the average custodial share; and endowment values are tied to the average endowment per student. The calibration targets and the calibrated values are summarized in Table 3.2.

[15]The average tuition and fees a private nonprofit universities during the 2011-2012 school year was $27,883 (Trends in College Pricing, College Board, 2014, Table 2) Data for the percent of total enrollment and private college enrollment was obtained from the 2012 NCES Digest of Education Statistics. The enrollment of students is assumed to be the percentage of recent high school graduates enrolled in a four-year college. The percent of students enrolled in private colleges is calculated from the number of FTE students at private nonprofit and public four-year universities. The average custodial cost is taken from Epple et al. [2006]. The per student endowment targets are obtained from the average endowment spending at different quality private universities.

Table 3.3: Baseline Model Results

Calibration Targets		
	Data	Baseline
Enrollment	42%	42%
Percent of Public Students	67%	67%
Average Private Tuition	27.9	27.9
Average Custodial Share	60%	55%
Private College Endowment per Student	.144, .226, .359, .702, 3.859	.143, .224, .355, .703, 3.856
Additional Moments Not Targeted		
	Data	Baseline
Public Completion Rate	57.2%	50.9%
Private Completion Rate	65.5%	73.0%
Fraction Receiving Federal Aid (Public)	45.8% - 71.4%*	51.2%
Fraction Receiving Federal Aid (Private)	37.8% - 74.9%*	52.4%
Average Public Tuition	8.28	8.82
Average Price Cap	32	31.5
Average Institutional Aid (Private)	4.1	3.6
Average Federal Aid (Public)**	3.8 - 8.8*	5.7
Average Federal Aid (Private)**	4 - 11.8*	6.7

*Any Federal Aid **Conditional on Positive Aid

Table 3.4: Baseline College Results

j	k_j	θ_j	e_j	q_j	Mean t_j	Mean $\bar{A}_j(b,y)$	Mean y	Mean $c(q_j,b,y)$
1	0.1409	2.905	6.01	3.182	8.815	2.90	85.06	50.92%
2	0.1409	2.905	6.01	3.182	8.815	2.90	85.06	50.92%
3	0.0333	3.281	14.22	3.981	24.924	3.65	125.23	69.42%
4	0.0311	3.313	15.41	4.059	26.476	3.62	130.15	71.04%
5	0.0289	3.347	16.57	4.137	28.021	3.57	136.08	72.69%
6	0.0265	3.391	17.94	4.230	29.736	3.46	144.26	74.67%
7	0.0196	3.558	21.01	4.505	32.719	2.93	165.49	80.38%

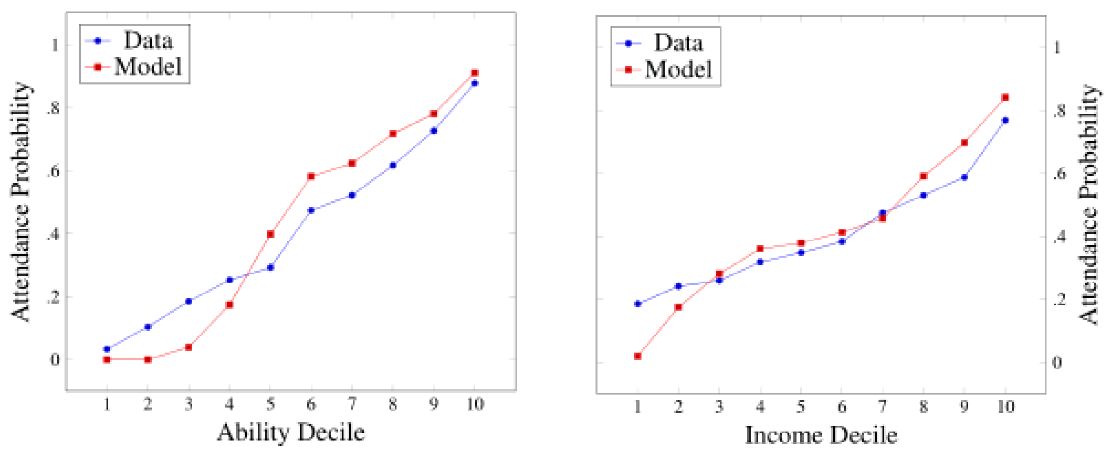
The model is able to closely approximate all calibration targets. To further test the model, important statistics that were not calibrated are compared with data to verify that the model is able to produce statistics that resemble the real world. The statistics used for verification are completion rate in public and private colleges, fraction of students receiving aid in public and private colleges, average public tuition, average federal aid in public and private colleges, average tuition cap in private colleges, and average institutional aid in private colleges. The results of this comparison are presented in Table 3.3.

The model is able to produce statistics very close to the checks found in the data. The percentage of students receiving federal aid in the model is closer to the percentage of students receiving a Pell grant than to the percentage of students receiving any federal aid found in the data. The same is true for the average amount of aid. The completion rate predicted in the model is lower for public colleges and higher for private colleges.

Table 3.4 displays the results of the calibration for each college. Colleges 1 and 2 are public colleges and colleges 3-7 are private colleges. Private colleges labeled with a higher number correspond to colleges with larger endowments and higher tuition caps. The baseline calibration shows that colleges with higher endowments enroll fewer students and the students they do enroll on average have higher income. In addition, average ability, expenditure per student, and average completion is higher in colleges with a larger endowment.

In summary, public colleges are less selective than private colleges. This is evident from the fact that students from all ability deciles attend public college while no students below the median ability attend any private college. Further, as colleges increase in quality they become more selective. The highest quality private college only admits students from the top two ability deciles while the lowest quality private college admits students in the top four ability deciles. Private colleges charge more tuition as income increases, since wealthier students are able to pay more. Further, higher ability students pay less in tuition.

Figure 3.2: Attendance Probability by Student Type



Colleges value the high ability students and choose to lower tuition to entice these students to matriculate. Higher quality colleges charge a higher tuition. Baseline tuition and student attendance choices are displayed in Appendix A.4.

The calibration of the model also results in an equilibrium where almost all types of students are able to attend some college. Lower ability students are only able to attend the lower quality public colleges while high ability students can choose from public and private colleges. Figure 3.2 shows that the overall attendance probability by income and ability produced by the model very closely resembles the probabilities seen in the NLSY 97 data.

3.7 POLICY DISCUSSION

Section 3.7.1 simulates the impact of a change from the attendance-based federal aid to a rating-based federal aid based on outcomes, affordability, or access. Section 3.7.2 discusses increases in the maximum amount of federal aid available. Section 3.7.3 finds the rating policy that maximizes the average welfare of potential students.

3.7.1 Policy Simulation

Each rating is modeled to be a linear function that takes the following form:

$$\upsilon(q_j, t_j(b,y), b, y) = \chi_1 + \chi_2 \cdot Measure_j.$$

$Measure_j$ is the variable used to measure either outcomes, affordability, or access. I use choose completion probability to measure outcomes, tuition charged to each student type to measure affordability, and an indicator that gives a value of 1 if the student is under the median income to measure access. In order to make the policies comparable between measures, χ_1 and χ_2 are chosen such that, before the policy change, the average rating and the difference between the minimum and maximum rating is the same for all three measures.[16]

To obtain a budget neutral policy change, I increase the maximum amount of aid and adjust the rating intensity κ to ensure that each policy change results in the same federal tax rate.[17]

[16]The average rating is computed by weighting by the number of students who attend each college. For the affordability-based rating, since public colleges are unable to change their tuition, the average and range is calculated only considering private colleges.

[17]In terms of the model I fix a $\tilde{A} > \bar{A}$. When $\Upsilon < 1$ raising κ lowers the total amount of aid and the tax rate, while lowering κ increases the total amount of aid and the tax rate.

Table 3.5: Effect of Policy Changes

	(1) Baseline	(2) Outcome Rating	(3) Affordability Rating	(4) Access Rating
Average Completion Rate (Public)	50.92%	51.79%	51.00%	50.35%
Average Completion Rate (Private)	73.00%	73.83%	73.16%	73.47%
Average Price Cap	31.54	31.47	31.45	31.46
Average Private Tuition	27.92	29.01	27.30	28.42
Average Institutional Aid	3.62	2.46	4.15	3.04
Average State Tuition	8.82	9.00	8.87	8.78
Accessibility of Public Colleges*	40.11%	32.77%	38.24%	43.91%
Accessibility of Private Colleges*	6.05%	9.96%	11.04%	13.64%
Total Enrollment	42%	39%	42%	41%
Share of Students in Public College	67%	65%	68%	68%
Average Federal Aid (Public)	5.66	4.35	5.85	5.23
Average Federal Aid (Private)	6.66	10.02	6.66	6.82
Fraction Receiving Aid (Public)	51.21%	43.84%	48.90%	53.40%
Fraction Receiving Aid (Private)	52.38%	59.41%	54.52%	57.01%
Maximum Aid	7.25	12.50	12.50	12.50
Intensity		0.43	1.18	0.58
χ_1		-0.161	2.066	0.328
χ_2		1.358	-0.0513	1.358
Average Rating Public		0.54	1.00	0.79
Average Rating Private		0.84	0.67	0.47
Change in Average Student Cost (Public)		1.18	0.09	0.07
Change in Average Student Cost (Private)		-1.37	-0.76	0.10
State Tax Rate	2.61%	2.38%	2.65%	2.60%
Federal Tax Rate	1.83%	1.83%	1.83%	1.83%

*The accessibility of a college is measured by the percentage of the students who are below median income.

3.7.1.1 Results for Outcome-Based Rating The results of the outcome-based policy change are presented in Column 2 of Table 3.5. Under the outcome-based aid system, the average completion rate in the public colleges and private colleges increases by 0.87 and 0.84 percentage points, respectively. However, changing the aid to be based on completion hurts the other two policy goals. The average tuition charged by public colleges increases \$180 and average tuition charged by private colleges increases \$1,090. Further, the overall number of low income students who attend college decreases.

The relatively small increase to the average completion rate at both types of colleges is a result of the colleges' limited ability to increase the completion rate. To increase the average completion rate, a college must either increase quality or alter the composition of their student body. Independent of the federal aid policy in effect, since college quality is in the objective function, both types of colleges benefit from having high quality. Therefore, under the attendance-based aid system colleges already would have adopted policies aimed to increase college quality. Then, when the federal aid switches to an outcome-based system, colleges are not able to greatly increase their completion rate by increasing educational quality, since any feasible change that greatly increases educational quality would have been adopted under the attendance-based aid system. Student selection also can only potentially result in minor changes to a college's completion rate. The best way to increase the completion rate through selection is to admit more students with a high completion probability. However, almost all of these students are already attending some college. Taking a student with a high completion probability from another college will not result in a higher average completion rate among all colleges. The gains in average completion rate must come from changes in enrollment to the few students with a high completion probability who are not attending college or by limiting enrollment of students with a low completion rate.

The private colleges respond to the outcome-based aid by changing their enrollment decisions in two ways. First, private colleges admit fewer low ability students. Second, private colleges increase tuition. Colleges use the additional tuition to increase their educational expenditure. Together these two changes increase education quality and raise the completion rate for all students.

Public colleges do not change their admission decisions much in response to the policy; the same type of students are admitted before and after the rating introduction. The admission changes made by private colleges positively impact the average completion rate of public college as many of the lower ability students that private colleges no longer admit decide to attend public colleges. Though these students were the low ability students in private colleges, they have higher ability than the average student in public colleges. The inflow of these students raises the average ability of the public colleges. In the end, the education quality of public college increases as well and results in a higher average completion rate.

Basing federal aid on completion results in private colleges receiving a higher rating than public colleges. A student who chooses to go to a private college will receive more federal aid than before. The higher quality private colleges become more affordable for poorer students and many students who would have gone to a public college now decide to attend a private college. At the same time, public colleges are now less affordable for low income students. Moreover, low income students who are not accepted into private colleges are more likely to choose the outside option over a public college. In sum, the change results in private colleges enrolling a higher percentage of low income students and public colleges enrolling a lower percentage of low income students, meaning that the total number of low income students attending college decreases.

Overall the completion-based rating system results in the total number of potential students who graduate decreasing from 24.5 percent to 23.4 percent. Though less federal money is going to students who will drop out, overall the number of students who are graduating from college is smaller. This result illustrates the importance of choosing the correct measure of achievement. If the government made this policy to try to increase the total number of college graduates, a rating based on the completion rate will not meet this goal. By basing aid on the completion rate, there is no importance placed on the quantity of students enrolled. In response to this rating, colleges decide to enroll fewer students and the overall number of college graduates declines.

3.7.1.2 Results for Affordability-Based Rating The results of the affordability-based policy change are presented in Column 3 of Table 3.5. Under the affordability-based rating system, the average private college tuition decreases by $620 while the average public tuition is virtually unchanged. The change to an affordability-based rating also affects the completion rates and accessibility of the colleges. In public colleges, both of these measures improve. The completion rate increases 0.17 percentage points and the percent of students below median income increases by 4.99 percentage points. In private colleges the completion rate increases by 0.08 percentage points and the percent of students below median income decreases by 1.86 percentage points.

The parameters chosen result in public colleges receiving the maximum possible rating while the private colleges receive a high rating. Private colleges become more affordable while the cost of public colleges is virtually unchanged. Admittance decisions are very similar to the attendance-based aid system. The decrease in cost leads to more low income students attending private colleges.

Changing the rating to be based on average tuition for private and public colleges may not be appropriate, since the public colleges can not change the tuition they charge to any one student. Further, by applying the same policy change to both types of colleges, it is hard to put a strong incentive on lowering tuition while having a budget neutral policy. Any policy that attaches a large reward to lower tuition would give a large amount of aid to public colleges who have an exogenous tuition that is always at a low level. In Appendix A.3, I consider a policy change where only the private colleges are subject to an affordability-based rating and the public colleges federal aid is attendance-based. This scenario is able to generate a much larger decrease in private tuition and, therefore, an increase in affordability.

3.7.1.3 Results for Access-Based Rating The results of the access-based change are presented in Column 4 of Table 3.5. Under the access-based rating system, the percent of students under median income enrolled in private colleges more than doubles (increases from 6.05% to 13.64%) and the percent of students under median income enrolled in public colleges increases slightly (increases from 40.11% to 43.91%). The change to this rating results in a $500 increase in tuition charged by private colleges. The completion rate increases by 0.47 percentage points in private colleges and decreases by 0.57 percentage points in public colleges.

Both college types respond to the policy change by admitting low income students that previously would not have been admitted. The private colleges further change their enrollment decisions and deny admittance to some high income students that were previously admitted. These two decisions result in a large increase in the percentage of low income students in private colleges. The denied students who would have attended private college change their enrollment decisions and attend public colleges. Public colleges receive an inflow of two types of students: the newly admitted low income students and the displaced high income students. The effect of these two groups entering public colleges offsets and the percent of low income students in public colleges increases slightly.

The private colleges charge a higher tuition to the remaining rich students. This additional charge is necessary to subsidize the entry of the newly admitted low income students who are unable to pay high levels of tuition.

3.7.2 Maximum Aid Change

Under the current attendance-based federal aid system, increases in the maximum aid amount are met with increases in tuition. Private colleges respond to an increase in aid by raising tuition since an increase in tuition is met with a one-to-one increase in aid. Students are happy to pay the higher tuition since the cost is actually paid by the federal government. Under a rating-based system this is no longer true for two reasons. First, students at most can only receive a fraction of the maximum aid. The maximum amount of aid any student could receive at college j is $\Upsilon_j^{\kappa}\tilde{A}$. A one dollar increase in $\tilde{A}$ will only increase this maximum amount of aid by $\Upsilon_j^{\kappa}\tilde{A}$ and students who are eligible for the maximum amount of aid will have to pay some portion $(1-\Upsilon_j^{\kappa})$ of that higher tuition. Second, under this new aid policy students can be charged a tuition in-between $EFC(y)$ and $EFC(y)+\tilde{A}$. The students being charged a tuition in this range are not receiving the maximum amount of federal aid that a student at college j can receive. Increasing the maximum amount of aid college j can receive will not affect these students. Under a rating-based system colleges would be expected to raise tuition in response to an aid change, but the magnitude of the increase should be smaller than the increase under an attendance-based system.

When a rating-based aid system is implemented, raising the maximum aid amount increases the importance of the college's rating. When more federal aid is available, changes in the college rating result in larger changes to student federal aid. When the amount of aid available is large, changes in college rating are more likely to change a student's attendance decisions. Therefore, when the maximum aid increases, colleges take further steps to increase their rating. If changing tuition affects the rating, colleges would be expected to further adjust tuition in response to maximum aid changes. For example, consider the tuition-based rating system. Under this system, if a college tried to increase tuition in response to an aid change, the college rating would decrease and the maximum aid amount a student would receive may also decrease. If the rating responds to tuition changes, raising tuition in response to an aid change could drive students away and lower the total amount of tuition collected.

I simulate the effect of increasing and decreasing the maximum federal aid available under the baseline and the three rating systems. I run scenarios that increase and decrease the maximum aid amount by 10 and 20 percent. The effect on tuition is presented in Table 3.6 while the effect on other variables is presented in Appendix A.4.

Under the attendance-based and outcome-based aid system, increases in the maximum amount of federal aid are met with increases in tuition. The magnitude of the tuition response under the attendance-based aid system is similar to the findings in Epple et al. [2016]. Surprisingly, the tuition increases under the outcome-based aid system are slightly larger than under the attendance-based system. Tuition is raised in the outcome-based system for two reasons. First, the rating received by private colleges is high. As a result, students who are eligible for aid only pay a small portion of any tuition increase. Second, colleges choose to increase completion by increasing the amount spent on education. To increase education spending, private colleges must charge a higher tuition. The combined effects result in private colleges responding to a maximum aid increase by increasing tuition more than they would under an attendance-based aid system. Under both attendance and outcome-based aid, the majority of the tuition increase comes from increases to the tuition for students receiving federal aid. These students only pay a fraction of any tuition increase and therefore are less likely to change their attendance decisions when tuition is increased.

Tuition does not increase following an increase of maximum aid under the affordability and access-based ratings. The incentives put in place by the affordability and access-based rating cancel out the incentive to increase average tuition and capture more federal aid

Table 3.6: Average Private Tuition Under Different Maximum Aid Levels

	20% lower aid	**10% lower aid**	**Baseline**	**10% higher aid**	**20% higher aid**
Attendance-Based	27.68	27.81	27.92	28.02	28.12
–Not Receiving Aid	29.28	29.34	29.36	29.38	29.41
–Receiving Aid	26.09	26.36	26.61	26.84	27.03
Outcome-Based	28.66	28.86	29.01	29.14	29.28
–Not Receiving Aid	30.45	30.60	30.65	30.67	30.66
–Receiving Aid	27.29	27.60	27.89	28.14	28.40
Affordability-Based	27.50	27.42	27.30	27.22	27.27
–Not Receiving Aid	30.32	30.11	29.90	29.54	29.30
–Receiving Aid	24.95	25.07	25.13	25.32	25.60
Access-Based	28.46	28.44	28.42	28.32	28.35
–Not Receiving Aid	31.26	31.33	31.42	31.55	31.41
–Receiving Aid	25.98	26.07	26.16	26.14	26.37

money. Under the affordability-based rating, the lack of a tuition increase is a result of two different tuition responses. The affordability rating puts pressure on the college to reduce tuition for all types of students. For the students receiving aid, the increase in available aid makes colleges want to raise tuition to capture the new money available. In the end, those receiving aid actually do have their tuition raised slightly while those not receiving aid have their tuition reduced. The average tuition levels decrease slightly. Under an access-based rating system, the average tuition for both those receiving and those not receiving aid increases slightly. However, tuition still decreases since the private colleges enroll more low income students. The decrease in overall tuition comes from the increase in the proportion of low income students who pay a tuition rate less than the average tuition.

Table 3.7: Student Welfare Change by Income and Ability Quartile

Ability Quartiles	Income Quartiles 1	2	3	4	All
Outcome Rating					
1	16	87	155	243	33
2	18	1	312	746	68
3	-40	-573	389	161	-79
4	-101	-254	1886	964	417
All	-4	-177	787	627	77
outcome-based rating					
1	-3	-19	-34	-68	-7
2	-4	25	-5	-129	-4
3	-3	229	137	-960	-3
4	30	559	442	-1535	-4
All	0	175	166	-956	-5
Access Rating					
1	0	2	4	-93	0
2	-86	-385	475	-628	-104
3	-86	-524	21	-1197	-234
4	-149	-216	-519	-1196	-392
All	-53	-282	-40	-970	-136

Each cell in this table shows the amount of income the average student of that type would have to receive to be indifferent between the baseline scenario and the policy change. Positive numbers indicate that students prefer the policy change and negative numbers indicate that students prefer the baseline.

3.7.3 Optimal Rating

After exploring how the policy changes alter the incentives, a natural question to ask is, ”What policy should be implemented?” Table 3.7 shows the welfare effect of each policy change on different types of students. This table reveals that the outcome-based rating improves overall welfare, the access-based rating lowers overall welfare, and the affordability-based rating has a small negative effect on overall welfare. The increase to average welfare from the completion rating comes from an increase to the well being of wealthy students. These students are not displaced because of the policy change and benefit from the increase in education quality. The affordability change, though it has virtually no average welfare effect, improves the welfare of low income students and lowers the welfare of high income students. The increase in affordability helps the low income students attend college. The high income students do not benefit much from the affordability increase and are hurt by the decrease in educational quality.

Basing a rating entirely on one area of interest seems to hurt the other areas the proposal hopes to improve. It is possible that the best rating to use may be a combination of multiple measures. I consider a new individual rating that is a convex combination of the outcome rating, outcome-based rating, and access rating.

I create a grid of possible weights and calculate the welfare of each rating combination. For every choice of weights the rating intensity κ is chosen to ensure that this new policy change is budget neutral for the federal government. Performing this exercise reveals that the policy that maximizes welfare is the rating system where full weight is place on the outcome rating. The outcome-based rating system maximizes the welfare of the potential students since increasing the outcome rating helps those who choose to attend college the most. By increasing the outcome rating, the educational quality increases and the decision to enter college becomes less risky for all students. When combining the outcome rating with other ratings, the addition of the other ratings weaken the incentive to increase the completion rate and the welfare gain is not as great.

Though the outcome-based rating maximizes the overall utility, it doesn't meet all the goals of the proposal. Specifically, the outcome rating results in reduced affordability in private colleges and reduced access in public colleges. Using the model, ratings can be combined in order to find a rating that can simultaneously satisfy all of the proposal's goals.

3.8 CONCLUSION

A quantitative equilibrium model of the market for college education with the possibility of non-completion is employed to simulate the effect of tying a student's federal financial aid to the performance of the college in which she chooses to enroll. A rating system that can take on many specifications is introduced into the theoretical model. Rating-based aid systems that are based on average completion rate, average tuition, and percent of student body below median income are explicitly considered.

The policy simulations reveal three main findings. First, basing college ratings heavily on one area of focus results in colleges making decisions that hurt other areas of concern. This was true when college aid was based on the completion rate, average tuition, and the accessibility of the college. For example, basing aid on the completion rate only modestly increased the completion rate but lowered the affordability of colleges and also resulted in fewer low income students attending college.

Second, the rating-based aid systems result in an overall increase in welfare when outcomes play a large role in determining the rating. Basing aid entirely on completion maximizes the average welfare of the students. I further show that each of these aid changes have different distributional effects. The outcome-based rating system increases the welfare of the high income students and lowers the welfare of the low income students. On the other hand, the affordability-based rating raises the welfare of the low income students and lowers the welfare of the high income students.

Third, I show that while the outcome-based rating system maximizes the overall welfare of the economy, it still had many of the problems of the original attendance-based aid system. Specifically, under both the attendance-based system and the outcome-based rating system, when the maximum aid amount increases, there is great incentive for colleges to respond by increasing tuition. This characteristic makes it difficult for the federal government to increase affordability by expanding aid. The proposed aid systems that base aid on tuition and access remove the incentive to match federal aid increases with increases in tuition. Under these rating-based systems, reducing tuition increases the rating. Therefore, when these systems are in place, the incentive to increase tuition that arises following an expansion of aid is canceled out by the increased incentive to lower tuition. It follows that increasing federal support under these two systems does not lead to an increase in college tuition and translates to an increase in affordability. This finding shows that a rating-based system, if designed correctly, could be implemented to eliminate the incentive to increase tuition following an expansion of federal aid.

This model can be modified to study the use of performance-based payment methods in other publicly provided services. Beyond education funding, the federal government has also began giving bonuses to certain medical providers based on their ability to limit the cost incurred by Medicare patients. A model such as the one developed here, can explore how this payment scheme will effect hospitals and patients.

From a broader perspective, this paper shows that while basing federal aid on college rating will change the behavior of colleges, if these ratings are not designed properly they can incentivize colleges to take actions that are not preferred by the policy maker. Therefore, it is important to analyze how a college will attempt to achieve a high rating. Once the likely response is identified, this response can be compared with the goals of the policymaker. This exercise will facilitate the decision of whether or not to use a particular rating system.

4.0 ALLOCATING FUNDING BETWEEN DIFFERENT LEVELS OF EDUCATION: A MAJORITY VOTING RESULT

4.1 INTRODUCTION

Standard models of public provision of education typically focus on one level of education. However, in reality the education budget of many governments is split between different levels of education, each attended by different groups of people. Heterogeneity among individuals leads to conflicting preferences as to which education allocation is most desirable. The existing models cannot easily be used to explain how a society would split a public education budget between two levels of education spending. In this paper, I present a majority voting model which supports multiple levels of publicly provided education spending. The model illustrates the tradeoffs that exist when choosing how to allocate resources between different levels of education and has predictions about why different societies may choose different education fund allocations. Further, the predictions made by the model match the pattern found in the data.

The standard public goods framework can be adopted to explain the existence of public provision of funds for primary and secondary education. However, a departure from this framework is necessary to explain the existence of public provision of funds for post-secondary education. In primary and secondary education, virtually all individuals are able to receive the benefits from public spending. This statement is not true for post-secondary education. Barriers to entry in post-secondary education prevent some students from benefiting from public post-secondary education funding. One barrier exists because public post-secondary funding typically isn't complete. If a student attends a public primary and secondary school, almost all of the education expenses are paid by the government. However, if a student chooses to attend a public post-secondary school, the funding received is usually only a fraction of the total tuition. In other words, the post-secondary education cost is partially subsidized while the primary and secondary education cost is paid entirely by the government.

Due to the partial subsidization of post-secondary education, there is a financial barrier to attending a post-secondary institution that does not exist in primary and secondary institutions. This financial barrier prevents low income students who would like to receive post-secondary education from enrolling in college. If low income students are unable to attend post-secondary institutions, then spending on primary and secondary education benefits poor students more than equivalent spending on post-secondary education. In addition, the tax revenue used to fund education is usually based on property value or income which is larger for rich people than poor people. Since the cost of primary and secondary education is shared between all those who attend primary and secondary school, rich families generally pay, in absolute amounts, more for primary and secondary education than poor families. In fact, prior research has found that education spending on post-secondary education acts as a transfer from the poor to the rich while education spending on primary and secondary acts as a transfer from the rich to the poor.[1]

Since this tension exists, in a framework where agents vote to decide how to split edu-

[1] As noted in Fernandez and Rogerson [1995], primary and secondary education spending being a transfer from the rich to the poor is documented in Glomm and Ravikumar [1992] and Saint-Paul and Verdier [1993]. Post-Secondary education spending being a transfer from the poor to the rich is documented in Bishop [1977] and Hansen and Weisbrod [1969].

cation funds, it is not clear how much funding each level of education would receive. To explore how a society would choose to split education funds when these conflicting interests exist, I develop a model of public provision of education which contains two levels of education. The two levels are modeled after the education system in the United States. The lower level of education is primary and secondary education and the higher level of education is post-secondary education. In the model, agents are distinguished by their income. These agents make decisions about whether or not to attend post-secondary education and also vote on how many public funds to allocate to post-secondary education. The total amount of public funds is exogenously given, only the split is decided by the agents. The model assumes that expenditure on lower levels of education increases the return to higher levels of education. This makes individuals of all incomes desire spending on lower levels of education. Expenditure on higher levels of education lowers the individual cost of higher education. Higher levels of education may only be partially funded. In this case, some agents many not be able to afford the remaining cost of post-secondary education.

Using the model, I explore how the choice to attend college changes for different income groups, as public education funds are shifted away from the lower level of education to higher levels of education. I then examine how the utility of the agents evolve as the split in education funds changes. Using this information, I am able to determine what education allocations could potentially be a majority voting equilibria.

Further, I propose an explanation as to why some societies would spend a higher proportion of education funds on post-secondary education. I show that different distributions of income lead to different education funding splits. Specifically, when a state experiences higher income inequality, a majority of the agents desire a higher amount of spending on post-secondary education when compared to states with less income inequality. This relationship exists since higher income agents are able to team up with the middle income agents to extract resources from the poor. However, when income inequality becomes too large, rich individuals would rather fund primary and secondary education in order to maximize the return to college. At very high levels of inequality, the rich do not want to subsidize the middle class's post-secondary education. This leads to the rich agents using the poor agent's preference for less college funding to shift funding away from post-secondary education back to primary and secondary education.

I turn to the data to test the implications of my model. Using state level data from 1977 until 2010, I examine how the allocation of education funds is related to the income distribution. The data show that the education allocation ranking between states is stable throughout time. Further, I find evidence that within a state income inequality and education fund allocation has an inverted U-shape as predicted by the model.

Previous literature has presented majority voting models which focus on one level of education, but none consider the allocation of funding between two levels of schooling. Papers discussing voting models of lower levels of education include Epple and Romano [1996b], Glomm and Ravikumar [1992], and Saint-Paul and Verdier [1993].

Explaining the existence of funding for post-secondary education requires a departure from the traditional public good models. The traditional arguments for public provision of education are centered around the idea of a redistribution from the rich to the poor. Therefore, one would expect public education funding to focus mostly on funding of primary and secondary education. Some models use externalities or other factors to explain why a society would desire post-secondary education spending. Fernandez and Rogerson [1995] have shown how a partially subsidized education system can lead to post-secondary education spending and a transfer from the poor to the rich without the presence of any externalities. The basic setup of my model most closely resembles this paper.

These papers focus either entirely on one form of education or on total education expenditure. They do not consider a model with both lower levels of education and higher levels of education. Given this limitation, previous literature does not consider how increasing spending on one level of education affects other levels. When expanding to a model with multiple levels of education, it is not immediately obvious if an economy would choose to move funding away from lower education, which benefits everyone, to higher education, which only benefits a fraction of the society. Furthermore, it is not clear why some states would choose to heavily subsidize higher education while other would choose to only spend a small amount of their education budget on higher education.

The rest of the paper proceeds in the following fashion: in Section 4.2, I setup a model which allows for multiple levels of education spending. After the setup, I analyze how each group's utility changes when the education allocation changes. In Section 4.3, I explore potential majority voting equilibria. In Section 4.4, I use the model to explain how changing the income distribution results in a shift of education funds from one level of education to the other. In Section 4.5, I present data on how states allocate education funds between primary and secondary education and post-secondary education. I explore how the income distribution and other state specific factors affect spending on different education levels within state. Specifically, I change the income distribution and show that the model's dynamics resemble the dynamics found in the data. Section 4.6 concludes.

4.2 MODEL

In this section, I first setup the framework of the model. Section 4.2.2 solves the model assuming that the education allocation is fixed. Section 4.2.3 explores how the decisions of the agents change as the education allocation changes. The majority voting education allocation is determined in Section 4.3.

4.2.1 Setup

In order to gain insight on how a state allocates education funds, a model with two types of education is developed.

Consider an economy with three types of agents, differentiated by their income. The three types of agents are high income (type 1), middle income (type 2), and low income (type 3). For simplicity (and without loss of generality), the measure of all agents is normalized to 1. The income level and the proportion of a type i agent is given by y_i and λ_i, respectfully. Let μ denote the average income of all individuals in the economy.

Agents gain utility from consumption and human capital attainment. Utility from consumption is assumed to be linear. Human capital can be attained from two levels of education. The two levels are designed to resemble the education levels in the United States. The first level of education is called “primary and secondary” or lower level education. Primary and secondary education is compulsory and is fully funded through taxation. The second level of education is called “post-secondary”, higher level education, or simply college. Post-secondary education is subsidized by the government but may not be fully funded. In addition, this level of schooling is not compulsory. Agents of the model choose whether or not to attend post-secondary school.

The utility gained from human capital is denoted by the function $H(\sigma, y, s)$. Human capital varies with the amount of public primary and secondary funding σ, the agent's income y, and the post-secondary schooling decision s. The schooling decision s is a binary variable which takes the value of one if an agent attends college and zero if an agent does not attend college. Below I make some simple assumptions about the human capital function

Assumption 8. *(Human Capital Function Derivatives)*

$$H_\sigma(\sigma, y, s) > 0 \textit{ and } H_y(\sigma, y, s) > 0$$
$$H_{\sigma\sigma}(\sigma, y, s) \leq 0 \textit{ and } H_{yy}(\sigma, y, s) \leq 0$$
$$H_{y\sigma}(\sigma, y, s) \geq 0$$

This assumption states that increasing lower school funding or having a higher income increases the human capital of an agent. Further, the human capital function has non-increasing returns in lower school funding and parental income. Finally, it is assumed lower school spending and parental income are complements in the human capital function.

Throughout the paper, the difference in human capital $H(\sigma, y, 1) - H(\sigma, y, 0)$ is referred to as the human capital premium. The next assumption outlines the properties of the human capital premium.

Assumption 9. *(Human Capital Premium Assumptions)*

$$H(\sigma, y, 1) - H(\sigma, y, 0) \geq 0$$
$$H_\sigma(\sigma, y, 1) - H_\sigma(\sigma, y, 0) > 0$$
$$H_y(\sigma, y, 1) - H_y(\sigma, y, 0) > 0$$

It is assumed the human capital premium is weakly positive. Attending college can never lower an agent's human capital. Further, the assumption states that the human capital premium is increasing in lower school funding. Primary and secondary education is a complement to post-secondary education. Spending more on lower school education increases the return to higher school education. In addition, the human capital premium is increasing in an agent's income. An interpretation of this assumption could be that a larger initial income is correlated with more spending on education early in a child's life. This allows the child to excel in all levels of school.

To fund education, a portion of every agent's income is taxed. The tax rate is exogenously given and is denoted as θ. The amount of funds available for education expenditure is equal to the tax rate times the average income, $\theta\mu$. A majority vote determines τ, how much of the tax pool is spent on the post-secondary subsidy. The amount spent on the post-secondary subsidy is $\tau\theta\mu$ and the amount spent on primary and secondary education is $(1-\tau)\theta\mu$.

The quality of primary and secondary school is determined by how much public funding is spent per student. Since the measure of students is one and all students attend primary and secondary school, the amount spent per person on lower education is equal to the total amount spent on primary and secondary education, $\sigma \equiv (1-\tau)\theta\mu$.

Post-secondary education is potentially only partially subsidized. The per person subsidy is determined by the total amount spent on post-secondary education and the number of students who choose to attend higher education. The total subsidy is split evenly among all the agents who decide to attend post-secondary education. Let $N(\tau)$ be the number of students who decide to attend college. College attendance depends on how much funding is available for college. Consequently, the per person subsidy amount is $\frac{\tau\theta\mu}{N(\tau)}$. It is assumed the per capita gross cost of higher education is E. Since it is possible that the gross cost of higher education is larger than the subsidy, in the presence of incomplete credit markets it may not be possible for all types of agents to afford education. Type i agents can afford to attend college if their after tax income is larger than the net cost of college, $(1-\theta)y_i \geq E - \frac{\tau\theta\mu}{N(\tau)}$.

Spending more on primary and secondary education increases the human capital received by all agents. In addition, because higher education and lower education are assumed to be complements, increasing the amount spent on primary and secondary education increases the return received from post-secondary education. On the other hand, increasing the amount spent on post-secondary education decreases the cost of higher education and potentially gives more agents the opportunity to attend college.

Given a tax split τ, an agent i chooses a mixed strategy ρ_i to maximize the following problem:

$$\max_{\rho_i}(1-\theta)y_i+\rho_i\left[H(\sigma,y_i,1)-(E-\frac{\tau\theta\mu}{N(\tau)})\right]+(1-\rho_i)H(\sigma,y_i,0)$$

$$s.t.$$

$$\rho_i\cdot\left[(1-\theta)y_i-(E-\frac{\tau\theta\mu}{N(\tau)})\right]\geq 0$$

$$\rho_i\in[0,1]$$

Here ρ_i is equal to the probability that agent i chooses to attend college. If an agent does not attend college he gets utility from after tax income and the human capital earned in high school. If an agent attends college he gains utility from income remaining after taxes and from the human capital earned in both primary and secondary school and in post-secondary school. In addition, this agent's utility is decreased since he has to pay the remaining cost of college.

The individual maximization problem reveals that attending college is beneficial if the human capital premium is larger than the net cost of attending college. The next equation summarizes this condition.

$$H(\sigma,y_i,1)-H(\sigma,y_i,0)\geq E-\frac{\tau\theta\mu}{N(\tau)} \tag{4.1}$$

I refer to Equation (4.1) as the return constraint. If this holds, an agent i will want to attend school if he can afford college and Equation (4.2), the budget constraint is satisfied.

$$(1-\theta)y_i\geq E-\frac{\tau\theta\mu}{N(\tau)} \tag{4.2}$$

The solution of the agent's problem can be summarized as follows: An agent will choose the maximum ρ_i such that both the return constraint and the budget constraint are simultaneously satisfied. If these constraints are never satisfied for any values of ρ_i, the agent will not choose to attend college.

It is not assumed that all individuals want to go to college if they can afford to attend. Here, by making college more affordable the value of college is decreased. This arises because in order to increase the affordability of college, funds have to be shifted to the college subsidy from lower school education. This creates a tradeoff between providing access to college and increasing the return to college.

4.2.2 Attendance Equilibrium

It is important to note the subsidy amount and the decision to enter school are jointly determined by τ. In an equilibrium, only some values of the subsidy and the college attendance can be jointly consistent. In this section an equilibrium is defined, then to determine what values are consistent, results about the equilibrium attendance decisions of each income group are developed.

In the definition of equilibrium, is it necessary to specify the beliefs of all agents. In this problem, the joint attendance decisions of all agents determine $N(\tau)$, the number of agents who attend college. At any tax allocation, each income group chooses whether or not to attend college. Since the subsidy is split evenly between all those who choose to attend college, the choice to attend college for any one agent is dependent on the choices of the other agents. The per student subsidy amount decreases as more students attend college. It is possible that the low income group would be able to afford college if only low income individuals choose to attend, but would not be able to afford college if individuals from the high income group and the middle income group also choose to attend college.

Similarly, there could be a case where students of some type i would want to attend college if no other students of type i attended college; however, if all students of type i entered college, the cost of college would make it such that type i students no longer would want to attend college. In this case, if type i students didn't realize that other type i students are making similar choices, type i students would cycle between attending and not attending college and there would be no equilibrium. To remove this cycle, I define the equilibrium such that students believe all students with a common type will make the same decision.[2] The formal definition of equilibrium is below.

Definition 1. *Given a tax split τ, an* ***attendance equilibrium*** *is a set of attendance decisions $\{\rho_1, \rho_2, \rho_3\}$ such that ρ_i ($i \in \{1,2,3\}$) solves the agent's problem assuming that all other agents of the same type also choose ρ_i.*

The following result simplifies the problem of whether or not an individual group will attend college.

Result 1. *In an equilibrium:*

1. *If $0 < \rho_i < 1$, then it must be the case that either the budget constraint or the return constraint is binding for group i.*
2. *If $0 < \rho_i < 1$ and $\sigma \neq 0$, then for any higher income group ($\forall k < i$) $\rho_k = 1$*

Proof. 1. This follows directly from the individual maximization problem. If neither constraint is binding then agents from group i could place a little more probability on attending college and achieve a higher return without violating either of the constraints.

2. By way of contradiction assume $\rho_k < 1$. By Part 1 of this result, for agent i either the budget constraint or the return constraint must be binding for group i. If the return constraint is binding for group i, by Assumption 9, the return constraint will not be binding

[2] This equilibrium concept follows the equilibrium concept described in Fernandez and Rogerson [1995].

for group k. Further, group k has a higher income than group i. If the budget constraint is satisfied for group i the budget constraint is not binding for group k.

Since the return constraint and the budget constraint are not binding, agents in group k could place slightly more probability on attending college. This would increase ρ_k slightly while still satisfying the budget constraint and the return constraint. This is true for any value of $\rho_k < 1$. This contradicts the assumption that agents from income group k were maximizing utility. Therefore, it must be the case that $\rho_k = 1$.

Part 1 of this result shows that the only reason all members of a certain income group wouldn't go to college is if increasing the probability of enrollment would result in the cost of college being larger than the after tax income or larger than the return to college. Part 2 of the result shows that when making the decision to enter post-secondary education, income groups are able to consider this decision assuming that all agents with higher income would attend college. Using the equilibrium definition, agents know what proportion of their own income group will choose to attend college. These pieces of information allow agents to deduce how many students would attend college if they were to attend college.

I am now ready to describe the procedure for determining the attendance rate for any given tax allocation. Before outlining this procedure, it is helpful to define the maximum number of students who can afford college, $A(\tau)$. The maximum number of students who can afford college can be found by identifying the maximum number of agents which could satisfy the budget constraint ignoring the return constraint. Since this value ignores the possibility of the return constraint not being satisfied, it must be the case that $A(\tau) \geq N(\tau)$.

Using Result 1, if an individual from group j would benefit from attending college then an individual from group $i < j$ would also benefit from attending college. The equilibrium attendance rate $N(\tau)$ then can be determined by a three step procedure.[3]

[3] A more detailed description of this procedure is contained in Appendix B.1.

1. Determine the maximum number of agents who can afford to attend college, $A(\tau)$. When making this determination use that fact that if a lower income level can afford to attend college then a higher income level also can afford to attend college. Label the agents who could afford college potential attendees.
2. Check if all of the potential attendees who can afford college satisfy the return constraint. If this is true then $N(\tau) = A(\tau)$, else proceed to step 3.
3. If there are some income groups who do not satisfy the return constraint, remove some of the lowest income agents from the group of potential attendees until all remaining attendees satisfy the return constraint. The proportion of agents that remains is then equal to the attendance rate.

4.2.3 Preferred Tax Allocation

I now look at how changes in the tax allocation affect the budget constraint and the return constraint.

Result 2. *The number of agents who can afford to attend college is non decreasing in* τ.

Proof. By way of contradiction, assume an increase in τ decreases the number of students who can attend college. This means there exists a $\tau' > \tau$ where $A(\tau) > A(\tau')$. However, if $A(\tau) > A(\tau')$ there must be some agent who previously could afford to attend college with some probability but now, at a higher tax split, can only afford to attend college at a lower probability. In terms of the model this mean $\exists$ i s.t.

$$(1-\theta)y_i \geq E - \frac{\tau\theta\mu}{A(\tau)}$$

$$\&$$

$$(1-\theta)y_i < E - \frac{\tau'\theta\mu}{A(\tau)}$$

However, this is a contradiction since

$$E - \frac{\tau\theta\mu}{A(\tau)} > E - \frac{\tau'\theta\mu}{A(\tau)}$$

The budget constraint binds for less students as the post-secondary education budget is increased. Another key factor of whether or not an income group attends post-secondary education is whether the return to education is higher than the cost of education. To simplify this problem I make the following single crossing assumption:

Assumption 10 (Single Crossing Assumption)**.** *The return to education, $H(\sigma,y,1) - H(\sigma,y,0) = H((1-\tau)\theta\mu,y,1) - H((1-\tau)\theta\mu,y,0)$, and the cost of higher education assuming everyone who can afford higher education attends, $E - \frac{\tau\theta\mu}{A(\tau)}$, satisfy a single crossing assumption for all income levels.*

Specifically, $\forall\tau \leq \tau_n(y)$,

$$H((1-\tau)\theta\mu,y,1) - H((1-\tau)\theta\mu,y,0) \geq E - \frac{\tau\theta\mu}{A(\tau)}$$

and $\forall\tau \geq \tau_n(y)$,

$$H((1-\tau)\theta\mu,y,1) - H((1-\tau)\theta\mu,y,0) \leq E - \frac{\tau\theta\mu}{A(\tau)}$$

Eventually lower school funding drops to a point where the return from attending college is not worth the cost of attending those schools, assuming everyone who could afford to attend college were to attend. The assumptions on the human capital function give us an ordering of these single crossing points. This ordering is established in Result 3. For the rest of these paper, the notation $\tau_n(y_1), \tau_n(y_2)$, and $\tau_n(y_3)$ is used to refer to the single crossing points for each income level as described in the single crossing assumption above.

Result 3. $\tau_n(y_1) > \tau_n(y_2) > \tau_n(y_3)$

Proof. In this section I prove $\tau_n(y_2) > \tau_n(y_3)$. The proof for $\tau_n(y_1) > \tau_n(y_2)$ is identical. Assume, by way of contradiction, that $\tau_n(y_2) \leq \tau_n(y_3)$. $\tau_n(y_2)$ is defined such that

$$H((1-\tau_n(y_2))\theta\mu, y_2, 1) - H((1-\tau_n(y_2))\theta\mu, y_2, 0) = E - \frac{\tau_n(y_2)\theta\mu}{A(\tau_n(y_2))}.$$

By single crossing, since $\tau_n(y_3) \geq \tau_n(y_2)$ at $\tau_n(y_3)$

$$H((1-\tau_n(y_3))\theta\mu, y_2, 1) - H((1-\tau_n(y_3))\theta\mu, y_2, 0) \leq E - \frac{\tau_n(y_3)\theta\mu}{A(\tau_n(y_3))}.$$

From Assumption 8 since $y_2 > y_3$

$$H((1-\tau_n(y_3))\theta\mu, y_3, 1) - H((1-\tau_n(y_3))\theta\mu, y_3, 0) <$$
$$H((1-\tau_n(y_3))\theta\mu, y_2, 1) - H((1-\tau_n(y_3))\theta\mu, y_2, 0)$$

$$\begin{aligned} H((1-\tau_n(y_3))\theta\mu, y_3, 1) - H((1-\tau_n(y_3))\theta\mu, y_3, 0) &< E - \frac{\tau_n(y_3)\theta\mu}{A(\tau_n(y_3))} \\ E - \frac{\tau_n(y_3)\theta\mu}{A(\tau_n(y_3))} &< E - \frac{\tau_n(y_3)\theta\mu}{A(\tau_n(y_3))} \end{aligned}$$

A contradiction.

The previous two results illustrate what happens to the two important constraints as τ is changed. According to Result 2, the budget constraint becomes less strict as τ is increased. When the tax allocation increases, more students can afford college. Result 3 and the single crossing assumption show that increasing τ eventually results in the return to college being smaller than the cost of college for some income levels. By analyzing how these constraints change, it is possible to determine how $N(\tau)$ changes as τ changes. Specifically, $N(\tau)$ is weakly increasing in τ before $\tau_n(y_3)$. After $\tau_n(y_3)$, some lower income students decide to not attend college. They make this decision since if they were to attend college the return to college would be less than the cost of college.

Figure 4.1: Return to College and Cost of College

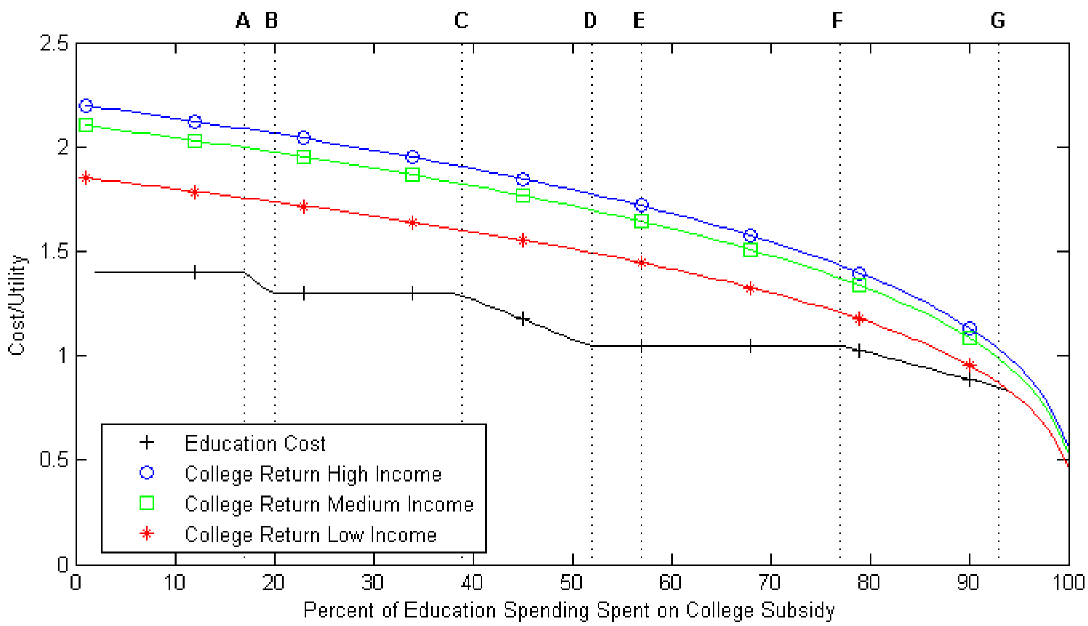


Figure 4.1 illustrates how the cost of education and return to education for each income group. For all groups the cost of college is lower than the return for most values of τ. At point G, the cost of college would become higher than the return to college for the low income group. This point corresponds to $\tau_n(y_3)$ discussed before. To the right of this point, students from the low income group drop out of college until the cost of college is exactly equal to the return to college. At tax allocations to the right of G, every low income individual is indifferent between attending college or not attending college.

To the left of point G, as the tax allocation increases, the cost of college either decreases or remains constant. The decrease in cost occurs because the subsidy amount is growing while the number of students attending college is staying constant. However, once the cost reaches a point where an income group who previously was not attending college can afford college, the cost stays constant. While the cost is constant, the total amount spent on college increases but the per student amount stays the same. The increase in college spending goes towards providing a greater number of subsidies to agents who can barely afford to attend college.

I now define notation to label the values of τ where the slope of the college cost changes. Let $\hat{\tau}_i$ be the maximum value of τ for which

$$(1-\theta)\,y_i < \left(E - \frac{\tau\theta\mu}{\sum_{j<i}\lambda_j}\right)$$

This is the highest value of τ such that no agents in group i could afford to attend college. In Figure 4.1, this point is labeled B for the middle income group and D for the lowest income group.

Define $\overline{\tau}_i$ to be the minimum value of τ for which

$$(1-\theta)\,y_i \quad > \quad \left(E - \frac{\tau\theta\mu}{\sum_{j\leq i}\lambda_j}\right)$$

This is the smallest value of τ such that all agents in group i can afford to attend college. In Figure 4.1, this point is labeled A for the highest income group, C for the middle income group and F for the lowest income group.

In between $\hat{\tau}_i$ and $\overline{\tau}_i$, only some members of group i are able to attend higher education. Increasing the amount of post-secondary education funds available does not make college more affordable. Instead, more agents from group i are able to attend higher education. At the same time, increasing the post-secondary education funds lowers the quality of primary and secondary education. It may be possible that the decrease in utility from lower quality of primary and secondary education is more than the corresponding increase in utility from increasing access for group i. I label the point where these two effects are exactly equal for group i as $\tau_e(y_i)$.

Holding fixed the number of agents who choose to attend college, increasing post-secondary education funds lowers the cost of post-secondary education for all agents who choose to attend college. However, increasing the post-secondary education funds also lowers the quality of primary and secondary education. Define $\tau_r(y_i)$ to be the point where the benefit from increasing the post-secondary subsidy is exactly equal to the cost associated with moving education funds away from primary school. It follows that $\tau_r(y_i)$ satisfies the following equation

$$H_\tau((1-\tau_r(y_i)\theta\mu, y_i, 1) = -\frac{\theta\mu}{N(\tau_r(y_i))}$$

In Figure 4.1, $\tau_r(y_1)$ is labeled E.

Proposition 1 summarizes how the utility of each group changes as τ changes. The proof is contained in Appendix B.2.

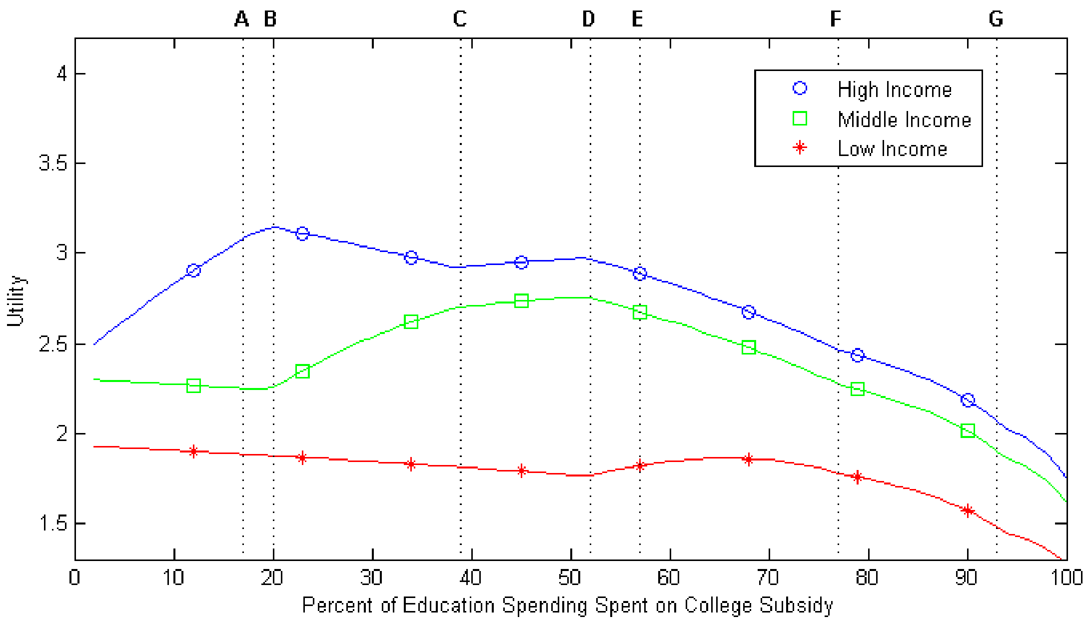
Proposition 1. *Assume the single crossing assumption holds, then*

For income 1: Utility is decreasing on $(\tau_r(y_1), 1]$. *If* $\exists\tau_e(y_1)$ *s.t.* $0 \le \tau_e(y_1) < \overline{\tau}_1$, *then for* $\tau < \tau_r(y_1)$, *utility is increasing on* $(0, \tau_e(y_1))$, *decreasing on* $(\tau_e(y_1), \overline{\tau}_1)$, *increasing on* $(\overline{\tau}_1, \hat{\tau}_2)$, *decreasing on* $(\hat{\tau}_2, \overline{\tau}_2)$, *increasing on* $(\overline{\tau}_2, \hat{\tau}_3]$, *decreasing on* $(\hat{\tau}_3, \overline{\tau}_3)$, *and increasing on* $(\overline{\tau}_3, 1]$. *If* $\nexists\tau_e(y_1)$ *s.t.* $0 \le \tau_e(y_1) < \overline{\tau}_1$, *then for* $\tau < \tau_r(y_1)$, *utility is increasing on* $(0, \hat{\tau}_2)$, *decreasing on* $(\hat{\tau}_2, \overline{\tau}_2)$, *increasing on* $(\overline{\tau}_2, \hat{\tau}_3]$, *decreasing on* $(\hat{\tau}_3, \overline{\tau}_3)$, *and increasing on* $(\overline{\tau}_3, 1]$.

For income 2: Utility is decreasing on $(\tau_r(y_2), 1]$. *If* $\exists\tau_e(y_2)$ *s.t.* $\hat{\tau}_2 \le \tau_e(y_2) < \overline{\tau}_2$, *then for* $\tau < \tau_r(y_2)$, *utility is decreasing on* $[0, \hat{\tau}_2)$, *increasing on* $(\hat{\tau}_2, \tau_e(y_2))$, *decreasing on* $(\tau_e(y_2), \overline{\tau}_2)$, *increasing on* $(\overline{\tau}_2, \hat{\tau}_3)$, *decreasing on* $(\hat{\tau}_3, \overline{\tau}_3)$, *and increasing on* $(\overline{\tau}_3, 1]$. *If* $\nexists\tau_e(y_2)$ *s.t.* $\hat{\tau}_2 \le \tau_e(y_2) < \overline{\tau}_2$, *then for* $\tau < \tau_r(y_2)$, *utility is decreasing on* $[0, \hat{\tau}_2)$, *increasing on* $(\hat{\tau}_2, \hat{\tau}_3)$, *decreasing on* $(\hat{\tau}_3, \overline{\tau}_3)$, *and increasing on* $(\overline{\tau}_3, 1)$.

For income 3: Utility is decreasing on $(\tau_r(y_3), 1]$. *If* $\exists\tau_e(y_3)$ *s.t.* $\hat{\tau}_3 \le \tau_e(y_3) < \overline{\tau}_3$, *then for* $\tau < \tau_r(y_3)$, *utility is decreasing on* $[0, \hat{\tau}_3)$, *increasing on* $(\hat{\tau}_3, \tau_e(y_3))$, *decreasing on*

Figure 4.2: Expected Utility of Income Groups



$(\tau_e(y_3), \overline{\tau}_3)$, *and increasing on* $(\overline{\tau}_3, 1]$. *If* $\nexists \tau_e(y_3)$ *s.t.* $\hat{\tau}_3 \leq \tau_e(y_3) < \overline{\tau}_3$, *then for* $\tau < \tau_r(y_3)$, *utility is decreasing on* $[0, \hat{\tau}_3)$ *and increasing on* $(\hat{\tau}_3, 1)$.

It is not clear what tax allocation is the maximum here without specifying the parameters and human capital function. Also it is obvious that in most cases preferences are not single peaked. Figure 2 illustrates one possible evolution of the expected utilities. Notice point B or $\hat{\tau}_2$ is the maximum of high income agents, D or $\hat{\tau}_3$ is the maximum of the middle income group and The maximum utility for group 3 occurs in between point E and F.

4.3 MAJORITY VOTING EQUILIBRIUM

I now evaluate what values of τ could be a majority voting equilibrium. I first define a majority voting equilibrium.

Definition 2. *A majority voting equilibrium is a tax distribution τ^* such that $\forall \tau \in [0,1]$, the number of agents with $EU_i(\tau^*) \geq EU_i(\tau)$, is strictly greater than 0.5*

To eliminate trivial cases the following assumption is made.

Assumption 11 (Non-Trivial Equilibria)**.** $\forall i \; \lambda_i < 0.5$

This assumption allows us to ignore cases where one group is the majority and the preferences of the other two groups do not matter. It follows from this assumption, that the sum of the proportions of any two groups must be larger than 0.5. Therefore, if any two groups have the same preferred point, this point is a majority voting equilibrium.

Result 4 helps narrow down the number of potential majority voting equilibrium candidates. The possible candidates are presented in Proposition 2.

Result 4. *In order for τ^* to be an equilibrium, τ^* must be a local maximizer for at least one of the three groups.*

Proof. By way of contradiction, assume that τ^* is not a local maximizer for any of the three groups. If τ^* is 0 it must be the case that all utilities are increasing at 0. Otherwise τ^* would be a local maximizer. When all utilities are increasing and τ^* is 0, any τ' slightly above 0 would be preferred by all members. So τ^* can't be 0. With similar reasoning τ^* will not take the value of 1.

Now consider the case where τ^* is between 0 and 1. At τ^* group 1 either has increasing or decreasing utility. Assume type 1 agents have increasing utility. It follows that either both type 2 and type 3 agents have decreasing utility or at least one of them has increasing utility at τ^*. In either scenario, at least two groups either have increasing or decreasing utility. If two groups have increasing utility, a tax split τ' that is slightly above τ^* will be preferred for more than fifty percent of the population. Similarly, if two groups have decreasing utility any tax split τ' that is slightly below τ^* will be preferred by more than fifty percent of the population. Either way this is a contradiction and τ^* can not be an equilibrium. If group 1 has decreasing utility at τ^*, the same logic can be used to show that τ^* still can not be an equilibrium.

Proposition 2. *If a majority voting equilibrium exists, the only possible equilibrium values of τ are 0, $\hat{\tau}_3$, $\tau_r(y_1)$, and $\tau_r(y_2)$.*

Proof. According to Result 4 if a majority voting equilibrium exists it must be a local maximizer for at least one income group. From Proposition 1, the local maximizers for each group can be determined.

The potential local maximizers for each of the three income groups are

- Income group 1: $\{\hat{\tau}_2, \hat{\tau}_3, \tau_r(y_1)\}$
- Income group 2: $\{0, \tau_e(y_2), \hat{\tau}_3, \tau_r(y_2)\}$
- Income group 3: $\{0, \tau_e(y_3), \tau_r(y_3)\}$

Further note that any interior τ where two groups have increasing or decreasing utility could not be a maximum. If two groups had increasing or decreasing utility at an interior τ, slightly increasing or decreasing τ will result in a tax split that the majority of students prefer. Using this logic most possible candidates for equilibrium can be eliminated.

First consider $\hat{\tau}_2$. A τ slightly smaller than $\hat{\tau}_2$ will yield higher utility for groups 2 and 3. Therefore this can not be an equilibrium.

If $\tau_e(y_2)$ and $\tau_e(y_3)$ exist in between $\hat{\tau}_2 \leq \tau_e(y_2) < \overline{\tau}_2$ and $\hat{\tau}_3 \leq \tau_e(y_3) < \overline{\tau}_3$ then $\tau_e(y_2)$, and $\tau_e(y_3)$ are local maximums for group 2 and 3. However, at these points utility for the other two groups are decreasing. Therefore, even if parameters welcome the existence of $\tau_e(y_2)$ and $\tau_e(y_3)$ they could not be potential equilibria values.

Next consider $\tau_r(y_1), \tau_r(y_2)$ and $\tau_r(y_3)$. The utility for each group i is decreasing after $\tau_r(y_i)$ and $\tau_r(y_1) < \tau_r(y_2) < \tau_r(y_3)$, it is not possible for any values of $\tau > \tau_r(y_2)$ to be an equilibrium. This rules out $\tau_r(y_3)$. Also if $\tau_r(y_1) > \hat{\tau}_3$ then at $\tau_r(y_1)$ utility for groups 2 and 3 are increasing and $\tau_r(y_1)$ can not be an equilibrium.

The possible equilibria depend on where $\tau_r(y_1)$ and $\tau_r(y_2)$ occur.

- If $\tau_r(y_1) \geq \hat{\tau}_3$
  - If $\tau_r(y_2) > \overline{\tau}_3$ the potential equilibria are $\{0, \hat{\tau}_3, \tau_r(y_2)\}$
  - If $\hat{\tau}_3 < \tau_r(y_2) < \overline{\tau}_3$ the potential equilibria are $\{0, \hat{\tau}_3\}$
- If $\overline{\tau}_2 < \tau_r(y_1) \leq \hat{\tau}_3$ the potential equilibria are $\{0, \tau_r(y_1)\}$
- If $0 < \tau_r(y_1) \leq \overline{\tau}_2$ then the only potential equilibrium is $\{0\}$

This being said, the interesting equilibria are the internal ones. Equilibrium value of 0 corresponds to no college funding and the value of $\tau(y_2)$ is the case where everyone attends college. Both of these are not in line with reality. The equilibrium values of $\hat{\tau}_3$ and $\tau_r(y_1)$ are the equilibrium values that coincide with partial college attendance and positive college funding.

4.4 EQUILIBRIUM DYNAMICS

Since the benefits of different levels of education depend on an agents income, it is natural to believe the income distribution may affect the equilibrium education allocation. Using the model, I show that this is true. At low levels of income inequality, as income inequality increases, education spending begins to shift towards college. Eventually, when income inequality is large enough, a further increase in inequality shifts education funds back towards primary and secondary school.

The intuition behind this result is as follows, an internal equilibrium requires the rich and middle class to agree on an income level that excludes the poorest agents from college. When income inequality increases, larger subsidies can be provided to the rich and the middle class without allowing the poor to enter college. Motivated by an ability to extract more resources from the poor, the rich and middle class increase the funding sent to the college subsidy. Eventually there becomes a level of income inequality where if the rich were to shift more resources to the college subsidy, the return to college would decrease more than the cost of college would decrease. Once this point is reached, the high income agents prefer to spend less on the college subsidy and the middle income agents want to spend more on college. Spending less than the optimum level of the middle class is possible because the lower class support a smaller subsidy. For the middle class, this smaller college subsidy is still better than no subsidy which the lower class desires. Therefore, the rich are able to use the lower class to move the equilibrium level away from what the middle class desires.

By focusing on the internal equilibria candidates, I use the model to show how a change in income distribution can lead to the tax split first increasing and then decreasing. First consider an equilibrium where $\hat{\tau}_3$ is the equilibrium tax split. Under this tax split, the high and middle income agents receive post-secondary education. This split is the maximum tax split such that low income agents can not afford to attend college. The tax split $\hat{\tau}_3$ can only be the equilibrium if the return to college decreases more than the cost of college at an education split above $\hat{\tau}_3$. In other words, if $\hat{\tau}_3 < \tau_r(y_1)$.

Now consider an increase to income inequality which keeps mean income constant. To simulate this change, increase the highest group's income and decrease the middle and lowest income groups' income. This changes both potential internal equilibria.

Since the poorest agents now have less income, these agents require more college funding to be able to enter college. At education splits slightly above the original equilibrium low income agents can no longer afford to attend college. The two higher income agents can now extract more income from the lowest income agents if they increase the tax split. This is reflected by an increase in $\hat{\tau}_3$.

The increase of the rich agents income changes $\tau_r(y_1)$. Recall $\tau_r(y_1)$ is the tax split where any further increase in the tax split would lower utility for group 1. At this point, overall utility decreases since the increase in college affordability increases utility less than the decrease in lower school funding lowers utility. The tax split $\tau_r(y_1)$ was the value of τ such that

$$H_\tau((1-\tau)\theta\mu, y_1, 1) = -\frac{\theta\mu}{N(\tau)}.$$

When y_1 increases, by the assumptions on human capital, $H_\tau((1-\tau)\theta\mu, y_1, 1)$ decreases. Further, when y_2 and y_3 decrease $N(\tau)$ weakly decreases. This decrease only happens if low income agents are partially enrolled in college at the tax split $\tau_r(y_1)$. However, once the low income agents can no longer afford college at tax allocation $\tau_r(y_1)$, the change in $N(\tau)$ is equal to zero. Therefore, when income inequality increases a large amount, $\tau_r(y_1)$ will decrease.

Based on the above analysis, if the original equilibrium level corresponds to an equilibrium split of $\hat{\tau}_3$, when income inequality is marginally increased, the equilibrium tax split will increase. This will send more resources towards the college subsidy. When the income inequality is increased a large amount, eventually $\hat{\tau}_3$ will become larger and $\tau_r(y_1)$ will decrease. When $\tau_r(y_1)$ falls under $\hat{\tau}_3$ the tax split will begin to decrease and the society will begin to shift resources back towards primary and secondary education.

It is interesting to note that this relationship is dependent on the presence of primary and secondary education. In a model which does not consider the existence of lower levels of education, when income inequality increases the rich and middle class agents would increase spending on higher education. The increase in higher education spending would happen even for high levels of income inequality.[4]

Table 4.1: U.S. Education Statistics in 2008

	Average	**Standard Deviation**	**Maximum (State of Max)**	**Minimum (State of Min)**
Primary and secondary spending per 5 to 17 year old	9,888	2,536	17,138 (Wyoming)	6,500 (Tennessee)
Post-secondary spending per 18 to 24 year old	2,534	700	6,590 (Wyoming)	237 (Colorado)
Primary and secondary spending per student	10,624	2,991	18,966 (New York)	6,768 (Utah)
Post-secondary spending per student	6,604	1,838	18,719 (Wyoming)	655 (Colorado)
Correlation between a state's primary and secondary spending per 5 to 17 year old and post-secondary spending per 18 to 24 year old (Significance Level)				0.1618 (0.2616)

4.5 DATA ANALYSIS

I now turn to the data to test the predictions of the model. First I take a general look at how states spend on different levels of spending. The first striking feature I notice is across states there are large differences in education spending. Table 1 presents key statistics on the population adjusted and student adjusted local and state government education spen-

[4]This is shown in a model of only post-secondary education in Fernandez and Rogerson [1995].

ding in 2008. The table shows that that differences in education spending are still present even when adjusting for the state's population. Further, states spend on average more on primary and secondary education than post-secondary education. Interestingly, it seems that primary and secondary education spending is not a good indicator of post-secondary education spending. Many states which spend relatively a lot on primary and secondary (post-secondary) education spend relatively little on post-secondary (primary and secondary) education. For example, North Carolina ranks 5th among all states in post-secondary spending per eligible student but ranks 44th in primary and secondary spending per eligible student. In the other direction, Massachusetts ranks 45th among all states in post-secondary spending per eligible student but ranks 7th in primary and secondary spending per eligible student. Other states have similar ranks for both categores, Wyoming ranks 1st in both post-secondary and primary and secondary spending and Montana ranks 37th in both categories. The insignificant and small correlation between primary and secondary spending and post-secondary spending is evidence that primary and secondary education spending is not a good indicator of post-secondary education spending. Further, it suggests that some states may have a preference towards one type of education spending.

Overtime, the proportion of education funds allocated to colleges is relatively stable. Table 2 contains information on the proportion of education expenditure across states in different years. The table also shows the standard deviation and average proportion spent on college slightly increases with time. Another striking feature of the data is the many of the states who spend a relatively large portion of their budget on college are the same states who in the past spent a large portion of their education budget on college. Using education spending data from 1960 until 2010, I calculate the Spearman rank correlation of the proportion of education funds allocated to college education. The results are displayed in Table 3. The table reveals that the rank between 1960 and 2010 are highly correlated. This suggests that differences in the education allocation across the states may be attributed to state specific features.

The model predicts that within a state, different income distributions may result in differences in the distribution of education expenditure. To test this prediction, I run a fixed effect regression to see how the income distribution is related to the percent of education funds spent on college education.

This regression is performed using data from the United States Census and the National Center for Education Statistics. I compiled data on all states for years between 1977 and 2010.[5]

The regression takes the following form:

$$Y_{st} = \alpha + \beta X_{st} + \gamma_t + \delta_s + \varepsilon_{st} \tag{4.3}$$

The dependent variable of interest Y_{st} is the percent of education funds that states spend on post-secondary education. In the data, this includes all direct expenditure by state and local governments to public schools. This is obtained from the Census State and Local Finance data.[6] In various specifications, the covariates X_{st} include the income distribution, the average income, population composition, and the amount spent on education by the government. To quantify the income distribution, I use the mean household income divided by the median household income of each state. This data is calculated from the IPUMS CPS data. The population composition is represented as the college age population divided by the sum of college age population and primary and secondary age population. The amount spent on education by the government is equal to the total public expenditure spent

[5]The earliest year of data is 1977 since the IPUMS data used to estimate the mean and median income in each state does not specify the exact state in years before 1977. Data on years 2001 and 2003 are not included in the regression. For these years, the Census did not gather data on state and local finances separated by state. Instead only an aggregate number for the entire United States is available.

[6]Unfortunately, this does not contain scholarships given directly to students to pay for private primary and secondary schools, public colleges, or private colleges. The census does not have scholarship data separated by primary and secondary scholarships and post-secondary scholarships, therefore scholarships are not included in the dependent variable.

Table 4.2: Split of Education Expenditure

	1980	1990	2000	2010
Average Proportion of Education Funds Allocated to Colleges	28.3%	28.5%	29.0%	31.3%
Standard Deviation	5.49%	5.86%	5.71%	6.04%
Maximum (State)	38.5 (HI)	38.1 (ND)	40.3 (UT)	43.5 (UT)
Minimum (State)	14.1 (MA)	16.8 (CT)	15.5 (NY)	18.3 (NJ)

Table 4.3: Spearman Rank Correlation

	1960	1970	1980	1990	2000	2010
1960	1	.62	.47	.40	.54	.59
1970		1	.70	.67	.64	.65
1980			1	.87	.76	.77
1990				1	.90	.81
2000					1	.89
2010						1

Table 4.4: Fixed Effect Regressions

	1	2	3	4	5
Mean/Median Income	1.953** (0.952)	0.839** (0.391)	1.278** (0.411)	1.227** (0.413)	1.005** (0.451)
(Mean/Median Income)^2	-0.803** (0.380)	-0.317** (0.148)	-0.492** (0.157)	-0.464** (0.157)	-0.384** (0.174)
Log of Mean Income	-	-	-	-0.028 (.031)	-0.049* (0.026)
College Age Population/ Primary and Secondary Age Population	-	-	-	0.358** (0.123)	0.282** (0.130)
Total Amount Spent on Education /Mean Income	-	-	-	-	-0.050** (0.013)
State Fixed Effects	No	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	No	Yes	Yes	Yes

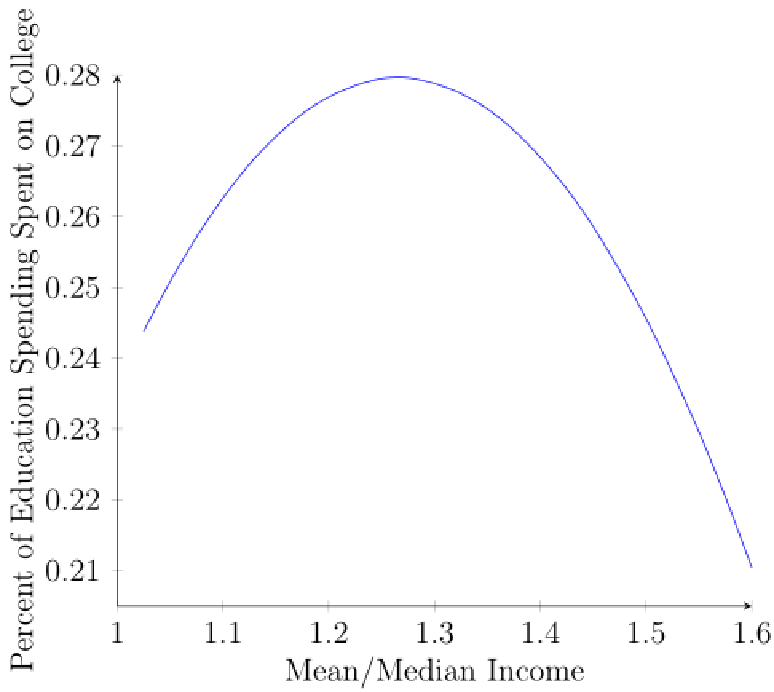
Significance level: * $p < 0.1$, ** $p < 0.05$

on education. This measure is normalized by average income in the state. This variable is included as a robustness check since in the model, total expenditure on education is treated as exogenous. The terms γ_t and δ_s are the time and state fixed effects.

Table 4.4 shows the results of this regression. The regression is weighted by the average state population in the sample years. The standard errors reported are clustered at the state level.

The regression results show the distribution of income is an important determinant in how states decide to allocate education funds. Further, the data supports the prediction of the model. When the income distribution becomes more unequal, states tend to spend more on college education. However, this relationship is not linear. Eventually, when the distribution becomes too unequal, states shift education funds back to lower levels of education. Figure 4.3 illustrates this quadratic relationship. Columns 1 through 5 show this relationship persists even if year fixed effects, state fixed effects, and other state specific

Figure 4.3: Fitted relationship between education allocation and the mean median ratio



variables are added to the regression.

4.6 CONCLUSION

This paper examines how different states split their education budget between primary and secondary education and post-secondary education. A majority voting model is created to gain insight into how states decide to split education funds between different levels of education. Using model of education attainment with multiple levels of education, I observe when the income distribution increases more funds are allocated towards college. However, this relationship is not linear. Eventually, when income inequality is very high, education funds are shifted back towards primary and secondary school.

The model illustrates how, in a majority voting framework, the rich can use the preferences of the other agents to receive the tax allocation they desire. I show at low levels of income inequality, when a state experiences higher income inequality, a majority of the agents desire a higher amount of spending on post-secondary education when compared to states with less income inequality. The intuition behind this is higher incomes and the middle income levels both wish to extract resources from the poor. When income inequality increases, it is harder for the poor to afford to attend college and these two income groups can lower the price of college while still excluding the poor. However, when income inequality becomes too large, rich individuals would rather fund primary and secondary education to maximize their return to college. At very high levels of inequality, the rich do not want to subsidize the middle class's post-secondary education since, at the allocation level the middle incomes desire, the return to college for the rich decreases. Therefore, when income inequality increases further the rich agents use the poor agent's preference for less college funding to shift funding away from post-secondary education back to primary and secondary education.

Using data from the United States, I am able to confirm the relationship between income distribution and education fund allocation present in the model. Specifically, I show that within a state, as the income distribution becomes more unequal, first the state spends a large portion of their education budget on higher education. However, once the income distribution becomes too high the state shifts public funds back to lower levels of education. This feature of the data is not present in previous models of education spending which only consider one level of spending.

This paper could benefit from an extension of the model that allows agents to choose not only the split of a tax pool but also the tax rate itself. Allowing agents to choose this variable will allow the model to closer resemble real life. Under this model it is possible to explore if there is any correlation between how much total is spent on education and how education funds are split. In addition, further analysis could be done to uncover what other state specific features determine why states allocate education funds differently.

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APPENDIX A

ACCESS, AFFORDABILITY, AND OUTCOMES

A.1 EQUILIBRIUM SOLUTION - BASELINE

A.1.1 Public optimization solution

The derivation of the admittance decision for public schools, outlined in Equation (3.1), follows the process used in Epple et al. [2016].

To solve for the equation set up the Lagrangian of the public school problem.

$$L = \int\int o(q,b,y)\alpha(b,y)r(b,y)f(b,y)dbdy$$
$$-\lambda\left[F + V(k) + ke - kz - \int\int t(b,y)\alpha(b,y)r(b,y)f(b,y)dbdy\right]$$
$$-\eta\left[\int\int b\alpha(b,y)r(b,y)f(b,y)dbdy - \theta k\right] - \Omega\left[\int\int \alpha(b,y)r(b,y)f(b,y)dbdy - k\right]$$

Then take the derivative with respect to the admittance decision and divide this expression by λ. Note that λ is the multiplier associated with the budget constraint. Use L_θ, L_e, and L_k to simplify this expression. From feasibility constraints, note $\alpha(b,y) > 0$ iff $L_{\alpha(b,y)} > 0$. Which yields the equation:

$$\frac{o(q,b,y)}{\lambda} + t(b,y) + z \geq V'(k) + e + \frac{q_\theta}{q_e}(\theta - b) \iff \alpha(b,y) > 0 \tag{A.1}$$

By using Equation (A.1) with a utility maximization argument Equation (3.1) is obtained.

A.1.2 Private optimization solution

The derivation of the implicit tuition equation , outlined in Equation (3.2), follows the process used in Epple et al. [2016].

Suppressing the j subscript the Lagrangian is:

$$L = q + \lambda \left[\int\int t(b,y) r(b,y) f(b,y) dbdy - F - V(k) - ke + D \right]$$
$$-\eta \left[\int\int br(b,y) f(b,y) dbdy - \theta k \right] - \Omega \left[\int\int r(b,y) f(b,y) dbdy - k \right]$$

Then take the derivative with respect to the charged tuition. Use L_θ, L_e, and L_k to simplify this expression. This yields Equation (3.2). Equation (3.3) is obtained by substituting in $\frac{\partial r(b,y;T,Q)}{\partial t(b,y)}$ and solving for $t(b,y)$.

I differentiate with respect to θ, e, and k

$$L_\theta = q_\theta + \lambda \left[\int\int t(b,y) \frac{\partial r(b,y)}{\partial q} q_\theta f(b,y) dbdy \right] + \eta \left[k - \int\int b \frac{\partial r(b,y)}{\partial q} q_\theta f(b,y) dbdy \right] \tag{A.2}$$
$$-\Omega \left[\int\int \frac{\partial r(b,y)}{\partial q} q_\theta f(b,y) dbdy \right] = 0$$

$$L_e = q_e + \lambda \left[\int \int t(b,y) \frac{\partial r(b,y)}{\partial q} q_e f(b,y) dbdy - k \right] - \eta \left[\int \int b \frac{\partial r(b,y)}{\partial q} q_e f(b,y) dbdy \right] \tag{A.3}$$

$$-\Omega \left[\int \int \alpha(b,y) \frac{\partial r(b,y)}{\partial q} q_e f(b,y) dbdy \right] = 0$$

$$L_k = -\lambda \left[V'(k) + e \right] + \eta \theta + \Omega = 0 \tag{A.4}$$

I combine (A.2) and (A.3)

$$\frac{\eta}{\lambda} = -\frac{q_\theta}{q_e} \tag{A.5}$$

Dividing (A.4) by λ and substitute in equation (A.5) yields

$$\frac{\Omega}{\lambda} = V'(k) + e + \frac{q_\theta}{q_e} \theta. \tag{A.6}$$

I now take the derivative with respect to $t(b,y)$. Then substitute in equations (A.5), (A.6), and the derivative of the matriculation function. Finally I solve for $t(b,y)$.

$$L_{t(b,y)} = \lambda \left[t(b,y) \frac{\partial r(b,y)}{\partial t(b,y)} f(b,y) + r(b,y) f(b,y) \right]$$
$$-\eta b \frac{\partial r(b,y)}{\partial t(b,y)} f(b,y) - \Omega \frac{\partial r(b,y)}{\partial t(b,y)} f(b,y) = 0$$

This simplifies to

$$\left[t(b,y) - \frac{\eta}{\lambda} b - \frac{\Omega}{\lambda} \right] \frac{\partial r(b,y)}{\partial t(b,y)} = -r(b,y)$$

Substituting in equation (A.5) and (A.6) yields

$$\left[t(b,y) - \left(V'(k) + e + \frac{q_\theta}{q_e} (\theta - b) \right) \right] \frac{\partial r(b,y)}{\partial t(b,y)} = -r(b,y)$$

I now solve for $t(b,y)$ and plug in the derivative of the demand function.

$$t(b,y) = \left(V'(k) + e + \frac{\gamma_1 e}{\gamma_2 \theta} (\theta - b) \right) + \frac{r(b,y)}{\frac{\rho}{y - t(b,y)} r(b,y)(1 - r(b,y))}$$

A.1.3 Admittance Based Federal Aid

In the discussion that follows I outline the procedure to determine the tuition a college charges in the presence of federal aid. Since colleges are monopolistically competitive, in order to find the optimal tuition I find the point where marginal revenue is equal to effective marginal cost. An illustration of a possible student demand, marginal revenue, and marginal cost is shown in Figure 3.1. In this figure, the student demand is kinked. The top part of the demand curve corresponds to the student demand for a college if they were to receive the full federal aid amount, $\bar{A}$. The bottom part of the curve corresponds to the demand if they were not to receive any aid. Once tuition reaches the expected family contribution, $EFC(y)$, the student qualifies for federal aid. From that point until $EFC(y)+\bar{A}$, any increase in tuition will be matched with an increase in government aid. This creates a kinked demand curve.

The marginal revenue is given by

$$t_j(b,y)+\frac{r_j(b,y)}{\frac{\partial r_j(b,y)}{\partial t_j(b,y)}}.$$

If we plug in the derivatives of student demand. This results in

$$t_j(b,y)+\frac{r_j(b,y)}{\frac{\partial r_j(b,y)}{\partial t_j(b,y)}}=\begin{cases} t_j(b,y)-\frac{y-t_j(b,y)}{\rho(1-r_j(b,y))}, & \text{if } t_j(b,y)<EFC(y) \\ t_j(b,y)-\frac{y-t_j(b,y)+\bar{A}}{\rho(1-r_j(b,y))}, & \text{if } t_j(b,y)>EFC(y)+\bar{A} \end{cases} \tag{A.7}$$

Note for tuition $t_j(b,y)\in[EFC(y),EFC(y)+\bar{A}]$, the derivative of the demand function is zero and the marginal revenue is not defined.

The effective marginal cost is given by

$$V'(k_j)+e_j+\frac{q_{\theta_j}}{q_{e_j}}(\theta_j-b).$$

The marginal cost is not a function of $r_j(b,y)$. If marginal revenue crosses marginal cost to the left of the kink then tuition is set by the upper part of the demand curve. This corresponds to a tuition of

$$t_j(b,y) = EMC_j(b,y)\left[\frac{\rho(1-r_j(b,y))}{\rho(1-r_j(b,y))+1}\right] + (y+\bar{A})\left[\frac{1}{\rho(1-r_j(b,y))+1}\right] \tag{A.8}$$

If marginal cost crosses between the discontinuous marginal revenue curves, then the optimal tuition is $EFC(y)+\bar{A}$. If marginal cost crosses marginal revenue to the right of the kink, then because of the discontinuous marginal revenue, there are two values that could be optimal. Either the tuition is set by the lower portion of the demand curve or the tuition is set to be $EFC(y)+\bar{A}$. The tuition at the lower part of the demand curve is equal to the tuition without any federal aid presented in Equation (3.3). The tuition that would maximize profit is chosen.

A.2 EQUILIBRIUM SOLUTION - RATING-BASED AID

A complexity arises in the maximization problem due to the fact that the rating constraint is a minimum function. If the solution to the maximization problem with the constraint:

$$\Upsilon_j = \frac{1}{k_j}\int\int \upsilon(q_j,t_j(b,y),b,y)\alpha_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy. \tag{A.9}$$

results in a rating, $\Upsilon_j^* < 1$ the minimum is irrelevant and this is the solution. In practice the student rating can always be chosen such that at the optimum $\Upsilon_j^* < 1$.

In the policy changes I implement, the rating is always less than 1 with the exception of the affordability-based rating. In affordability-based rating, the parameters chosen result in both public colleges having

$$\frac{1}{k_j}\int\int \upsilon(q_j,t_j(b,y),b,y)\alpha_j(b,y)r_j(b,y;T,Q)f(b,y)dbdy > 1.$$

However, under the affordability-based rating, the only way to affect the rating is for colleges to change their tuition, something that public colleges are constrained from doing. Under this scenario, independent of their actions the public colleges will always receive a rating of 1. Therefore, the problem can be solved by setting $\Upsilon_j = 1$.

Since the minimization is not relevant to my policy changes, In this section I present the solution to the optimization problem using the constraint in Equation A.9.[1]

A.2.1 Public Optimization

The derivation of Equation (3.4) follows a process similar to equation (3.1). Suppressing the j subscript the Lagrangian is:

$$\begin{aligned}
L = &\int\int o(q,b)\alpha(b,y)r(b,y)f(b,y)dbdy \\
&+\lambda\left[\int\int t(b,y)\alpha(b,y)r(b,y)f(b,y)dbdy - F - V(k) - ke + kz\right] \\
&+\eta\left[\theta k - \int\int b\alpha(b,y)r(b,y)f(b,y)dbdy\right] + \Omega\left[k - \int\int \alpha(b,y)r(b,y)f(b,y)dbdy\right] \\
&-\Psi\left[\Upsilon k - \int\int \upsilon(q,t(b,y),b,y)\alpha(b,y)r(b,y)f(b,y)dbdy\right]
\end{aligned}$$

[1]The more general case can be solved by first performing the maximization outlined here, then if the resulting solution has $\Upsilon_j^* > 1$ for any college j perform a further maximization with the additional constraint that $\Upsilon_j \leq 1$. The end result can then be obtained by comparing the realized objective function in the first maximization problem with the rating replaced with 1 to the realized objective function in the second maximization problem.

To obtain the admittance equation, take the derivative with respect to $\alpha(b,y)$ and divide this expression by λ. Use L_θ, L_e, and L_k to simplify this expression. From feasibility constraints, note $\alpha(b,y) > 0$ iff $L_{\alpha(b,y)} > 0$. Which yields:

$$\frac{o(q,b)}{\lambda} + t(b,y) + z \geq V'(k) + e + \frac{q_\theta}{q_e}(\theta - b) + \frac{\Psi}{\lambda}(\Upsilon - \upsilon(q,t(b,y),b,y)) \\ \iff \alpha(b,y) > 0 \tag{A.10}$$

A.2.2 Private Optimization

To obtain the updated tuition equation, again start with the Lagrangian. Suppressing the j subscript the Lagrangian is:

$$L = q + \lambda\left[\int\int t(b,y)r(b,y)f(b,y)dbdy - F - V(k) - ke + D\right] \\ +\eta\left[\theta k - \int\int br(b,y)f(b,y)dbdy\right] + \Omega\left[k - \int\int r(b,y)f(b,y)dbdy\right] \\ -\Psi\left[\Upsilon k - \int\int \upsilon(q,t(b,y),b,y)r(b,y)f(b,y)dbdy\right]$$

Then take the derivative with respect to the charged tuition. Use L_θ, L_e, and L_k to simplify this expression. Then due to kinked demand $\frac{\partial r(b,y;T,Q)}{\partial t(b,y)}$ has different expressions for different values of $t(b,y)$.

$$\frac{\partial r(b,y;T,Q)}{\partial t} = \begin{cases} -\frac{(1-\Upsilon^\kappa)\rho}{(y-t+\Upsilon^\kappa\tilde{A}(b,y))} r(b,y)(1-r(b,y)), & \text{if } EFC(y) < t < EFC + \tilde{A} \\ -\frac{\rho}{(y-t+\Upsilon^\kappa\tilde{A}(b,y))} r(b,y)(1-r(b,y)), & \text{otherwise} \end{cases} \tag{A.11}$$

Plugging this expression into the modified $L_{t(b,y)}$ yields:

If $EFC(y) < t < EFC + \bar{A}$

$$t(b,y) = (y + \Upsilon^{\kappa}\tilde{A}(b,y))\frac{\left(1 + \frac{\Psi}{\lambda}\frac{\partial \upsilon(q,t(b,y),b,y)}{\partial t(b,y)}\right)}{\left(1 + \frac{\Psi}{\lambda}\frac{\partial \upsilon(q,t(b,y),b,y)}{\partial t(b,y)}\right) + (1-\Upsilon^{\kappa})\rho_1(1-r(b,y))}$$
$$+ \left(V'(k) + e + \frac{q_\theta}{q_e}(\theta - b) + \frac{\Psi}{\lambda}(\Upsilon - \upsilon(q,t(b,y),b,y))\right)\frac{(1-\Upsilon^{\kappa})\rho_1(1-r(b,y))}{\left(1 + \frac{\Psi}{\lambda}\frac{\partial \upsilon(q,t(b,y),b,y)}{\partial t(b,y)}\right) + (1-\Upsilon^{\kappa})\rho_1(1-r(b,y))} \tag{A.12}$$

else

$$t(b,y) = \left(V'(k) + e + \frac{q_\theta}{q_e}(\theta - b) + \frac{\Psi}{\lambda}(\Upsilon - \upsilon(q,t(b,y),b,y))\right)\frac{\rho_1(1-r(b,y))}{\rho_1(1-r(b,y)) + \left(1 + \frac{\Psi}{\lambda}\frac{\partial \upsilon(q,t(b,y),b,y)}{\partial t(b,y)}\right)}$$
$$+(y + \Upsilon^{\kappa}\tilde{A}(b,y))\frac{\left(1 + \frac{\Psi}{\lambda}\frac{\partial \upsilon(q,t(b,y),b,y)}{\partial t(b,y)}\right)}{\rho_1(1-r(b,y)) + \left(1 + \frac{\Psi}{\lambda}\frac{\partial \upsilon(q,t(b,y),b,y)}{\partial t(b,y)}\right)} \tag{A.13}$$

The top equation gives the expression for the middle portion of the demand curve and the bottom equation gives the expression for the upper and lower portions of the demand curve. These equations give us the the marginal revenue.

The marginal revenue now has three pieces. These are equal to

$$t_j(b,y) + \frac{r_j(b,y)}{\frac{\partial r_j(b,y)}{\partial t_j(b,y)}} = \begin{cases} t_j(b,y) - \frac{y - t_j(b,y)}{\rho(1-r_j(b,y))}, & \text{if } t_j(b,y) < EFC(y) \\ t_j(b,y) - \frac{y - t_j(b,y) + \Upsilon_j^{\kappa}\tilde{A}_j(b,y)}{\rho(1-\Upsilon_j^{\kappa})(1-r_j(b,y))}, & \text{if } EFC(y) < t_j(b,y) < EFC(y) + \tilde{A} \\ t_j(b,y) - \frac{y - t_j(b,y) + \Upsilon_j^{\kappa}\tilde{A}}{\rho(1-r_j(b,y))}, & \text{if } t_j(b,y) \geq EFC(y) + \tilde{A} \end{cases}$$

The effective marginal cost is

$$EMC_j = V'(k_j) + e_j + \frac{q_{\theta_j}}{q_{e_j}}(\theta_j - b) + \frac{\Psi_j}{\lambda_j}(\Upsilon_j - \upsilon(q_j, t_j(b,y), b, y))$$

The marginal cost is equal to the baseline marginal cost plus a term that depends on the student's rating compared to the college's average rating. Once again the marginal cost is not a function of $r_j(b,y)$.

If marginal revenue crosses marginal cost to the left of the first discontinuity, then tuition is set by the upper part of the demand curve and tuition is equal to Equation (A.13) with $\tilde{A}(b,y) = \tilde{A}$. Note if $\frac{\partial v(q_j, t_j(b,y), b, y)}{\partial t_j(b,y)} = 0$ and $\Upsilon_j^{\kappa} = 1$, tuition is exactly the same as in the baseline scenario.

If marginal cost only crosses the second portion of the marginal revenue curve then tuition is set by the middle portion of the demand curve and tuition is equal to Equation (A.12).

If the curves don't cross at all and instead marginal cost is between the first discontinuity of the marginal revenue curve, then the optimal tuition is $EFC(y) + \tilde{A}$.

If marginal cost only crosses the third portion portion of the marginal revenue curve then tuition is set either by the bottom portion of the demand curve or it is set to be $EFC(y) + \tilde{A}$. The tuition level that maximizes profit is the one chosen. The tuition at the bottom portion of the curve and tuition is equal to Equation (A.13) with $\tilde{A}(b,y) = 0$.

Finally, if the marginal cost curve crosses both the second portion of the marginal revenue curve and the third portion of the marginal revenue curve then tuition is either set by the middle of the demand curve or by the bottom portion of the demand curve. Again the tuition that maximizes profit is the one chosen.

A.3 PRIVATE ONLY AFFORDABILITY RATING

The results of a private college only policy change are presented in Column 3 of Table A1. I change the parameters used in the affordability-based rating and apply this rating to only private colleges. This scenario results in a large reduction in average tuition since a budget neutral change that only affects private colleges attaches a stronger incentive to lowering tuition than the comparable policy that effects all colleges. The total reduction

Table A1: Alternative Rating Specifications

	(1) Baseline	(2) Affordability All Colleges	(3) Affordability Private Only
Average Completion Rate (Public)	50.92%	51.00%	50.81%
Average Completion Rate (Private)	73.00%	73.16%	72.96%
Average Price Cap	31.54	31.45	31.45
Average Private Tuition	27.92	27.30	26.96
Average Institutional Aid	3.62	4.15	4.49
Average State Tuition	8.82	8.87	8.87
Accessibility of Public Colleges*	40.11%	38.24%	37.88%
Accessibility of Private Colleges*	6.05%	11.04%	12.11%
Total Enrollment	42%	42%	42%
Share of Students in Public College	67%	68%	67%
Average Federal Aid (Public)	5.66	5.85	5.68
Average Federal Aid (Private)	6.66	6.66	6.86
Fraction Receiving Aid (Public)	51.21%	48.90%	48.65%
Fraction Receiving Aid (Private)	52.38%	54.52%	54.78%
Maximum Aid	7.25	12.50	12.50
Intensity		1.18	0.90
χ_1		2.066	2.485
χ_2		-0.0513	-0.07
Average Rating Public		1.00	-
Average Rating Private		0.67	0.60
Change in Average Student Cost (Public)		0.09	0.19
Change in Average Student Cost (Private)		-0.76	-1.23
State Tax Rate	2.61%	2.65%	2.64%
Federal Tax Rate	1.83%	1.83%	1.83%

*The accessibility of a college is measured by the percentage of the students who are below median income.

in average private tuition is $960. Further, under this scenario a further increase in overall private affordability occurs. However this change results in a slight decrease in completion rates for both types of colleges. In addition, private colleges enroll more low income students and public colleges enroll less low income students.

A.4 ADDITIONAL TABLES

Table A2: Completion Regression

	Probit Estimates	Marginal Effects	Marginal Effect Adjusted by Std Dev
Family Income	0.0014**	0.0005**	0.0407
	(0.0004)	(0.0001)	
Student Ability	0.4118**	0.1560**	0.0579
	(0.0877)	(0.0326)	
College Quality	0.3502**	0.1326**	0.0489
	(0.1187)	(0.0351)	
Constant	-2.4060**	n/a	
	(0.4174)		
N	1,927	1,927	

Standard errors clustered at the college level are in parenthesis, **p< .01 *p< .05

Table A3: Tuition

Income Decile	Ability Decile 1	2	3	4	5	6	7	8	9	10
	Worst Private College									
1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7.43
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	24.56	19.65	9.36
3	n/a	n/a	n/a	n/a	n/a	n/a	28.00	25.85	20.89	11.66
4	n/a	n/a	n/a	n/a	n/a	n/a	28.00	26.83	22.21	13.65
5	n/a	n/a	n/a	n/a	n/a	n/a	28.00	27.60	23.43	15.68
6	n/a	n/a	n/a	n/a	n/a	n/a	28.00	27.95	24.85	18.18
7	n/a	n/a	n/a	n/a	n/a	n/a	28.00	28.00	26.40	21.14
8	n/a	n/a	n/a	n/a	n/a	n/a	28.00	28.00	27.67	24.36
9	n/a	n/a	n/a	n/a	n/a	n/a	28.00	28.00	28.00	22.02
10	n/a	n/a	n/a	n/a	n/a	n/a	28.00	28.00	28.00	25.13
	Best Private College									
1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7.47
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7.84
3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	34.20	8.76
4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	35.40	12.96
5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	35.93	16.91
6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	36.00	21.55
7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	36.00	25.99
8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	36.00	31.04
9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	36.00	33.59
10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	36.00	34.55

Table A4: College Attendance Proportions

		Ability Deciles									
		1	2	3	4	5	6	7	8	9	10
		State Colleges									
Income Deciles	1	0	0	0	0	0	0.051	0.072	0.074	0.090	0.091
	2	0	0	0	0	0	0.400	0.510	0.535	0.556	0.527
	3	0	0	0	0	0.146	0.614	0.669	0.684	0.704	0.577
	4	0	0	0	0	0.355	0.704	0.715	0.729	0.740	0.518
	5	0	0	0	0	0.374	0.653	0.668	0.677	0.655	0.331
	6	0	0	0	0.127	0.532	0.540	0.555	0.523	0.455	0.171
	7	0	0	0	0.178	0.519	0.531	0.542	0.396	0.313	0.109
	8	0	0	0.007	0.429	0.619	0.631	0.642	0.329	0.249	0.126
	9	0	0	0.103	0.702	0.713	0.723	0.731	0.350	0.252	0.140
	10	0	0.004	0.431	0.809	0.821	0.830	0.831	0.198	0.128	0.070
		Private Colleges									
	1	0	0	0	0	0	0	0	0	0	0.087
	2	0	0	0	0	0	0	0	0	0	0.103
	3	0	0	0	0	0	0	0	0	0	0.206
	4	0	0	0	0	0	0	0	0	0.008	0.326
	5	0	0	0	0	0	0	0	0.009	0.062	0.545
	6	0	0	0	0	0	0	0.001	0.085	0.234	0.727
	7	0	0	0	0	0	0	0.003	0.291	0.461	0.824
	8	0	0	0	0	0	0	0.007	0.500	0.633	0.824
	9	0	0	0	0	0	0	0.007	0.530	0.670	0.822
	10	0	0	0	0	0	0	0.009	0.764	0.849	0.919
		Best Quality Private									
	1	0	0	0	0	0	0	0	0	0	0.005
	2	0	0	0	0	0	0	0	0	0	0.003
	3	0	0	0	0	0	0	0	0	0	0.011
	4	0	0	0	0	0	0	0	0	0	0.012
	5	0	0	0	0	0	0	0	0	0	0.032
	6	0	0	0	0	0	0	0	0	0.002	0.061
	7	0	0	0	0	0	0	0	0	0.011	0.120
	8	0	0	0	0	0	0	0	0	0.032	0.204
	9	0	0	0	0	0	0	0	0	0.069	0.232
	10	0	0	0	0	0	0	0	0	0.078	0.307

Table A5: Effect of Maximum Aid Change

	20% lower aid	10% lower aid	Baseline	10% higher aid	20% higher aid
	Attendance-Based Aid				
Average Federal Aid (Public)	4.78	5.27	5.66	5.85	5.86
Average Federal Aid (Private)	5.41	6.04	6.66	7.27	7.88
Fraction Receiving Aid (Public)	48.25%	50.03%	51.21%	51.51%	51.33%
Fraction Receiving Aid (Private)	49.99%	51.25%	52.38%	53.36%	54.44%
State Tuition Average	8.91	8.86	8.82	8.82	8.82
Private Tuition Average	27.68	27.81	27.92	28.02	28.12
Change in Average Student Cost (Public)	0.68	0.30	-	(0.11)	(0.11)
Change in Average Student Cost (Private)	0.55	0.29	-	(0.29)	(0.60)
Total Enrollment	40.36%	41.35%	42.10%	42.45%	42.62%
Maximum Aid	5.80	6.53	7.25	7.98	8.70
Tax Rates (State/Federal)	2.46% / 1.38%	2.54% / 1.62%	2.61% / 1.83%	2.63% / 1.97%	2.65% / 2.05%
	Outcome Rating				
Average Federal Aid (Public)	4.35	4.35	4.35	4.35	4.35
Average Federal Aid (Private)	8.22	9.13	10.02	10.91	11.78
Fraction Receiving Aid (Public)	44.86%	44.30%	43.84%	43.28%	42.75%
Fraction Receiving Aid (Private)	56.56%	58.14%	59.41%	60.48%	61.38%
State Tuition Average	8.98	8.99	9.00	9.01	9.02
Private Tuition Average	28.66	28.86	29.01	29.14	29.28
Change in Average Student Cost (Public)	(0.06)	(0.03)	-	0.03	0.07
Change in Average Student Cost (Private)	0.96	0.49	-	(0.52)	(1.01)
Total Enrollment	39.03%	39.24%	39.43%	39.59%	39.71%
Maximum Aid	10.00	11.25	12.50	13.75	15.00
Tax Rates (State/Federal)	2.36% / 1.58%	2.37% / 1.71%	2.38% / 1.83%	2.39% / 1.96%	2.4% / 2.08%

Table A6: Effect of Maximum Aid Change

	20% lower aid	10% lower aid	Baseline	10% higher aid	20% higher aid
Average Federal Aid (Public)	5.84	5.85	5.85	5.86	5.86
Average Federal Aid (Private)	5.43	6.03	6.66	7.23	7.58
Fraction Receiving Aid (Public)	49.80%	49.41%	48.90%	48.52%	48.56%
Fraction Receiving Aid (Private)	52.52%	53.40%	54.52%	55.06%	54.98%
State Tuition Average	8.86	8.86	8.87	8.88	8.88
Private Tuition Average	27.50	27.42	27.30	27.22	27.27
Change in Average Student Cost (Public)	(0.06)	(0.04)	-	0.03	0.02
Change in Average Student Cost (Private)	0.98	0.53	-	(0.44)	(0.57)
Total Enrollment	41.81%	41.90%	42.05%	42.15%	42.28%
Maximum Aid	10.00	11.25	12.50	13.75	15.00
Tax Rates (State/Federal)	2.64% / 1.7%	2.64% / 1.76%	2.65% / 1.83%	2.66% / 1.9%	2.66% / 1.94%
			Access Rating		
Average Federal Aid (Public)	5.30	5.28	5.23	5.16	5.17
Average Federal Aid (Private)	5.25	5.97	6.82	7.82	8.52
Fraction Receiving Aid (Public)	55.28%	54.37%	53.40%	51.78%	51.67%
Fraction Receiving Aid (Private)	52.93%	54.94%	57.01%	59.69%	60.65%
State Tuition Average	8.74	8.76	8.78	8.82	8.82
Private Tuition Average	28.46	28.44	28.42	28.32	28.35
Change in Average Student Cost (Public)	(0.17)	(0.10)	-	0.15	0.15
Change in Average Student Cost (Private)	1.15	0.62	-	(0.88)	(1.34)
Total Enrollment	41.12%	41.29%	41.50%	41.67%	41.95%
Maximum Aid	10.00	11.25	12.50	13.75	15.00
Tax Rates (State/Federal)	2.59% / 1.66%	2.6% / 1.74%	2.6% / 1.83%	2.6% / 1.94%	2.59% / 2.06%

APPENDIX B

ALLOCATING FUNDING BETWEEN DIFFERENT LEVELS OF EDUCATION

B.1 ATTENDANCE RATE PROCEDURE

1. Determine the maximum number of agents who can afford to attend college, $A(\tau)$. When making this determination use that fact that if a lower income level can afford to attend college then a higher income level also can afford to attend college. Label the agents who could afford college potential attendees.

2. Check if all of the potential attendees who can afford college satisfy the return constraint. If this is true then $N(\tau) = A(\tau)$, else proceed to step 3.

3. If there are some income groups who do not satisfy the return constraint, remove some of the lowest income agents from the group of potential attendees until all remaining attendees satisfy the return constraint. The proportion of agents that remains is then equal to the attendance rate.

To determine $A(\tau)$ solve the following problem

$$\begin{aligned} &\max && i \\ &\text{s.t.} && (1-\theta)y_i - E + \tfrac{\tau\theta\mu}{(\sum_{j<i}\lambda_j)} > 0 \end{aligned}$$

Given this i find the greatest p_i such that

$$(1-\theta)y_i - E + \frac{\tau\theta\mu}{(\sum_{j<i}\lambda_j) + p_i\lambda_i} \geq 0$$

It follows that $A(\tau) = \sum_{k<i}\lambda_k + \lambda_i p_i$. The potential attendees are all agents of type k with $k < i$ and p_i percent of agents of type i.

To remove potential attendees who could afford college, but do not find college beneficial follow the following procedure. By Assumption 9, if college is not beneficial for some of the income groups who can afford it, the lowest income level who can afford college does not find college beneficial. Denote this income group l. The following inequality must hold

$$H(\sigma, y_l, 1) - H(\sigma, y_l, 0) < E - \frac{\tau\theta\mu}{A(\tau)}$$

To determine if any portion of group l may find college beneficial, first check if college would be beneficial to agents of type l if no other agents of type l attended college. If this is true the following inequality would hold:

$$H(\sigma, y_l, 1) - H(\sigma, y_l, 0) > E - \frac{\tau\theta\mu}{A(\tau) - p_l\lambda_l}.$$

If this inequality is true, there exists some attendance level for group l such that the return to college is exactly equal to the cost of college. Denote this level as p_l'. Attendance is given by $N(\tau) = \lambda_1\rho_1 + \lambda_2\rho_2 + \lambda_3\rho_3$ where $\rho_l = p_l'$, $\rho_j = 1 \forall j < i$, $\rho_k = 0\ \forall k > l$. However, if

$$H(\sigma, y_l, 1) - H(\sigma, y_l, 0) < E - \frac{\tau\theta\mu}{A(\tau) - p_l\lambda_l}$$

then even if all of group l did not go to college, the cost of college would still be higher than the return of college for anyone in group l. Therefore, attending college will never be beneficial for group l.

We now look at the second lowest income group $l-1$ who can afford college and if college is beneficial for this group when all income groups below it do not attend. If it is, then attendance is given by $N(\tau) = \lambda_1\rho_1 + \lambda_2\rho_2 + \lambda_3\rho_3$ where $\rho_l = 0$, $\rho_j = 1 \forall j < l$, $\rho_k = 0\ \forall k > l$. If college isn't beneficial for group $l-1$ when all of the members of group $l-1$ attend college then repeat the procedure applied to group l.

Eventually there will be some fraction of agents who will find college beneficial. This follows from that fact that agents are atomless. This guarantees that for any value of $H(\sigma, y_1, 1) - H(\sigma, y_1, 0)$ there exists an attendance ρ_1 small enough such that

$$H(\sigma, y_1, 1) - H(\sigma, y_1, 0) > E - \frac{\tau\theta\mu}{\rho_1\lambda_1}.$$

B.2 PROPOSITION 1 PROOF

The utility of an agent of group i can be written as

$$U_i(\tau) = (1-\theta)y_i + H((1-\tau)\theta\mu, y_i, 0) + \\ \rho_i\left[\frac{\tau\theta\mu}{N(\tau)} - E + H((1-\tau)\theta\mu, y_i, 1) - H((1-\tau)\theta\mu, y_i, 0)\right]$$

The derivative of the utility with respect to τ yields

$$H_\tau((1-\tau)\theta\mu, y_i, 0) + \rho_i\left(\frac{\theta\mu}{N(\tau)} - \frac{\tau\mu\theta N_\tau}{N(\tau)^2} + H_\tau((1-\tau)\theta\mu, y_i, 1) - H_\tau((1-\tau)\theta\mu, y_i 0)\right) \\ + \left[\frac{\tau\theta\mu}{N(\tau)} - E + H((1-\tau)\theta\mu, y_i, 1) - H((1-\tau)\theta\mu, y_i, 0)\right]\rho_{i\tau}$$

Now for various values of τ this expression can be evaluated to determine how utility responds to changes in tax allocation.

I examine how utility changes in each of the following four exhaustive ranges of possible tax allocations.

1. **Tax allocations where income group i can not yet afford college and college would be beneficial for all agents ($\tau < \hat{\tau}_i$ & $\tau < \tau_n(y_3)$)**

In this subset of allocations, no one from group i attends college. This means $\rho_i = 0$. Further, a marginal increase in τ will not be enough to allow anyone from group i to attend college. It follows that the derivative of utility is equal to

$$H_\tau((1-\tau)\theta\mu, y_i, 0) < 0.$$

In this range, an increase in the college subsidy lowers the human capital received by group i from lower school and decreases group i's overall utility.

2. **Tax allocations where all of income group i can afford college and college would be beneficial for all agents ($\tau \geq \overline{\tau}_i$ & $\tau < \tau_n(y_3)$)**

In this subset of allocations all members of income group i are able to afford college and benefit from college. Therefore, $\rho_i = 1$. Further, any increase in τ will not raise or lower the number of students in group i attending college. If follows that the increase in utility in this range is:

$$H_\tau((1-\tau)\theta\mu, y_i, 1) + \frac{\theta\mu}{N(\tau)} - \frac{\tau\mu\theta N_\tau}{N(\tau)^2}$$

The sign of this expression is dependent on whether the income groups below i are partially enrolled in college or not. If any other income group below i is partially enrolled in college, i.e. $0 < \rho_j < 1 \forall\ j > i$, then it must be the case that group j must spend all of there income to attend college at tax allocation τ. If more of group j were to try to attend college, the per person subsidy would drop to a level where no member of group j can afford to attend college. Therefore, any increase in this tax allocation will be used to provide additional subsidies to members of group j. In other words, in response to an education fund allocation increase the subsidy amount will not increase only the number of subsidies provided will increase. Mathematically, this means that

$$\frac{\theta\mu}{N(\tau)} = \frac{\tau\mu\theta N_\tau}{N(\tau)^2}.$$

Therefore, if any lower income group is partially enrolled, an increase in τ will change income group i's utility by

$$H_\tau((1-\tau)\theta\mu, y_i, 1) < 0.$$

However, if no other lower income groups are partially enrolled in college then an increase in τ will not change enrollment($N_\tau = 0$). The change in utility is then equal to

$$H_\tau((1-\tau)\theta\mu, y_i, 1) + \frac{\theta\mu}{N(\tau)}.$$

This term is the sum of the decrease in higher education return plus the increase in subsidy. Note $H_\tau((1-\tau)\theta\mu, y_i, 1)$ is negative and decreasing in τ while $\frac{\theta\mu}{N(\tau)}$ is positive and decreasing in τ. Recall $\tau_r(y_i)$ is the first τ such that

$$-H_\tau((1-\tau_r)\theta\mu, y_i, 1) = \frac{\theta\mu}{N(\tau_r)}$$

It can be shown that for every tax allocation $\tau \in (\tau_r(y_i), \tau_n(y_i))$,

$$-H_\tau((1-\tau)\theta\mu, y_i, 1) > \frac{\theta\mu}{N(\tau)}.$$

Then for any $\tau > \tau_r(y_i)$, utility is decreasing in τ. For any $\tau < \tau_r(y_i)$, utility of group i is increasing in τ if $\tau > \overline{\tau}_i$ with τ not in between $\hat{\tau}_j$ and $\overline{\tau}_j, \forall j > i$.

3. **Tax allocations where some of income group i can afford college and college would be beneficial for all agents ($\hat{\tau}_i \leq \tau < \overline{\tau}_i$ & $\tau < \tau_n(y_3)$)**

In the third subset of allocations when $\hat{\tau}_i \leq \tau < \overline{\tau}_i$, members of group i are partially enrolled in college ($0 < \rho_i < 1$). The change in utility from changing τ is:

$$H_\tau((1-\tau)\theta\mu, y_i, 0) + \rho_i \left(\frac{\theta\mu}{N(\tau)} - \frac{\tau\mu\theta N_\tau}{N(\tau)^2} + H_\tau((1-\tau)\theta\mu, y_i, 1) - H_\tau((1-\tau)\theta\mu, y_i, 0) \right)$$
$$+ \left[\frac{\tau\theta\mu}{N(\tau)} - E + H((1-\tau)\theta\mu, y_i, 1) - H((1-\tau)\theta\mu, y_i 0) \right] \rho_{i\tau}$$

Increasing τ in this range simply increases access to members of group i. Therefore, $\frac{\theta\mu}{N(\tau)} = \frac{\tau\mu\theta N_\tau}{N(\tau)^2}$ which simplifies the above equation to

$$(1-\rho_i)H_\tau((1-\tau)\theta\mu, y_i, 0) + \rho_i H_\tau((1-\tau)\theta\mu, y_i, 1)$$
$$+ \left[\frac{\tau\theta\mu}{N(\tau)} - E + H((1-\tau)\theta\mu, y_i, 1) - H((1-\tau)\theta\mu, y_i, 0) \right] \rho_{i\tau}$$

In this range utility increases if the benefit from granting access to more individuals is greater than the decrease in human capital of those attending lower education plus the decrease in return for those attending higher education. The decrease in human capital is increasing in τ and the increase in utility from more access is decreasing in τ. Therefore, if this ever occurs at $\tau \in [\hat{\tau}_i, \overline{\tau}_i)$ it also occurs at $\forall \tau'$ s.t. $\tau < \tau' < \overline{\tau}_i$. Let the smallest τ where the above equation is equal to 0 be called $\tau_e(y_i)$. This value of τ may or may not exist depending on the specific parameters and the human capital function. If it does occur, utility is increasing from $\hat{\tau}_i$ until $\tau_e(y_i)$ then decreasing from $\tau_e(y_i)$ until $\overline{\tau}_i$.

4. **Tax allocations where college is not beneficial for all agents($\tau > \tau_n(y_3)$)**

To analyze how utility changes in this range, it is useful to talk about each specific income group. First consider income group 3. As discussed in Section 4.3, for τ slightly above $\tau_n(y_3)$ members of income group 3 begin to drop out of school. They drop out until the point where the return to college is exactly equal to the cost. In other words increasing τ changes utility for group 3 by

$$(1-\rho_3)H_\tau((1-\tau)\theta\mu, y_3, 0) + \rho_3 H_\tau((1-\tau)\theta\mu, y_3, 1) < 0$$

Therefore, the change in overall utility is negative. Once τ increases to levels where even if all of group 3 didn't go to college, the cost of college would still be higher than the return of college for anyone in group 3, then no one from group 3 attends college and increases in τ do not change attendance for group 3. The change in utility is then

$$H_\tau((1-\tau)\theta\mu, y_3, 0) < 0$$

Next consider the utility of income group 2. First consider $\tau_n(\tau_2) > \tau > \tau_n(y_3)$, in this range students from group 3 are potentially dropping out. However, group 2 is not changing attendance decisions. The increase in utility is

$$H_\tau((1-\tau)\theta\mu, y_2, 0) + \left(\frac{\theta\mu}{N(\tau)} - \frac{\tau\mu\theta N_\tau}{N(\tau)^2} + H_\tau((1-\tau)\theta\mu, y_2, 1) - H_\tau((1-\tau)\theta\mu, y_2, 0)\right)$$

When group 3 begin to drop out, before all of group 3 has dropped out of college,

$$\frac{\tau\mu\theta N_\tau}{N(\tau)^2} - \frac{\theta\mu}{N(\tau)} = H_\tau((1-\tau)\theta\mu, y_3, 1) - H_\tau((1-\tau)\theta\mu, y_3, 0)$$

therefore the change in utility for group 2 can be written as

$$(H_\tau((1-\tau)\theta\mu, y_3, 1) - H_\tau((1-\tau)\theta\mu, y_3, 0) + H_\tau((1-\tau)\theta\mu, y_2, 1)) < 0$$

The sum of these first two terms is less than zero and the third term is less than zero, therefore utility is decreasing when only a fraction of group 3 remains in college. When none of group 3 remains in college the derivative is

$$H_\tau((1-\tau)\theta\mu, y_2, 1) + \frac{\theta\mu}{N(\tau)}$$

as stated this is negative after $\tau_r(y_2)$. For $\tau > \tau_n(\tau_2)$ the utility change will always be negative, the logic follows the same logic as in the case of group 3. Therefore, utility for group 2 is always decreasing after $\tau_n(y_3)$. Similarly the change in utility for group 1, will be negative if $\tau > \tau_r(y_3)$.