Why do federal loans crowd out the private market?
Evidence from graduate PLUS loans *

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Abstract

I investigate why federal student loans crowd out the private market by exploiting the introduction of graduate PLUS loans, which relaxed the federal borrowing limit on graduate students. Access to PLUS loans led students to replace private with PLUS loans almost one-for-one, but did not increase borrowing. This suggests that students did not face credit rationing in the absence of PLUS loans. I use credit data from Equifax Inc. to compare private to federal loans. Previous research has been unable to make these comparisons due to a lack of private loan and credit file information. I find that most graduate students could receive private loans with an interest rate below the federal rates. This amounts to the average health student paying an extra $13,000 over ten years. Federal and private loans also differ in that federal loans offer income-based repayment (IBR). I model the expected utilities from federal and private loans and find that IBR rationalizes the decision to have higher interest federal loans for most borrowers by functioning as insurance against low future wages. The value of IBR varies by program of study with health students benefiting most.

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1 Introduction

The total amount outstanding in federal loans has more than doubled over the past 9 years, from $516 billion in 2007 to $1.262 trillion in September 2016. This increase is due to a number of factors including rising college costs, increased enrollment and changes in federal student loan policy. One such policy change was the introduction of graduate PLUS loans in 2006, which relaxed the federal borrowing limit on graduate student borrowers. Prior to the change, graduate students whose needs surpassed these limits would resort to private loans. After, students could borrow any amount up to the total cost of attendance through the government.\(^1\) The introduction of the graduate PLUS program provides a unique opportunity to study the government’s role in the graduate student loan market and to compare federal to private loans.

One economic rationale behind federal loan programs is to solve a market failure in which private markets do not allocate credit efficiently. Due to information asymmetries, and the fact that human capital cannot be collateralized, lenders see students as risky investments (Mankiw, 1986). The federal government is able to directly address this issue given its access to tax returns and refunds, as well as its ability to garnish wages. Thus, access to PLUS loans may enable some students to borrow more at a lower cost. The extent to which there exists credit rationing for graduate students in the absence of federal loans is unclear. Graduate students are generally less risky and only 6% of students borrowing graduate loans are expected to default, compared to 24% of students borrowing undergraduate loans.\(^2\) Moreover, lenders have more information about these borrowers since they have already attained a degree and have a longer credit history.

I use nationally representative survey data on graduate students to explore whether graduate students faced credit rationing in the absence of PLUS loans and to study how federal loans crowd out the private market.\(^3\) My findings indicate that borrowing above the annual limit did not increase after the introduction of PLUS loans. This suggests that the introduction of PLUS loans did not address a pre-existing market failure in which students lacked access to credit. Instead, the federal expansion crowds out the private market for student loans and graduate students forgo private loans for PLUS loans almost one-for-one. Using a difference-in-difference framework I demonstrate that these changes in borrowing can be explained by the introduction of PLUS loans, and not other changes, by comparing graduate to undergraduate borrowing.

I next use anonymized credit data from Equifax Inc. on borrowers after the introduction of PLUS loans to investigate whether the shift away from private loans can be rationalized, given the

\(^1\) For example, in 2012 the average law student could borrow up to $53,000 in federal loans. Absent the policy change the same student would only be able to borrow $20,500 in federal loans.

\(^2\) Budget of the United States Government, Fiscal Year 2017

\(^3\) I also consider the effects on tuition and enrollment in Appendix D.
private loans available to graduate students. When comparing the two types of loans I consider the difference in interest rates and repayment options available with private and federal loans. While the survey data includes some private loan data, it lacks important information such as the interest rates associated with private loans, the cumulative amount borrowed, and credit report characteristics. The absence of this information makes it difficult to compare federal to private loans, thus previous research has been unable to make these comparisons. Credit data is necessary to understand students’ decisions.

The fact that students forego private loans for PLUS loans could be rationalized if graduate borrowers are risky and face high interest rates in the private market. This would result in a substantial amount of sorting by risk, or credit score, into private or federal loans. I find that there is some adverse selection into federal loans, but there is very little among those who borrow the most.\footnote{In fact, the Congressional Budget Office reports from 2015 estimate a profit of 24\% on Graduate PLUS loans and a profit of 18\% on graduate Stafford loans. This is much higher than the estimated profit on undergraduate loans.} I leverage the credit data to show that more than 30\% of graduate loan borrowers could have received private loans with lower interest rates than any federal rate, and over 60\% could have received a rate below the PLUS rate. Students pay $4,000 more on average over a ten year repayment period; those in health programs, such as physicians, pay an even higher difference of $13,000 on average. In a static setting, based on interest rates alone, it looks as though these students may be biased toward federal loans, similar to the default bias that has been documented when individuals choose retirement plans.\footnote{See Madrian and Shea (2001) and Duflo and Saez (2001).}

To fully understand students' borrowing decisions it is essential to consider the repayment options available with federal loans, namely income-based repayment (IBR). IBR offers insurance against future wage uncertainty or income shocks by allowing students to pay a maximum of 10-15\% of their income toward their loans. This enables borrowers to make payments that are below the standard 10-year amount and to defer large payments to later years if income increases.

I model the expected utility from having private and federal loans and estimate parameters of relative risk aversion consistent with borrowing federal loans. I model uncertainty over future wages by estimating different wage states using the American Community Survey. My results indicate that IBR can rationalize the decision to borrow more expensive federal loans. This suggests that the primary market failure for graduate student borrowers was not a lack of credit, but rather a lack of insurance against low wages post-graduation. The value of IBR varies by program of study, with health students benefiting most. Absent PLUS loans, students were forced to use the standard repayment plans offered by private lenders which lacked valuable insurance and consumption-smoothing features. The government, given its informational advantage through
access to tax returns, can remedy this by offering income-based repayment plans. For non-medical students who have private information on future earnings and expect to earn above the median, as may be the case among students in more prestigious programs, IBR cannot rationalize this decision to take out expensive federal loans.

This paper highlights that student loans cannot be adequately summarized by one feature; interest rates must be considered along with the repayment plans available. Finkelstein and Porterba (2002) document a similar finding in annuity markets. Many graduate students, particularly health students, borrow over $30,000 each year and are very likely to qualify for income-based repayment in the future. The income-based repayment option enables them to make lower payments each year and rationalizes borrowing federal loans despite the higher interest rates.

This paper is unique in its ability to compare federal to private loans for graduate students. This is one of the first papers, to my knowledge, to use such detailed credit data to make these comparisons. I use both survey and administrative data to comprehensively compare the federal and private loan options. By studying this decision, this paper contributes to the literature on household decisions and financial literacy. The literature generally finds that “mistakes” tend to be made among lower educated, young or old individuals and shows that individuals can exhibit biases when making financial decisions. I find that graduate students, a young, highly-educated group, seem to make good financial decisions more consistent with the findings of Agarwal et al. (2015). These graduate students may be very sophisticated in their financial planning by considering their wage dynamics post-graduation. Closest to this paper is Field (2009) who documents sensitivity in career choice among law students in response to financial aid packages, indicating that students consider their loans when making occupational decisions.

Second, I add to the literature on information asymmetries and the government’s role in credit markets. Many indicate that one primary market failure for students is credit rationing in the absence of federal intervention, preventing some students from pursuing an education. I show that this is not the case for graduate students but that there is value in income-based repayment. These results are consistent with the student loan contracts literature, and the literature that considers optimal taxation in relation to education loans, which emphasizes the importance of

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7 See Lusardi et al. (2010), Lusardi (2008), Lusardi and Tufano (2009), Hastings and Mitchell (2011), and Agarwal et al. (2009).
9 See Porterba (2002b), Mankiw (1986), and Dymarski (2014) for discussions on federal involvement in student loan markets. Solis (2015) and Gurgand et al. (2011) show how providing loans enables students to pursue an education while Stinebrickner and Stinebrickner (2008) directly asks undergraduates whether they are borrowing constrained.
10 Enrollment into graduate programs changes very little after the introduction of PLUS loans. See Appendix D.5.
income-contingent loans and loan forgiveness. I also use the introduction of PLUS loans to estimate the extent to which federal student loans crowd out the private market. Due to the longevity of the federal loan program, and few large changes in the availability of credit, this crowd out has not been previously documented.

In 2012, graduate students made up only 15% of enrolled students but borrowed 35% of student loans. While there is a large and growing literature on credit constraints and human capital investments, few have focused graduate students decisions'. By studying graduate students I shed light on a small group of students that borrow a disproportionately large amount in loans.

The following section summarizes graduate student loans. Section 3 describes the data. Section 4 documents changes in the use of private loans and Section 5 tests for adverse selection into federal loans. Section 6 uses credit data to compare federal loan borrowers to private loan borrowers and contains the main results of this paper. First, this section shows that a large number of students could have received more favorable rates in the private student loan market. Next in section 6.2 I use a simple model to estimate parameters of risk aversion that are consistent with students’ borrowing decisions. Finally, Section 7 concludes.

## 2 Graduate Student Loan Market

### 2.1 Stafford Loans

Before taking out PLUS loans, students borrow through the Stafford program which has always been available. Students who would like any federal student loan or grant must fill out the Free Application for Federal Student Aid (FAFSA) but no credit check is required. Stafford loans may be subsidized or unsubsidized. Eligible students take out subsidized Stafford loans first since they do not accrue interest while students are enrolled. From 2006 - 2013 interest rates on all Stafford loans were fixed at 6.8%, though they have changed in recent years.

Table 1 summarizes the annual and cumulative limits on Stafford borrowing. Eligibility for

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**References**


14. Some articles have highlighted the possible benefits of IBR, and PLUS loans, to graduate students (Schrag (2007), Delisle and Holt (2015), and Delisle (2013)).

15. Students also have access to Perkins loans which I do not study.

16. Since 2014 Stafford rates depend on the 10-year treasury bond when students borrow. For example, graduate students received an interest rate of 5.41% on Stafford loans borrowed in 2014. All federal loans have an origination and default fee which is a percentage of the amount borrowed.
subsidized Stafford loans depends on students’ “need” calculated from the FAFSA.\footnote{The FAFSA is used to calculate each student’s expected family contribution, the estimated amount that students can contribute to their education, and each student’s estimated financial assistance. Finally, student “need” is determined by subtracting these amounts from the cost of attendance, which includes tuition, fees, books, personal expenses, room and board.} Prior to July 2012, the maximum a graduate student could borrow in subsidized Stafford loans was $8,500. Starting in July 2012 graduate students no longer had access to subsidized Stafford loans. Graduate students are limited to taking out a cumulative amount of $65,500 in subsidized Stafford, including those from their undergraduate education. Limits on total Stafford loans vary according to degree program, and students in Health programs are allowed to borrow more. In general, students who borrowed before July 2007 faced an annual limit of $18,500 with a cumulative limit of $138,500 in all Stafford loans. The annual and cumulative limits then increased to $20,500 and $158,500, respectively. In Table 1, students in Health A programs includes those in Doctor of Allopathic Medicine, Osteopathic Medicine, Dentistry, Veterinary Medicine, Optometry, and Podiatry programs. Students pursuing a Doctor of Pharmacy, Chiropractic, Clinical Psychology or a degree in public health or health administration are categorized as Health B. Stafford limits are highest for those in Health A programs. Prior to July 2007 these students were able to take out $38,500 each year and faced a cumulative limit of $189,125. The annual limit for those in Health B programs was $31,000. In July 2007 the annual limits increased by $2,000 and the cumulative limit for all health students increased to $224,000.

2.2 Graduate PLUS Loans

Beginning in July 2006, the Deficit Reduction Act of 2005 expanded the Parent Loan for Undergraduate Student (PLUS) program to include graduate and professional students. Borrowers in the PLUS program face few limitations. The borrowing limit is determined by the cost of attendance (COA), which includes tuition, fees, books, personal expenses, room and board, and amounts taken out in other federal loans. Students are not allowed to take out more than the COA in federal aid, including loans and grants.

The introduction of graduate PLUS loans allowed students to borrow up to their COA from the government. Unlike the Stafford program, PLUS borrowers are subject to a basic credit check. Students who are at least 90 days delinquent on a debt payment or have defaulted on a loan in the past five years are ineligible for PLUS loans. Those who have experienced foreclosure, repossession, wage garnishment or other repercussions related to defaulting on debt are also unable to borrow PLUS loans.\footnote{See 34 C.F.R. 682.201(c)(2)(ii) and 685.200(c)(2)(vii). Adverse credit history includes subjects of foreclosure, repossession, wage garnishment, etc. In general, borrowers must not have an adverse credit history. The definition} Ineligible students may acquire PLUS loans with an eligible cosigner.
When first available, graduate PLUS loans borrowed through the Federal Family Education Loan Program (FFELP) had a fixed interest rate of 8.5% and those taken out through the Direct Loan Program (DLP) had a fixed interest rate of 7.9%. Universities determined the program through which loans are borrowed. Since the FFELP was closed in 2010, students could only acquire PLUS loans through the DLP at a rate of 7.9%. More recently, the interest rates on graduate PLUS loans have changed, for example in 2014 the interest rate was 6.41%.

2.3 Private Loans

Graduate students may also borrow from private lenders. Before 2006, graduate students who needed to borrow beyond the Stafford limit had to resort to private lenders, who consider the student’s credit history when determining the terms of a loan. Students may apply with a cosigner to improve their loan terms. Cosigners function as collateral and can often be family members.

A 2012 report by the Consumer Finance Protection Bureau describes the underwriting criteria and private loan market for a sample of 9 private lenders from 2005 to 2011. Generally, private interest rates track the LIBOR or PRIME rates. A student’s credit score, or that of their cosigner, determines the margin charged above the LIBOR or PRIME rate.

Figure 1, from the Consumer Finance Protection Bureau’s Private Student Loan Report, depicts the interest rates of private loans by academic year and student type. The top horizontal line depicts the PLUS interest rate of 7.9% and the bottom line depicts the Stafford rate of 6.8%. The figure highlights that there is an advantage to borrowing private loans over PLUS loans for many students. In 2012, for example, 75% of law students who borrowed a private loan received an interest rate that was at most the PLUS rate. This figure raises the question of whether there are students who did not take out private loans and could have received lower rates on the private market.

2.4 Repayment Plans

Private and federal loans also differ in the repayment options available to borrowers. Private loans have limited repayment options. Most require fixed payments for 10 or 15 years, though students may choose other lengths. Federal loans, on the other hand, offer a number of repayment options. The income-driven repayment plans available with federal loans can be particularly beneficial to borrowers. The most recent statistics on the use of income-driven repayment plans come from a 2015 report by the Government Accountability Office focusing on students in repayment in

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19 DLP loans are directly lent from the federal government. FFELP loans are guaranteed by the government but originate from private lenders.

20 Sometimes borrowers pay an origination fee.
September 2014. The report indicates that 19% of borrowers enrolled in an income-driven repayment plan, a majority of whom enroll in income-based repayment (IBR).\textsuperscript{21} Approximately 27% of graduate student borrowers enrolled in an income-driven repayment plan.\textsuperscript{22} Students from a range of graduate schools utilize the income-driven repayment options. For example, among students who entered repayment in 2011, Stanford University and California State - Monterey Bay both had 20% of graduate student borrowers enrolled in such a program in 2014.\textsuperscript{23}

I focus on IBR, since it is the most popular income-driven repayment plan. For those who enroll, IBR reduces monthly payments to 15% of the borrower’s income above 150% of the federal poverty line (FPL), provided that this is less than the payment for a standard 10-year plan.\textsuperscript{24} Students are never expected to pay more than the standard 10-year payment amount. Interest continues to accrue while in IBR and any amount remaining after 25 years is forgiven. The forgiven balance will be treated as income and taxed accordingly.

Figure 2 depicts an example of IBR in the case of a $50,000 loan with an interest rate of 7%. This is the 75th percentile of cumulative loans borrowed by second year masters students in 2012. The interest rate of 7% is the rate associated with $41,000 of Stafford loans and $9,000 of PLUS loans. The standard monthly payment is $651.66, or $7,820 per year, for 10 years. After 10 years the borrower will have paid $78,199. At salaries below 150% of the federal poverty line ($16,590 in the example) individuals are not required to make any payments and have $154,350 forgiven after 25 years. This is true if the individual is unemployed as well. At a salary of $38,000, IBR payments are well below the standard 10-year repayment amount, and the borrower pays $80,288 over the course of 25 years. Over $74,000 is forgiven since the payments cannot cover both the interest that accrues and the principal. Finally, there are cases in which students qualify for IBR and repay the loan over a longer period of time. In Figure 2 this occurs when the borrower earns $52,000. The borrower pays less than the standard 10-year repayment amount and ultimately pays $102,690 over the course of 19 years, at which point the loan is paid off. While this is more than the amount that would be paid under the 10-year repayment plan, the borrower is able to smooth consumption and repay the entire loan. The more students borrow in federal loans, the more likely

\textsuperscript{21}IBR made up 13% of loans in repayment and other income-driven plans made up only 6% of loans in repayment.\textsuperscript{22} Based on authors’ calculations from figures in the report. The report also indicates 51% of all borrowers are eligible for income-driven repayment.\textsuperscript{23} Based on data from the Federal Student Aid Office. The data also indicates that 34% of all graduate students who entered repayment in 2011 were enrolled in an income-driven repayment plan in 2014.\textsuperscript{24} There are a number of IDR plans. IBR changed to paying 10% of disposable income for 20 years for new students borrowers as of June 2014. PAYE lets students pay 10% of their disposable income for 20 years, but is restricted to new borrowers as of October 2007 who received a Direct Loan after September 2011. I focus on IBR and will consider PAYE when modifying my main model. REPAYE, introduced in December 2015, did not exist during the time I study. ICR allows students to pay 20% of their income toward their loans or the monthly amount associated with a 12 year repayment plan, but there is no payment cap so ICR payments can exceed the standard 10 year amounts.
they are to benefit from IBR. This example shows how IBR, and other income-driven repayment plans, function as insurance against unemployment or low wages and enables borrowers to smooth consumption over a longer time horizon.

Finally, the government also offers Public Student Loan Forgiveness (PSLF). With PSLF students must work in a nonprofit organization and make 10-years of consecutive payments, after which the amount outstanding in federal loans will be forgiven. The first cohort of borrowers with PSLF have not yet had their loans forgiven yet but a recent report indicates that over 630,000 borrowers have been pre-certified for forgiveness in 2017. This number includes a combination of graduate and undergraduate borrowers across a variety of fields (Government Accountability Office, 2016).

3 Data

I use the National Postsecondary Student Aid Study and anonymous credit data from one of the three major credit bureaus to conduct my analysis. I also incorporate data from the Integrated Postsecondary Education Data System and the American Community Survey.

3.1 National Postsecondary Student Aid Study

To document changes in graduate student borrowing before and after the introduction of graduate PLUS loans I use the National Postsecondary Student Aid Study (NPSAS) from 2004, 2008 and 2012. The NPSAS contains nationally representative cross sections of postsecondary institutions and students. I compare students in 2004, who did not have access to PLUS loans, to those in 2008 and 2012. The 2004 sample includes 10,894 graduate and first-professional students who were enrolled during the 2004 academic year. The NPSAS 2008 has 14,166 graduate and first-professional students while the 2012 survey has 15,958. The NPSAS contains comprehensive information regarding students' financial aid and program of study. The surveys also include students’ characteristics, education, and background.

Table 2 summarizes graduate student characteristics and suggests that the composition of graduate students has not changed markedly from 2004 to 2012. Between 2004 and 2012 the percentage of female graduate students increased slightly from 57.8% to 60.3%. The percentage of minority graduate students has also increased slightly. Over 90% of graduate students are not in a health-related program, indicating that few students are allowed more than $20,500 in Stafford loans.

Table 2 also summarizes graduate student borrowing. Overall, the fraction of students who borrow has increased slowly over time. While only 40-45% of students borrow a student loan, 75-80% of first professionals take out a student loan. This suggests that first professionals are
most likely to respond to the introduction of the PLUS loan program. The table also indicates that the loan to cost ratio and the average amount borrowed has increased little over time among students with a federal loan. While the average amount borrowed has increased modestly since 2004 from $18,500 to $20,500, the average loan to cost ratio among borrowers with a federal loan has not changed across each of these samples. Focusing on students with federal loans who borrow outside the Stafford program reveals that the amount they borrowed in private loans has decreased substantially. By 2012 these students funded only 4% of their costs with private loans on average, compared to 26% in 2004. This decrease is offset by an increase in PLUS loan use; by 2012 those with a federal loan who borrowed outside the Stafford program funded 30% of their costs on average in PLUS loans.  

The NPSAS contains information on both undergraduate and graduate students. This enables me to estimate changes in borrowing among graduate students relative to changes among undergraduate students to determine whether the move away from private loans is due to the introduction of PLUS loans, or whether there are other factors affecting students’ loan decisions. If students are generally trending away from private loans, or private lenders are reluctant to lend, then a similar pattern would be expected among undergraduate students. While undergraduates are not a perfect control group for graduate students, this methodology can highlight the extent to which changes in the post-period are graduate-student specific.

### 3.2 Credit Bureau Data

To evaluate the decision to take out federal or private student loans I use anonymized credit data from Equifax Inc., one of the three major credit bureaus. This is one of the first papers to use such detailed credit data and is the first paper to compare private to public loans. While the NPSAS includes some private loan information, it lacks important factors such as the interest rates associated with private loans, the cumulative amount borrowed, and credit report characteristics. The absence of this information makes it difficult to compare the private to federal loans and to understand students’ borrowing decisions.

Credit data includes credit score, balance, and repayment information for student loans, credit cards, mortgages and more. The data is organized in snapshots of individuals’ credit reports. I focus on snapshots from September 2014 which includes loan information that dates as far back as 10 years, though I do have access to reports from 2010 onward and sometimes incorporate these. Focusing on September 2014 enables me to see 24 months of balance, repayment and other loan

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25 The patterns are similar when looking at all students who borrow outside the Stafford program and when focusing on student with federal loans. Since Stafford limits do not increase much, students do borrow more outside the Stafford program in general.
information from September 2012 to September 2014, regardless of the date the loan was opened. In any given academic year students can open a number of loans.

While the information on loan characteristics is extremely detailed, information on borrowers is limited. I focus on all borrowers who opened a loan in the 2011 - 2014 academic years and are 24 - 35 years of age in September 2014. These borrowers are unlikely to be borrowing on the behalf of children and are also more likely to be graduate students than younger individuals. I use the amount borrowed in federal loans to identify graduate students and to group students into the “Health A” and “Health B” categories defined in Section 2. Figure 3 depicts the categorization of borrowers into groups. Since no undergraduate student cannot borrow more than $12,500 in an academic year, any student who borrows more must be a graduate student. I use this criterion to define my sample of graduate students. I then categorize students based on the amount borrowed in federal loans across at most 8 loans in one academic year. Any student who borrows exactly $40,500 in federal loans in one academic year, whether as one loan or as the sum of 2-8 loans, is categorized as a Health A student. Similarly, any student who borrows exactly $33,000 in federal loans is categorized as a Health B student. Lastly, students who borrow exactly $20,500 in federal loans are placed in the Other group. Based on the Stafford limit for non-Health students, I can be sure these students do not fall into the Health A or Health B categories. Students who do not borrow these exact amounts but borrow more than $20,500 cannot be categorized since they may fall into any of these three categories, though most are likely to be non-health students borrowing PLUS loans. In the 2012 NPSAS, 15.4% of students borrowing above $20,500 are Health A students, 13.7% are Health B students, 14.7% are law students and 7.3% are MBA students.

These student categorizations are based on the amounts that students borrow in one academic year, however, students do not necessarily borrow the same amounts each year. Once a student has been identified as a graduate student in the credit data, I assume future borrowing is also for a graduate program. This enables me to track graduate students who borrow less in federal loans in following years. Similarly, once a student has been identified as a Health A, Health B or Other student I assume future borrowing is for that program. In the rare case of a student borrowing exactly two Stafford limits, I give preference to Health A, Health B, and finally Other programs.

In many instances a borrower is classified into one of the student categories in the second year of borrowing or later (from 2011 - 2014), but is identified as a graduate student in all years. In this case, I assume that previous graduate borrowing was also for the same program type. For example,

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26Less than 1% of borrowers have more than 8 government loans in a given academic year.
27Students in the Other category are unlikely to fall into the Health A or Health B categories since they have borrowed exactly the limit for Other students. Uncategorized students includes health students since I only identify 3% of graduate borrowers as health students, where as 12% of borrowers are in a health program in the NPSAS 2012.
if a student is in the Health A group in 2013 and was labeled as a graduate student in 2011 and 2012 then I assume the student is a Health A student in 2011 and 2012 as well.\textsuperscript{28}

Figure 3 also depicts the percent of borrowers who fall into each category.\textsuperscript{29} Overall about 29\% of student-years are classified as graduate students. I find that approximately 1.5\% of these graduate students can be classified as Health A students and nearly 1.7\% fall into the Health B category. Almost 30\% of graduate students fall into the Other category based on the definitions outlined in Figure 3. While there are likely many Health A and B students who borrow various amounts, I am unable to determine the student types without more information. The NPSAS 2012 indicates that 28\% of borrowers ages 24 - 35 are graduate students, close to what I find in the credit data. Among all graduate borrowers in that age group, 6.9\% were Health A students while 6.4\% were Health B students. Focusing on students who borrowed the Stafford maximums, the NPSAS indicates that 3.7\% of graduate borrowers are in Health A programs and borrow the maximum, 1.8\% are in Health B programs and borrow the the Health B maximum, and 26.7\% other students borrowed the standard maximum of $20,500. These comparisons indicate that relying on amounts borrowed are a good way to estimate student type.

I manually categorize loans based on lender names. In 2012, 7.3\% of borrowers in this age group had a private loan, lower than the 11.4\% of students 24 - 35 who report having a private loan in the NPSAS 2012. I find that 4\% of borrowers do not have any federal loans, very close to the 3.7\% of students without a federal loan in the NPSAS 2012. Based on the NPSAS, 6.1\% of graduate students with over $12,500 in federal loans took out a private loan. This is very close to the 5.4\% of graduate students (based on my categorization) in the credit data who have private loans in 2012. Based on this information, my categorization of loans is close to what is reported in the NPSAS, though I may be missing private loans for some individuals. Appendix Table F.8 summarizes the types of loans students borrow in the credit data by academic year.

4 Crowding Out of the Private Market

How much does access to PLUS loans crowd out the private market? PLUS loans are most relevant for students who exhaust their Stafford limits. These students are facing a decision to not borrow above the Stafford limit or to take out either private or PLUS loans. In this section I focus on the decision to take out private loans as well as the amount borrowed above the Stafford limit. While the loan to budget ratio or total amounts borrowed may also increase, I do not find strong evidence

\textsuperscript{28}\textsuperscript{I have also tried an alternative definition in which I allow students to switch types from 2011 - 2014. This does not significantly change the sample of Health or Other students. See Appendix A for details.}

\textsuperscript{29}\textsuperscript{A more detailed summary by year and a comparison with the NPSAS 2012 can be found in Appendix Table F.7.
of this occurring. See Appendix D for details.

To evaluate the change in private borrowing I first categorize students into six groups based on their Stafford limit and degree type. The first group includes students in Health A programs, as defined in Section 2. I split Health B into two groups: Health B first professionals and Health B other. Finally, I split those who face the lowest Stafford limit into three categories: Other first professionals, which includes those in Law and Ministry students, Other Masters; and Other Doctoral students.\(^{30}\)

For each of these groups I estimate the raw and regression adjusted difference in the probability of having a private loan by estimating

\[ y_{it} = \alpha + \beta X_i + \lambda_p + \delta post_t + \epsilon_i \] (1)

for all students together and for each of the six groups. This is a linear probability model in which the dependent variable \(y_{it} = 1\) if the student has a private loan and \(post_t = 1\) if the student is a post sample.\(^{31}\) I include program fixed effects \((\lambda_p)\), of which there are 27, and student characteristics such as age, race, gender, expected family contribution (EFC) which is calculated by the university, COA, year-in-school fixed effects, and school-type fixed effects \((X_i)\). I use robust standard errors and dollar amounts are in 2008 dollars. The coefficient of interest, \(\delta\), describes the difference in the probability of having a private loan once PLUS loans were introduced. Results are presented in Table 3.

The first column and second row of Table 3 show that, after controlling for individual and school characteristics, the overall probability of having a private loan decreased by 1.3 percentage points (pp). The use of private loans decreased among all student types except among masters students (in column 6). The regression adjusted probability of borrowing a private loan among law and ministry students fell by 22pp, or by 77%, more than any other group of students. Health A students also decreased private loan use by 10.8pp, or 70%. In rows 3 and 4 of Table 3 I focus on students whose cost of attendance (COA) is above the Stafford limit. Students with costs above the annual limit are most likely to respond to the introduction PLUS loans. These rows indicate that the movement away from private loans is indeed largely among students who face high costs. Columns 2 and 5 of Table 3 show that the graduate students who moved away from private loans were primarily Health A or law students. This is not surprising given that these students make up the majority of first professionals and are thus most likely to respond on this margin.

The estimated effect of \(post_t\) in Equation 1 assumes that the pre- and post-periods have similar

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30\(I\) exclude post-baccalaureates and students who are not enrolled in a specific program from my analysis.

31 Appendix D considers the probability that students borrow above the Stafford limit and the loan to budget ratio.
trends, a strong assumption for this 8 year period. Other changes in the federal loan programs from 2004 - 2012 affected both graduate and undergraduate students similarly. Undergraduate students have had access to private loans but have never, and still do not, have access to PLUS loans. The one exception is parents of undergraduate students, who have had access to parent PLUS loans since before the 1990s. To shed light on whether the decrease in private loan use is due to the introduction of PLUS loans, as opposed to other changes in the economy or the student loan landscape, I use a differences-in-differences strategy in which undergraduate students function as a control for graduate students.

To understand how graduate borrowing differs from undergraduate borrowing after the introduction of the graduate PLUS program, I incorporate data on undergraduate students from the NPSAS and estimate:

\[ y_{igt} = \alpha + \gamma_f + \lambda_p + \beta X_i + \sum_{g=1}^{6} \delta_g \text{post}_t \times \text{group}_i + \epsilon_i \]  

(2)

where \( \gamma_f \) represents year in school fixed effects (survey specific) and \( \lambda_p \) represents program fixed effects. Undergraduates are considered to be in one program. \( X_i \) includes gender, race, age, sector, EFC and COA. I also include controls for whether the student is married, owns a home, has children and is a dependent. \( \text{post}_t \times \text{group}_i \) represents the category a student is in, as described in the previous section, interacted with an indicator for whether they are in the post samples. Dollar amounts are all in 2008 dollars. The coefficient of interest, \( \delta_g \), represents the difference between graduate student groups relative to undergraduates in the post period. This methodology assumes that the difference in borrowing between undergraduate and graduate students is similar across time in the absence of PLUS loans. In this specification, the dependent variable is again an indicator for whether the student borrows a private loan. Standard errors are clustered at the group, NPSAS, year in school level.

Figure 4 shows how the probability of having a private loan changes for graduate students relative to undergraduates after the introduction of PLUS loans. Panel (b) shows the \( \delta_g \) coefficients from Equation 2 while panel a shows the raw difference in probabilities. The decrease in the probability of having a private loan among graduate students, relative to undergraduates, is large and supports the finding that the movement away from private loans is indeed due to the introduction of graduate PLUS loans. In fact, panel (a) of Figure 4 indicates that undergraduate students actually increase their use of private loans while graduate students are moving away from

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32For example, an increase in Stafford limits, the introduction of fixed interest rates, and the introduction of the self-certification form described in Ang and Alexandrov (2016). Likewise, private lenders changed their lending criteria and some even left the market after the 2008 recession.
them. Once again, the decrease is largest among Health A and Other first professionals, students who are expected to respond the most.

I next focus on students most constrained by the annual limits to evaluate how borrowing above the Stafford limit changes in dollar terms. To do this I focus on those with a COA above the Stafford limit. These students are most likely to make the PLUS vs private loan decision. To understand the relationship between costs and amount borrowed I estimate

\[ y_i = \alpha + \gamma_f + \lambda_p + \beta X_i + \theta \max_i + \delta \text{post}_t \times \max_i + \epsilon_i \]  

(3)

on the students whose cost is above their Stafford limit. In Equation 3, \( \max_i = \text{COA} - \text{Limit} \) and measures the amount that a student is constrained by Stafford limits. I include survey-year-year-in-school fixed effects \( (\gamma_f) \) to control for economic conditions, program fixed effects \( (\lambda_p) \) and individual controls such as age, gender, race and EFC. I also include the interaction between \( \max_i \) and \( \text{post}_t \). The dependent variables are the amount in private loans and the amount of the sum of PLUS and private loans. The \( \theta \) coefficient describe how much students borrow outside the Stafford program, or in private loans, for every dollar they are constrained by the Stafford limit. The \( \delta \) coefficient describes how this differs in the post-period. Standard errors are clustered at the group, NPSAS, year in school level.

The results from estimating Equation 3 are presented in Table 4. Columns 1, 2, 5 and 6 use all the NPSAS samples, while columns 3, 4, 7 and 8 restrict to the 2004 and 2008 samples. The first row depicts the estimated \( \theta \) coefficients while the second row depicts the estimated \( \delta \) coefficients. For every dollar that a student is constrained by the Stafford loan program, the first row of columns 2 and 4 indicate that students borrow 20 cents in a private or PLUS loans. The second row indicates that there was no statistically significant increase in the post period. In other words, the use of loans outside the Stafford program does not differ after the introduction of PLUS loans. This indicates that few students were priced out of the market for private loans in the absence of PLUS loan. Columns 5 - 8 of Table 4 show that before the introduction of PLUS loans students borrowed 20 to 22 cents from private lenders for every dollar they were constrained by the Stafford limit. In the post period, however, the second row shows that students decreased their use of private loans by 19-20 cents for every dollar they were constrained. This result is robust to controlling for student characteristics and even to dropping the 2012 sample. Table 4 shows that students replaced private with plus loans one-for-one once PLUS loans were introduced. In other words, over 80% of the amount borrowed above the Stafford Limit was through PLUS loans in the post period. From a static perspective, this huge movement away from private loans would make sense if most students receive interest rates in the private market that are higher than what is offered by
the government. This seems unlikely, given the distribution of interest rates in Figure 1. From a
dynamic perspective, however, this movement may be rationalized by a preference for the insurance
associated with the federal income-based repayment plan. I explore this more in section 6.2.

To test whether this change is graduate student specific, I modify Equation 3 and estimate

\[ y_i = \alpha + \gamma f + \lambda_p + \beta X_i + \theta_1 \max_i + \delta_1 \text{Post}_t \times \max_i + \theta_2 \text{graduate}_i \times \max_i + \delta_2 \text{graduate}_i \times \text{Post}_t \times \max_i + \epsilon_i \]

(4)

where \text{graduate}_i is an indicator for whether the student is a graduate student. The program fixed
effects, \lambda_p, include an additional category for undergraduate students. Once again the dependent
variable of interest is the amount borrowed in private loans and the amount borrowed in private and
PLUS loans. Dependent undergraduate students have had access to parent PLUS loans since before
the year 2000 which I include. Once again I focus on students whose COA is above the Stafford
limit. In this specification, \delta_2 shows how borrowing, for every dollar a student is constrained, above
the Stafford limit changes among graduate students relative to undergraduates.

Table 5 depicts the estimates of \theta_1, \delta_1, \theta_2 and \delta_2 from Equation 4 and describes how borrowing
above the Stafford limit changed for graduate students relative to undergraduates, who did not
experience an expansion in federal loans. For every dollar they are constrained by the Stafford
program, undergraduates borrow about 12 cents in supplemental loans and graduate students
borrow 20 cents on average. The change in this outside amount is not statistically different in the
post period for either group. Undergraduates only borrow about 5 cents of this amount through
private lenders while graduate students borrowed the whole 20 cents in private loans before the
introduction of PLUS loans. While undergraduates use of private loans did not change, or even
increased slightly as shown in column 6 row 2, Table 5 confirms that graduate students move
away from private loans almost one-for-one and that this movement is very different from the
undergraduate pattern. This indicates that other changes in the student loan market cannot fully
explain the crowd out of the private market among graduate student borrowers. More importantly,
the movement away from PLUS loans cannot be explained by a drying up of available private funds.

These results provide strong evidence that the graduate student movement away from private
loans can be attributed to the introduction of PLUS loans. The rates depicted in Figure 1 suggest
that this movement is too large to be explained by students receiving rates above 7.9% in the
private market. While it is unlikely that all students with PLUS loans are riskier than those with
private loans, the NPSAS does not contain sufficient information to answer this question. Next, I
use credit data in the following sections to assess the extent to which there is sorting into federal
loans and to understand why students move away so dramatically from private loans.

5 Selection into Private Loans

The previous two sections have shown that the introduction of graduate PLUS program led students to replace private loans with the federal option. The movement away from private loans is large, raising the possibility that students may be biased toward federal loans. Selection into private loans based on students’ perceived risk, or credit score, is expected since “low risk” students could receive more favorable rates in the private market. In this section I evaluate whether this is the case by testing for selection into the private option.

Table 6 summarizes credit scores the month before students open a new loan, among graduate borrowers from 2011 to 2014. The credit score used is students’ VantageScore® 3.0 generated by the credit bureau and is an approximation of the score used by lenders when providing loans. Credit scores range from 300 to 850 points with higher scores indicating that the person is lower risk. Comparing credit scores among students with and without private loans can highlight the extent to which there is adverse selection into federal loans and advantageous selection into private loans. Credit score is one of the most important factors to determine the private interest rate a student could receive. Students with private loans are expected to have higher credit scores on average.

The median credit score for all graduate borrowers in the sample is 652, as shown in column 2. Health A and Health B students have much higher median credit scores of 725 and 705, respectively. Row 1 and column 3 of Table 6 shows that the median credit score among graduate students borrowing through the private market is 20 points higher than the median score of the students, consistent with the notion that riskier students have federal loans. The opposite is true for Health A (row 2) and Health B (row 3) students. The median credit score among Health A students who borrow private loans is 15 points lower than that among Health A students overall. Among Health B students, the median score for those taking out private loans is 3 points lower than the overall median. Within these categories there seems to be advantageous selection into federal loans. This suggests that a number of Health students may receive low interest rates in the private market, but nonetheless choose to take out federal loans.

Next I consider the regression-adjusted differences in credit score. I split uncategorized graduate students into two groups: graduate students who borrow less than the Stafford limit of $20,500 and graduate students who borrow above $20,500 (and are likely taking out PLUS loans). These groups are mutually exclusive. To evaluate the difference in credit score between those who have

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33Unfortunately FICO scores were not available, but the VantageScore® function as a good approximation. See Consumer Finance Protection Bureau (2012a) for a comparison of FICO and different credit bureau scores.
private loans and those who do not, I estimate:

\[ \text{score}_i = \beta X_i + \theta g + \sum_{g=1}^{6} \delta_g \text{group}_i \times \text{private}_i + \epsilon_i \]  

(5)

where \( X_i \) includes academic year fixed effects, month fixed effects and trade number. Controlling for year and month effects allows for differences in credit scores that are attributed to the student populations when they borrow. For students who open multiple loans in one year, the trade number describes the order in which they are opened. This controls for possible credit score changes that may be attributed to a new loan. The \( \text{group}_i \) variable indicates student type and the coefficients of interest, \( \delta_g \), describe the difference in credit scores between students with private loans relative to students without private loans in the same group. The goal is to test for selection into federal loans, regardless of the reason, thus I exclude age and location in this specification since they may contribute to the adverse selection.\(^{34}\) Standard errors are clustered at the state-academic-year level.

Figure 5 shows the regression adjusted difference in credit scores (when students borrow) between students who have private loans and those who do not. Below the group names are the average credit scores for each group as well as the average amount borrowed each year for the group. The first point estimate shows that the credit score of graduate students who borrow below the Stafford limit and take out a private loan is 48 points, or 7.9 \%, higher on average than those who only take up federal loans. This translates to moving 18 percentiles from the median score of students in this category. This suggests that, among students borrowing smaller loan amounts, there is adverse selection into federal loans. The second point estimate in Figure 5 shows the difference in credit scores among uncategorized students who borrow above the Stafford limit. Here, the credit scores of students with private loans are 20 points, or 3\%, higher on average, a relatively small amount which translates to moving 8 percentiles from the median. The third estimate shows a difference of 26 points among students who have private loans in the Other category relative to students in the Other category who only take out federal loans. This difference translates to moving 10 percentiles from the median score of Other students.

Generally, lenders group borrowers into credit score bins when pricing loans. These bins can range from 20 - 100 points. Thus, except for students borrowing below the Stafford limit, the documented differences in credit scores are not necessarily large enough to significantly influence the interest rates students could receive in the private market. While there does seem to be some positive selection into private loans overall, there is also a large amount of overlap between students with private and federal loans. Thus, many students with only federal loans may receive

\(^{34}\)I focus on students within a certain age range, thus the informativeness of the credit score does not vary by group. Estimating Equation 5 including controls for age yields the same pattern and results.
more favorable rates in the private market. I explore this further in the next section.

In contrast, the differences in credit scores among health students, depicted by the last two point estimates in Figure 5, are small. Health B students with private loans have credit scores that are only 5 points, less than 1%, higher than those who choose federal loans on average. This translates to moving less than 2 percentiles from the median. Among Health A students there very little advantageous selection into federal loans and the difference of one credit score point is not statistically significant at the 5% level.

These results highlight some interesting phenomena. The riskiness of graduate students with large amounts of federal loans, and particularly Health students, is not very different from similar students who borrow private loans. There is some selection into private loans, but these differences in credit scores are relatively low and indicate that there are students with federal loans who could potentially receive more favorable private interest rates. These differences in credit scores alone do not explain the one-to-one movement away from private loans documented in Section 4. The larger amount of sorting among students who borrow below the Stafford limit suggests that graduate students may be aware of the lower interest rates offered in the private market, but still opt for federal loans. One reason why adverse selection into federal loans may not be as prominent among students who borrow larger amounts is because of income-based repayment available with federal loans. In a dynamic setting, students who face future wage uncertainty may like the option to pay their loans based on income rather than being forced to make fixed payments. Given that only about 5% of graduate students have private loans, however, it is unlikely that all students borrowing above the Stafford limit do not expect to be able to afford their loans.

6 Evaluating the Federal vs. Private Loan Decision

6.1 Private Loan Interest Rates

In order to evaluate whether students receive lower interest rates in the private market for student loans, it is essential to model the interest rates offered to students in the private market. If these estimated rates are above the federal rates offered, the large movement away from private loans is easily rationalized. The credit reports I work with contain monthly information for each account (loan, credit card, etc) from September 2012 to September 2014. This monthly information is available for the amount borrowed, the balance, payments, scheduled payments and characteristics of each account. Loan characteristics include information on whether the loan is deferred, in default, cosigned and much more.

With this information, I back out the interest rates, month-to-month, students face using the
credit report information from September 2012 to September 2014. I focus on loans opened in the 2010 to 2014 academic years. I am able to back out at most 24 rates for each loan, depending on when it was opened. For each loan, I use the median of the estimated rates as the interest rate associated with the loan. Appendix A.3 describes how I use this information to back out the interest rates students receive. Since the LIBOR and PRIME rates were relatively stationary from 2010 to 2014, I am unable to distinguish between fixed and variable interest loans.

The CFPB private student loan report indicates that lenders use credit score, program, school information and other personal and credit specific information when pricing student loans (Consumer Finance Protection Bureau, 2012b). Credit score generally incorporates this additional credit information and is one of the characteristics most closely related to the rates students receive. Focusing on graduate student private loans, I separate private loans into 20 groups, each containing 5% of the sample based on credit score. The first group contains the 5% of students with the lowest credit scores while the last contains the 5% of students with the highest credit scores. Figure 6 depicts the relationship between credit score and the median interest rate students receive for each of these groups. The figure clearly indicates that, as expected, students with higher credit scores receive lower interest rates in the private market for student loans. Over 60% of students with private loans received an interest rate below the PLUS rate of 7.9% and 15% of these students received a rate below the Stafford interest rate of 6.8%.

I use the interest rates calculated among graduate private loans to predict the interest rates students with federal loans may have received on the private market. To do this I focus on graduate private loans, winsorized at a 2% level, and estimate:

\[ rate_i = f(X_i, \text{score}_i, \text{cosign}_i, \text{group}_i) + \lambda_i + \epsilon_i \]

I include controls for credit score as well as the square and cube of credit score (\text{score}_i), whether the student has a cosigner (\text{cosign}_i), student type (\text{group}_i) and personal characteristics (\text{X}_i). The matrix \text{X}_i includes academic year, the month borrowed, presence of an account that is 30 days past due within two months of borrowing, presence of a derogatory account within 6 months of opening the loan, the age of the oldest trade and the number of open trades. The \text{X}_i matrix also includes lender fixed effects for the 3 largest lenders, and interactions between academic year, lender, student type and credit score. The \lambda_i matrix controls for the probability that students are

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35 An academic year runs from the previous July to June. For example, the 2010 academic year includes July 2009 to June 2010.

36 PLUS interest rates were 7.9% and Stafford rates were 6.8% from 2011 - 2013, after which they decreased.
enrolled in specific programs based on their zip code when opening the loan.\footnote{See Appendix A.4 for details on the probability students are enrolled in specific programs.} The goal of this exercise is simply to predict interest rate as a function of variables that may be used when lending to students. Additional details on the specification and the methods used to choose this model are in Appendix B.

One concern with the methodology used is selection into private loans. In particular, I only see private loans that students take out, not those which are rejected. A majority of private loans are lent through lenders who have online applications, and the loan terms are determined by the application information. Thus, it is unlikely that there are unobservables that may influence a student’s interest rate, aside from university, as may occur with auto or mortgage loans. More importantly, there is substantial overlap between the students who have federal and private loans. Furthermore, estimating a Heckman two-step model on a random sub-sample of loans, in which the instrument is age, suggests there is no selection into private loans. Appendix B.1 provides details and a more thorough discussion of selection.

After prediction I use the estimated coefficients to calculate

$$\hat{\text{rate}}_i = \hat{f}(X_i, score_i, Cosign_i, Group_i, Prob_i) + \hat{\lambda}_z$$

for all graduate student borrowers. I predict whether students would have a cosigned loan by using the status of their other accounts.\footnote{65\% of borrowers with a private student loan and another shared account have a shared private student loan.} If the borrower has another account that is joint or shared in some way, I assume they could have a cosigner when borrowing a private student loan. This gives $\hat{\text{rate}}_i$: the estimated interest rate students would have received had they borrowed through the private market. I calculate a predicted rate for each lender and select the lowest predicted rate each student would have received if they had taken a private loan.

Based on these predicted interest rates I determine whether the estimated interest rate is below the Stafford or PLUS rates offered by the government in the 2011 - 2014 academic years. Figure 7 describes the percentage of borrowers who are predicted to receive interest rates in the private market below the federal rates. For each student category, the left bars describe the percentage of students whose estimated rate is below the Stafford rate and the middle bars depict the percentage of students whose estimated rate is below the PLUS rate. The rightmost bars describe the percentage of students with a private loan.

Overall, over 30\% of graduate students are predicted to receive an interest rate below the Stafford rates that were offered. What’s more, nearly 60\% of Health B students and 65\% of Health A students are predicted to receive an interest rate below the Stafford rate while over 50\% of
students in the Other category have a predicted rate below the Stafford rate. An even larger percentage, over 60%, of students have a predicted interest rate below the PLUS rate offered. Among the well-defined student groups, more than 70% of students have a predicted rate below the PLUS rate.\footnote{Failing to allow for lender-specific pricing reduces the percent of students whose predicted rate is below the Stafford and PLUS rates. See Appendix B for details.}

Figure 7 confirms that a large percentage of graduate students with PLUS, and even Stafford, loans could have received more favorable rates on the private market. To evaluate the extra amount students pay for these loans I calculate the total difference in the amount paid over a 10-year loan repayment in Table 7.\footnote{The standard repayment plan for federal loans, and many private loans, is 10 years.} The table depicts the extra amount paid in PLUS loans among students whose predicted rate is below the PLUS rate, and the extra amount paid in PLUS and unsubsidized Stafford loans among students whose predicted rate is below the Stafford rate. When calculating the extra amount paid in Stafford loans I assume students received the maximum amount in subsidized loans ($8,500 through 2012, and $0 otherwise), thus this is a lower bound on the extra amount paid. Overall, column 2 shows that graduate students pay $30-35 extra per month for the federal loans amounting to an additional $3,400 - $4,100 over the course of 10 years, as shown in column 1. Health students, who borrow more and have lower predicted private rates, pay an extra $50 - $100 each month for ten years. Health A students pay approximately $13,000 extra over the course of 10 years on average.

### 6.2 Income-Based Repayment

In this section I focus on borrowers who did not have private loans in the years I observe, but had a predicted private loan interest rate below the relevant federal rate in at least one year. I test whether the availability of IBR can rationalize the decision to borrow federal loans for these students using an expected utility framework. If these students do not plan to use IBR (or any other income-driven repayment plan), no coefficient of relative risk aversion can rationalize borrowing federal loans based on the 10-year payments, assuming interest rates will not change. I restrict the sample to students who fall into the Health A, Health B, or Other category because I can model their expected wage paths more accurately than I can for the uncategorized group which contains all student types.

Enrollment in IBR is substantial, so it is important to estimate whether the demand for the insurance it provides drives the willingness to pay a higher interest rate for federal loans. The examples in section 2.4 have shown that IBR can be very valuable to borrowers by allowing them to pay less than the standard monthly amount when income is low, and enabling them to defer
larger payments to later years only if income rises. Enrollment into IBR depends on borrowers’
debt to income ratio. Borrowers benefit from IBR if the standard 10-year monthly payment is
more than 15% of their income above 150% of the FPL. As a result, high income borrowers can
still qualify for IBR if they have accumulated a large amount in federal loans.\footnote{For example, assuming a 6.8% interest rate, a borrower with $160,000 of debt from 4 years of school would not make any payments with a salary below $17,800, would pay approximately $12,000 per year with a salary of $100,000, and would pay the standard amount of $26,600 per year with a salary of $296,000+.}

When modeling students’ borrowing decisions I focus on the uncertainty over future wages. Ex-ante, students are unlikely to know the exact wage they will receive upon graduation. They may, however, have some idea of the distribution of wages for the professions associated with their degree. To model students’ borrowing decisions, it is necessary to model the wage distribution students expect, given their education. For students pursuing Health A or Health B degrees the range of occupations they are likely to enter is limited. For those in the Other category, I model two scenarios: the distribution of wages associated with law occupations and the distribution among workers with a master’s degree. Based on the NPSAS 2012, about 83% of those in Other programs borrowing $20,500 or more are enrolled in a law or masters program.

I use the 2013 ACS 5-year estimates to model earnings at the state-occupation-age group level in which age is a proxy for work experience (Ruggles et al., 2015). The ACS 5-year data contains averages from 2009 - 2013 and provides detailed information on the occupation and educational attainment of each worker. To model expected future wages, I focus on full-time workers and calculate the 5th, 10th, 25th, 50th, 75th, 90th, and 95th income percentiles for workers at the state-occupation-age group level. This yields 7 possible wage paths that students in each occupation group may enter once in repayment. There are 5 age groups (25-28, 29-32, 33-36, 37-40, 41-65) and 4 occupation groups (Health A, Health B, Law, and Master’s). Average income is highest for Health A workers and is more than twice that for those with a Masters degree.\footnote{The main results do not change if I split the 41-65 group into finer groups.} Appendix Figure F.4 depicts two examples of these wage paths and reveals that, for most paths, income increases over time. Thus, IBR may be very appealing to students by insuring against low wage outcomes \textit{and} by enabling students to defer large payments to later, high-income, years.\footnote{See Appendix A.4 for more details on the ACS and how I model wage paths.}

While the ACS allows for wage to differ by location and occupation, it also has limitations. Since the ACS contains cross-sectional data, it is difficult to model transitory shocks and I cannot allow for movement across wage paths, or movements into and out of employment. These movements would introduce more uncertainty over future wages, particularly after students have entered repayment. By assuming workers are always full-time, and failing to take these movements into account, I likely
understate the value of IBR. With this information, I model the expected utility associated with federal and private loans separately for each borrower. For each person, I solve for the lowest parameter of relative risk aversion such that the expected utility of having federal loans is higher than that of private loans. Since I focus on borrowers who could receive a private interest rate below the federal rate, and IBR can lead borrowers to pay more over the life of a loan, the expected utility from private loans is generally higher than that from federal loans in the risk-neutral case. For high enough levels of risk aversion, the expected utility from federal loans surpasses that from private loans. Thus, I am able to back out a lower bound on the coefficients of risk aversion that rationalize having federal loans.

The expected utility from federal loans incorporates the 10 year repayment on federal loans as well as the possibility that students use IBR, and is described in detail below. I define the utility for a given wage \( w \) and payment \( p \) as:

\[
V(w, p) = \sum_{t=1}^{30} \beta^t u(w_t - p_t).
\]

Using a real interest rate of 2%, I set \( \beta = 0.98 \) and assume borrowers have CRRA utility. I model the expected utility from federal loans for each borrower as:

\[
E[U(w, fed)] = \sum_{p \in E} pr_{op}V(w_{op}, ibr_{op}) + \sum_{p \in N} pr_{op}V(w_{op}, fed).
\] (6)

In Equation 6, \( w_{op} \) represents the wages associated with income percentile \( p \) of occupation group \( o \). The probability that individuals will fall in the \( p \) percentile wage group for occupation \( o \) is \( pr_{op} \). I assume, for example, that borrowers expect to fall into the 5th percentile of earners with a probability of 5%, and so on. Uncertainty is resolved once students enter repayment. This model allows for income to increase with time, but does not allow movement between percentile groups.

For some income percentile groups, \( p \), associated with occupation, \( o \), there are wages in \( w_{op} \) that are eligible for IBR and fall into the set of eligible wage paths, \( E \). If no wage in \( w_{op} \) is eligible for IBR then this income group falls into the set of ineligible wage paths \( N \). When students are eligible for IBR, the repayment amount \( ibr_{opt} \) is 15% of wage \( w_{opt} \) above 150% of the federal poverty line. Students are never required to pay more than the 10-year standard payment, \( fed_t \). When enrolled in IBR, loans accrue simple interest. As a result, the length of time students may need to

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44 One exception is if students have private information on their future earnings, which I address in Section 6.3
45 While students have the option to refinance their loans, refinancing is relatively new and is rare in practice. Thus, I exclude this possibility from my analysis.
46 An analysis of the 2010 and 2011 (also 2012 and 2013) March CPS supplements indicates that approximately 50% of individuals with a graduate degree who were in both surveys remained in the same income percentile group.
repay their loans depends on their wage paths and the total borrowed. For each student, I estimate whether each wage path, \( w_{op} \), is eligible for IBR and the number of years (\( T \)) the student would make payments. If after 25 years the loan has not been repaid, the amount outstanding is forgiven and the individual keeps his earnings.

If no wage associated with path \( p \) is eligible for income-based repayment, then the individual pays the standard repayment amount, \( fed_t \), for 10 years. The standard 10-year payments depend on the total amount borrowed and the interest rate. I estimate these payments using the observed borrowing from 2011 - 2014 and using an estimated total amount borrowed from 2006 - 2016, based on July 2016 credit reports. The total from 2006 - 2016 will more accurately reflect the cost, and payments, associated with the borrowers’ education since students may have enrolled prior to 2011, or continued their education after 2014.\(^{47}\)

The expected utility from having private loans is similar to that of federal loans. I model the expected utility from having private loans, only when the interest rate is more favorable than the federal rate, as

\[
E[U(w, priv)] = \sum_{p \in E} pr_{op} V(w_{op}, \tilde{ibr}_{op} + priv) + \sum_{p \in N} pr_{op} V(w_{op}, \tilde{fed} + priv) \quad (7)
\]

where \( priv \) is the monthly payment for 10-year private loans based on the individual’s estimated private interest rates.\(^{48}\) In this case, borrowers may also have federal loans from a year in which the estimated private rate is higher than both federal rates, or when the estimated rate is above the Stafford and below the PLUS rates. For some wages, these federal loans will still be eligible for IBR and the number of years a student is in repayment will change.\(^{49}\) When enrolled in IBR the repayment amount is \( \tilde{ibr}_{op} \) and in the case of no enrollment the standard 10-year repayment amount becomes \( \tilde{fed}.\)\(^{50}\)

I assume borrowers have CRRA utility and solve for the lowest coefficient of risk aversion, \( \gamma, \)

\(^{47}\)I assume students borrow the maximum allowed in subsidized Stafford loans each year. Assuming students have no subsidized Stafford loans yields similar results and the estimated risk aversion thresholds are slightly lower. For the estimated borrowing (using 2006 - 2016 loan amounts) I assume students expect the interest rates are 6.8% for Stafford Loans and 7.9% for PLUS loans. From 2014 onward the government did change these interest rates, however, this is not something that students would have anticipated. I assume borrowing estimated from the 2016 credit reports is in federal loans.

\(^{48}\)The amount borrowed in private loans depends on whether the estimated private loan interest rate is below the Stafford or PLUS rate each year. When the estimated interest rate is below the Stafford rate, I assume that the student borrows everything through private loans. Otherwise, the private loan payment depends on the amount borrowed in PLUS loans. This PLUS amount can only be calculated for the students whose types are identified.

\(^{49}\)In this scenario the eligibility threshold has changed since the student has a lower total federal loan amount.

\(^{50}\)I do not allow borrowers to repay more than required. If the estimated consumption after paying a private loan is less than the value of food stamps in 2016 ($2,328), then I assume consumption is equal to $2,328.
such that $\mathbb{E}[U(w, fed)] \geq \mathbb{E}[U(w, private)]$ using a grid search method for $\gamma \in [0,15].^{51}$

A number of studies have sought to estimate coefficients of relative risk (CRRA) aversion in the general population. An older literature estimates these coefficients to be around 1 or 2 (Arrow (1971), Friend and Blume (1975), and Kydland and Prescott (1982) to cite a few). Hall (1988) estimates an elasticity of intertemporal substitution (the inverse of the CRRA) of 0.5 which would correspond to a CRRA coefficient of 2. More recently Chetty (2006) shows that the coefficient of relative risk aversion can be calculated from labor supply elasticity estimates. Using this methodology he calculates the coefficient of relative risk aversion consistent with labor supply estimates from a number of studies. Among these studies Chetty (2006) finds an average estimate of 0.71 with estimates ranging from 0.15 to 1.78. Gourinchas and Parker (2002) estimate a model of lifecycle behavior of households using the Consumer Expenditure Survey and estimate the CRRA to be between 0.5 and 1.4. Gruber (2006) uses variation in the capital income tax rate to estimate an elasticity of intertemporal substitution of 2, which corresponds to a CRRA coefficient of 0.5.

The estimated risk aversion thresholds differ for each borrower and depend on the total amount borrowed and the wage paths that differ by occupation and location. Table 8 describes the thresholds of relative risk aversion that rationalize having federal loans over private loans based on Equations 6 and 7. These are lower bounds on borrowers’ coefficients of risk aversion. The left panel estimates these coefficients using the observed amounts borrowed from 2011 - 2014 while the right panel uses the estimated total from 2006 - 2016, which is closer to the total amounts students borrowed for their entire education. I compare the expected utility from having private loans, whenever the rate is below the federal rate, to having only federal loans as these borrowers chose.

Overall the estimated coefficients of relative risk aversion are within, or below, the range that has been estimated in the literature. This indicates that the insurance, or IBR, is valuable to borrowers who may face low wage outcomes. The estimated coefficients are lower when using the amount borrowed from 2006 - 2016. This is consistent with the fact that the benefit of IBR is increasing in the total federal amount that students borrow.

I focus on the estimated coefficients using the amount borrowed from 2011 - 2014. Row 1 and column 1 show that the average estimated coefficient is 0.46 among Health A students. The interquartile range, shown in column 3, is from 0.18 to 0.45. Much of the difference in estimated thresholds stems from the different amounts each student has borrowed. For Health A students,

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51 With this framework I cannot separate risk aversion from intertemporal substitution and work under the assumption that the CRRA coefficient is equal to the inverse of the elasticity of intertemporal substitution. Since uncertainty is revealed once students graduate, I cannot incorporate Epstein-Zin preferences.

52 Mehra and Prescott (1985) documented an equity premium puzzles in which risk aversion must be unrealistically high to rationalize observed data. If the estimated parameters of risk aversion I find are also high, the decision of graduate students is similarly puzzling.
IBR can rationalize the decision to borrow federal loans largely because they borrow so much each year. A majority of students in this category are medical students, so the first few years of income are low due to residency. Thus, these students benefit on a second dimension by deferring large payments during their first years of work. Even in high wage-states, and in the private loan case, Health A students would enroll in IBR to defer larger payments to post-resident years. Much of the benefits of IBR for Health A borrower stems from this consumption-smoothing feature of IBR.\textsuperscript{53}

In this model, medical students are not allowed to defer private loan payments while working as residents. While this is true of some private lenders, there were also some lenders who were offering some deferment while a subset of these students were enrolled in resident programs – although when these deferments were introduced (and whether these borrowers all had access to such deferment), as well as the take up of this deferment, is unclear. To account for this, I modify the private loan case for Health A students under the assumption that they have access to full deferment for the first 3 or 4 years of work. The results of this model, using the amounts borrowed from 2011 - 2014, can be found in Rows 1 and 5 of Appendix Table F.9. Even with this private student loan deferment, the decision to have higher interest federal loans can be rationalized, though the median threshold rises to 0.50 (3-year deferment) and 0.58 (4-year deferment). This largely stems from the insurance associated with IBR.\textsuperscript{54}

There is strong evidence that the other student groups also benefit from IBR. When using the amount borrowed from 2011 - 2014 I find that the 75th percentile of Health B students (row 2) has an estimated coefficient of 0.78. Health B students’ thresholds are higher than Health A students’ because they borrow less on average and their incomes are higher in the first years of employment. While the appropriate wage distribution for Other students is less straightforward, the estimated parameters of risk aversion estimated under the assumption that these students are all law students (row 3) and the assumption that they are masters students (row 4) yield similar results. The only difference between rows 3 and 4 are the calculated wage paths students face. In the law student case, the estimated parameters of risk aversion are the highest on average, 1.89 as shown in column 1 and 1.47 when imputing the total amount borrowed, shown in column 4. Assuming students borrow for a masters program, the estimated coefficients are lower with an average of 0.84 using 2011 - 2014 borrowing as in column 1 and 0.68 when estimating the total borrowed from 2006 -

\textsuperscript{53}Residency and fellowships can last 3+ years. The mean stipend in 2014 was $50,765, in which case the average Health A student would use IBR in the private and federal loan cases.

\textsuperscript{54}Furthermore, many medical students may find the federal PSLF option valuable if they plan to work at nonprofit organizations (as most hospitals are). It is difficult to assess the percentage of these students who may qualify for PSLF. An AMA report indicates that about 57% of physicians worked in practices that were wholly owned by physicians. The report also says that young physicians (under 40) were more than twice as likely as older physicians to be employed by hospitals with 12% being direct employees of hospitals but that 34% of young physicians owned their practice (Kane, 2015).
2016 as in column 4. These lower estimates stem from the fact that masters students earn less than practicing lawyers. The benefit to these students from IBR stems from the insurance that IBR provides against uncertain future wages.\textsuperscript{55}

I also model the consumption value of federal loans for each individual. To do so, I set a value of $\gamma$ and modify Equation 6 as follows:

$$
\mathbb{E}[U(w, fed)] = \sum_{p \in E} pr_{op} V(w_{op}, ibr_{op} - \bar{c}) + \sum_{p \in N} pr_{op} V(w_{op}, fed - \bar{c}).
$$

I solve for the value of $\bar{c}$ such that the expected utility of having private loans surpasses that of federal loans. Here, $\bar{c}$ describes the consumption value each year of having a federal loans that sets the utility equal to that of having private loans. If private loans are preferable, $\bar{c}$ will be negative.

Table 9 summarizes the estimated consumption values for $\gamma$ values of 0 (risk-neutral case), 0.5 and 1.00 (log-utility).\textsuperscript{56} In each bracket, the first element describes the 25th percentile, the second describes the 50th percentile, and the last describes the 75th percentile. In the risk-neutral case, using the amount borrowed from 2011 - 2014 as in row 1, private loans are generally preferable. The benefit of federal loans increases when including the amounts borrowed through 2016 as in row 2. Rows 3 - 6 also show, unsurprisingly, that the benefit of IBR also increases with risk aversion.

In all three scenarios Health A have the largest yearly consumption value from these loans, over 10 times the value for Masters students. Focusing on the amount borrowed through 2014, in the $\gamma = 0.5$ case, Health A students exhibit the largest benefit from federal loans with a median of $1,558 per year and 25% of borrowers benefiting by $4,070 or more each year as shown in row 3. Health B and other students, however, benefit much less with only 25% of borrowers benefiting by $553 or more in each category. The estimated benefit from federal loans is largest in the log-utility case. In the other (masters) category 25% of borrowers benefit by more than $2,060 using the amounts borrowed through 2016 as in column 4 and row 6. The benefit is again largest for Health A students. Assuming log-utility, using the amount borrowed from 2011 - 2014, 75% of Health A students benefit by more than $1,809 each year. The benefits of IBR to Health A students decrease when private loan deferral is incorporated as in rows 2 - 4 of Appendix Table F.9.\textsuperscript{57}

\textsuperscript{55}For example, modeling the utility from the expected wage, instead of the expected utility, on a random subsample yields a median CRRA estimate of 4.97, 10 and 2.46 for the Health B, Other Law and Other Masters borrowers. This will be illustrated more clearly in the following subsection.

\textsuperscript{56}Again using a grid search with $\bar{c} \in [-10000, 50000]$.

\textsuperscript{57}See Appendix E for details on the expected costs of IBR relative to the government’s standard repayment plans.
6.3 Model Modifications and Robustness

In this section I modify the main model to evaluate how the thresholds of risk aversion may change if students have private information about their future income, and if students based their decision on the possibility that private loans have variable rates. I also change some of the model assumptions to test the sensitivity of the estimated parameters of relative risk aversion. I focus on the amounts borrowed from 2011 - 2014, as in the left panel of Table 8. Table 10 summarizes the estimated coefficients of relative risk aversion under a number of different scenarios. Each bracket depicts the 25th, 50th and 75th percentiles of the estimated coefficients for each group of students. Each row in Table 10 describes the changes made to the original model.

In the first row, I model students’ decisions year-by-year rather than the all federal versus all private case. More specifically, this row models the case where students borrow a private loan only one year when the private rate is lower, rather than all the years they are lower. In this case the estimated parameters of risk aversion decrease because the students have already borrowed so much in federal loans that many already qualify for IBR. In that case, borrowing a private loan only reduces consumption in the first 10 years of work.

Model Modifications: Private Information

The wage distributions I have used thus far do not account for private information borrowers may have about their future income. Many students may have an idea of where, approximately, they will fall in the wage distribution based on the schools and programs in which they are enrolled or even based on the careers they plan to pursue. Thus, for some of these students the estimated parameters are an underestimate of the lower bound that rationalizes their choice, and for others they are an overestimate. I try to account for this by modeling wages under two scenarios in Table 10 rows 2 and 3. Row 2 models the wage distribution students may expect assuming they know they will earn above the median in their state. For example, students in this category may be attending prestigious graduate programs. Similarly, the row 3 calculates these parameters assuming students know they will earn below the median wage. These may be students in less prestigious programs or students who plan to enter fields known to yield lower pay such as primary care in medicine.\(^{58}\)

The results in row 2 indicate that having federal loans can be rationalized by IBR even if all Health A students (column 1) expect to earn above the median. Since Health A students are primarily physicians, IBR enables them to make low payments during low paying resident years. The estimated coefficients of risk aversion are slightly higher but are still well within a reasonable range of risk aversion with a median estimate of 0.50. Part of this result is driven by the fact that

\(^{58}\)I still model wages using full-time workers, thus these estimates will still understate the value of IBR.
even very specialized physicians must work as residents first. Health A students borrow more on average than others and qualify for IBR at higher incomes as a result.\textsuperscript{59}

The estimated thresholds are larger for Health B borrowers (column 2). The median estimate for Health B students (column 2) is 9.60. Recall that the estimated coefficients are censored at a value of 15 which is the 75th percentile estimate, indicating that at least 25\%, of Health B students hit this boundary. These large estimates suggest that for most Health B students who expect to earn above the median, IBR does not rationalize taking only federal loans.

The pattern among Other students, assuming they pursue law programs, is similar to that for Health B students. The median estimate of $\geq 15$ indicates that 50\% of students would need to be extremely risk averse to rationalize taking out only federal loans. Column 4 shows that the range for Other students, assuming they pursue a Masters, is wider. Overall the median estimate is 2.55 but again the 75th percentile is $\geq 15$. These results indicate that for many students who pursue a Masters degree and know they will have relatively high earnings, IBR may still rationalize the decision to borrow federal loans. For law students, however, this does not seem to be the case because the income in these high wage states are so high. Thus, there may be a nontrivial portion of borrowers who expect to have high earnings and exhibit a bias for federal loans.

Row 3 indicates that the benefit from federal loans is particularly high among students who expect to fall in the lower half of the income distribution. Across all four occupation types the estimated 25th, 50th, and 75th percentiles are lower than those from the left panel of Table 8.

Throughout this analysis I have focused on IBR, but there are a number of other income-driven repayment plans. Most notably, in December of 2012 President Obama introduced Pay As You Earn (PAYE). Students are eligible for this plan if they did not borrow before October 2007 and have borrowed after October 2011. PAYE is more favorable than IBR by enabling students to pay only 10\% of their discretionary income toward the loan for 20 years. In row 4 of Table 10 I estimate the parameters of risk aversion that rationalize having federal loans under the assumption that students can use PAYE.\textsuperscript{60} Column 2 indicates that at least 25\% of Health B students still have an estimated parameter $\geq 15$. Thus, for many Health B students who expect to be in the top half of the income distribution, the more favorable PAYE still does not rationalize taking out federal loans. I find a similar result among Other students, assuming they pursue law (column 3). In both the Health A and masters case, however, the more favorable plan can rationalize having federal loans even if the borrowers know they will be in the upper half of the income distribution.

\textsuperscript{59}When allowing for private loan deferment, as in Row 6 of Appendix Table F.9, the estimated thresholds increase but are still relatively consistent with the literature.

\textsuperscript{60}Based on borrowers’ credit reports, approximately 50\% of my sample may be eligible for PAYE.
Model Modifications: Variable interest loans

Row 5 of Table 10 allows for the possibility that students make their decision based on the fact that private loans offer variable interest rates. Credit reports do not always indicate whether students have a variable or fixed interest rate, and private lenders offer both. Until now I have assumed interest rates are fixed. In row 5 I do not allow for the use of IBR, but model the risk associated with variable interest loans. I use the Tauchen method to discretize interest rates into two states and solve for the expected utility of a private loan through backwards induction (Tauchen, 1985).\(^{61}\) Once again the maximum coefficient of relative risk aversion is censored at 15. For most borrowers the estimated parameter of risk aversion is \(\geq 15\), although the 25th percentile for Health B students is 6.78. These estimates are very high and require borrowers to be extremely risk averse to rationalize the decision to borrow federal loans. The row indicates that even if private lenders only offered variable interest rates, this alone cannot explain the decision to borrow federal loans at a higher, fixed, rate. The fact that private lenders also offer fixed rates furthers debunks the theory that variable interest rates can explain the decision to borrow federal loans. Incorporating the risk associated with variable interest rates would likely lower the estimated parameters in Table 8.

Robustness

In row 6 of Table 10 I allow for students to go into default when wages less the private loan payment is less than or equal to the value of food stamps, rather than setting a minimum consumption value. In this scenario, students default and 25\% of their wages are garnished.\(^{62}\) When students go into default, I assume they are only able to consume 90\% of wages less the garnishment to account for a penalty associated with going into default which may result from having a bad credit history. I allow this penalty to persist for seven years, consistent with the length of time a record of default would stay on an individual’s credit record. Allowing for borrowers to go into default does not much change the estimated coefficients of relative risk aversion.

Row 7 of Table 10 allows for higher level of minimum consumption. Federal loans guarantee at least a minimum consumption equal to 150\% percent of the federal poverty line, which is not the case with private loans. Instead of assuming a minimum consumption equal to the value of food stamps I increase this to be equal to the value of the federal poverty line. This does not change the estimated parameters of relative risk aversion very much and indicates that many of these students

\(^{61}\) The low state represents the state in which students borrowed their loan and is associated with a LIBOR rate of 0.39. Thus, the value function of the low state in the first period represents the expected utility from a variable interest loan. Details on the Tauchen method used can be found in Appendix C. Results are similar when allowing for 3 states and under the strong assumption that interest accrues at the high rate while loans are deferred.

\(^{62}\) In practice, many who go into default may not experience this garnishment since collection agencies have a limited amount of time to sue the borrower before collecting. Likewise, anecdotal evidence indicates that borrowers are able to settle their accounts by paying lower amounts up front or in a shorter period of time.
are not facing this minimum consumption threshold.

In row 8 I allow for taxes to be deducted from the amount forgiven, if any. While imperfect and only for illustrative purposes, the estimated parameters of relative risk aversion increase modestly if students consider taxes associated with loan forgiveness.

Finally, in row 9, I adjust the wage paths to account for family income instead of individual-income. To enroll in IBR married individuals can use their individual income if they file their tax returns separately from their spouse. If individuals do not do this, however, it is important to understand how the estimated thresholds may change relative to those using individual income. I thus use family income from the ACS for each occupation type to model wage paths. I also restrict to individuals who are full-time workers. I also must estimate the family size, since the federal poverty line and qualification for IBR varies by family size. I use the median family size for each state-occupation-age group combination as the estimate of family size. I then adjust the minimum consumption level and federal poverty line accordingly. Row 9 depicts the estimated risk aversion thresholds under this assumption. It shows that the thresholds are still low relative to estimates in the literature, and that IBR still rationalizes borrowers’ decisions.

7 Conclusion

This paper provides evidence that federal involvement in the graduate student loan market has substantially crowded out the private market. Private lenders are generally willing to lend to graduate students and the introduction of federal PLUS loans did not increase the amount students borrow relative to their costs of attendance. While the crowding out of private loans may be surprising, since most students could receive more favorable private interest rates, I show that this decision can be rationalized by the income-based repayment option available with federal loans. More recent student loan policy changes introduce income-driven repayment plans that are even more favorable for student borrowers. This paper highlights the government’s ability to extend insurance to borrowers that private lenders are reluctant to provide, particularly while students are still enrolled in school.

This is the first study to focus on the graduate PLUS loan program, an important and growing component of the federal student loan program. It also quantifies the benefits of income-based

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63I calculate the amount of tax based on the total forgiven, ignoring the individual’s salary at the time. If the tax is very high the IRS does allow individuals to apply to pay a different amount for six months or two years. Thus, if the tax is larger than 50% of the individual’s salary I assume the individual pays 40% of their salary to the IRS in the year the loan is forgiven and the subsequent year.

64This again leads to inflated wage paths as in the main estimates. I also model the wage paths by including the family income of everyone in the ACS who falls into each occupation group which leads the estimated thresholds to decrease.
repayment to borrowers. Future work could focus on the moral hazard, labor, and consumption implications of the program and its repayment options. Since graduate student loans are under-studied, future research could also focus on the effects of the significant debt burden on graduate students once they enter work.

While this paper has focused on the demand for student loans, the results raise the question of why private lenders did not offer more flexible repayment plans. Private lenders may be concerned with the risk over future wages as well as the moral hazard implications of offering income-based repayment plans. Similarly, loan forgiveness may not be profitable for private lenders. Nevertheless, in recent years, new loan refinancers have been disrupting this market. Once a student has attained a degree, and often a job, these lenders offer lower interest loans with flexible repayment plans. While not the same as IBR, some of these plans do allow for missed payments and some unemployment insurance. Many of these lenders are only willing to refinance loans to students who provide background on their education and income. This underscores the private sector’s aversion to future wage uncertainty: the lenders step in only after students have attained their degree, and in many cases have revealed their earnings potential. The presence of these lenders indicates the private sector’s recognition that there may be missing products in the market for student loans. While these lenders are still relatively small, they could have large effects on the federal loan program by leading students to sort into the federal and refinancing markets based on their income and work opportunities.
8 Figures

Figure 1

Source: Consumer Finance Protection Bureau, 2012. Figure depicts the distribution of private student loan interest rates received for 9 private lenders, by academic year and student type. The top horizontal line depicts the PLUS rate of 7.9% and the lower line depicts the Stafford rate of 6.8%. The middle line of each box depicts the median and the ends of each box show the 25th and 75th percentiles. The figure shows that many students who borrowed private loans received interest rates below the federal rates.
Figure 2: Income Driven Repayment Example
Example of income based repayment plan at different salary levels for a student with $50,000 in loans. The figure shows how income based repayment allows students to defer payments to a later date.
Figure 3: Student Categories: Credit Data
Categorization of student type in credit data. These categorizations depend on the observed amount borrowed in federal loans and are based on the federal annual borrowing limits faced by different types of student.
Figure 4: Difference in probability of borrowing a private loan relative to undergraduate borrowers

Notes: Change in probability of borrowing a private loan by student type. Base category is undergraduate students. Figure shows that all graduate student types reduced use of private loans relative to undergraduate students (who increased private loan use). Controls in 4b include race, age, gender, EFC, school type, first year school fixed effects, program fixed effects, have kids, dependent, and married.
Figure 5: Difference in credit scores between students with and without private loans

Notes: Each point is an estimated $\delta_g$ coefficient from Equation 5. Each coefficient shows how the credit scores of students with private loans differ from students, in the same category, with only federal loans. Controls include academic year fixed effects, month open fixed effects, trade number and student type. Standard errors clustered at the state academic year. Mean credit score in whole sample is 644.
Figure 6: Median Interest Rate by Credit Score Group

Notes: Sample is restricted to graduate student borrowers in the credit data. Interest rates calculated using private loans lent to graduate students. Each point represents 5% of the sample of graduate private loans.
Figure 7: Summary of predicted private loan interest rates

Notes: This figure summarizes the percentage of borrowers whose predicted private loan interest, in the first month of borrowing each academic year, is below the Federal Stafford (leftmost bar) or PLUS rate (middle bar). The rightmost bar shows the percentage of students in the credit data who have a private loan. A large percentage of students have predicted rates below the federal rate, but very few have private loans. Four interest rates are predicted for each person: one for each of the 3 largest lenders and one for all the other lenders. The interest rate assigned to each individual is the smallest of these four rates. One observation is a student-year combination.
### Table 1: Summary of Stafford Loan Annual Limits

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stafford Subsidized Loans (All)</td>
<td>8,500</td>
<td>8,500</td>
<td>65,500</td>
<td>65,500</td>
</tr>
<tr>
<td>Stafford Subsidized + Unsubsidized Loans</td>
<td>18,500</td>
<td>20,500</td>
<td>138,500</td>
<td>138,500</td>
</tr>
<tr>
<td>Stafford Subsidized + Unsubsidized (Health A)</td>
<td>38,500</td>
<td>40,500</td>
<td>189,125</td>
<td>224,000</td>
</tr>
<tr>
<td>Stafford Subsidized + Unsubsidized (Health B)</td>
<td>45,167</td>
<td>47,167</td>
<td>189,125</td>
<td>224,000</td>
</tr>
<tr>
<td>Stafford Subsidized + Unsubsidized (Health A)</td>
<td>31,000</td>
<td>33,000</td>
<td>189,125</td>
<td>224,000</td>
</tr>
<tr>
<td>Stafford Subsidized + Unsubsidized (Health A)</td>
<td>35,167</td>
<td>37,167</td>
<td>189,125</td>
<td>224,000</td>
</tr>
</tbody>
</table>

Notes: Health students can borrow the most in federal Stafford loans.
Health A students are enrolled in the following programs: Doctor of Allopathic Medicine, Doctor of Osteopathic Medicine, Doctor of Dentistry, Doctor of Veterinary Medicine, Doctor of Optometry, or Doctor of Podiatric Medicine.
Health B students are enrolled in the following programs: Doctor of Pharmacy, Graduate of Public Health, Doctor of Chiropractic, Doctoral Degree in Clinical Psychology or a Masters or Doctoral Degree in Health Administration.
Table 2: Summary of NPSAS Surveys

<table>
<thead>
<tr>
<th></th>
<th>Pre-PUS 2004</th>
<th>Post-PUS 2008</th>
<th>Post-PUS 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>32.5</td>
<td>32.4</td>
<td>32.3</td>
</tr>
<tr>
<td>% Female</td>
<td>57.8</td>
<td>59.9</td>
<td>60.3</td>
</tr>
<tr>
<td>% White</td>
<td>67.8</td>
<td>66.7</td>
<td>63.6</td>
</tr>
<tr>
<td>% Black</td>
<td>9.6</td>
<td>11.7</td>
<td>11.8</td>
</tr>
<tr>
<td>% Hispanic</td>
<td>7.9</td>
<td>8.0</td>
<td>8.7</td>
</tr>
<tr>
<td>% “Health A”</td>
<td>4.4</td>
<td>2.8</td>
<td>3.3</td>
</tr>
<tr>
<td>% “Health B”</td>
<td>2.3</td>
<td>2.4</td>
<td>3.8</td>
</tr>
<tr>
<td>% Other</td>
<td>93.3</td>
<td>94.8</td>
<td>92.9</td>
</tr>
<tr>
<td>Percent Borrow</td>
<td>40.0</td>
<td>42.7</td>
<td>45.1</td>
</tr>
<tr>
<td>Percent Borrow: Master’s</td>
<td>38.3</td>
<td>43.6</td>
<td>45.7</td>
</tr>
<tr>
<td>Percent Borrow: Doctoral</td>
<td>28.3</td>
<td>31.8</td>
<td>27.8</td>
</tr>
<tr>
<td>Percent Borrow: First Professional</td>
<td>74.6</td>
<td>78.7</td>
<td>80.8</td>
</tr>
<tr>
<td>Mean Amount Borrowed *</td>
<td>18,590</td>
<td>19,481</td>
<td>20,474</td>
</tr>
<tr>
<td>Mean Loan to COA Ratio*</td>
<td>0.67</td>
<td>0.68</td>
<td>0.67</td>
</tr>
<tr>
<td>Mean Private to COA Ratio**</td>
<td>0.26</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>Mean PLUS to COA Ratio**</td>
<td>0</td>
<td>0.14</td>
<td>0.30</td>
</tr>
<tr>
<td>N</td>
<td>10,894</td>
<td>14,166</td>
<td>15,958</td>
</tr>
</tbody>
</table>

Notes: Table summarizes personal and program characteristics of graduate students in each NPSAS sample. It shows that the composition of graduate students has not changed much over time.

* Restricts to students with a federal loan.

** Restricts to those with a federal loan who borrow outside the Stafford program.
Table 3: Difference in probability of having a private loan by student type

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>-0.00477</td>
<td>-0.0697***</td>
<td>-0.0346</td>
<td>-0.0434</td>
<td>-0.162***</td>
<td>0.0223**</td>
<td>-0.000962</td>
</tr>
<tr>
<td></td>
<td>(0.00523)</td>
<td>(0.0186)</td>
<td>(0.0413)</td>
<td>(0.0402)</td>
<td>(0.0222)</td>
<td>(0.00837)</td>
<td>(0.000867)</td>
</tr>
<tr>
<td>Regression Adjusted:</td>
<td>-0.0134***</td>
<td>-0.109***</td>
<td>-0.0308</td>
<td>-0.0402</td>
<td>-0.222***</td>
<td>0.0111**</td>
<td>-0.0118**</td>
</tr>
<tr>
<td></td>
<td>(0.00482)</td>
<td>(0.0206)</td>
<td>(0.0397)</td>
<td>(0.0415)</td>
<td>(0.0247)</td>
<td>(0.00952)</td>
<td>(0.00520)</td>
</tr>
<tr>
<td>Raw: Prob Borrow</td>
<td>-0.0635***</td>
<td>-0.168***</td>
<td>-0.126</td>
<td>-0.144</td>
<td>-0.224***</td>
<td>-0.0212</td>
<td>-0.0172</td>
</tr>
<tr>
<td>Private: COA &gt;</td>
<td>(0.0103)</td>
<td>(0.0311)</td>
<td>(0.0783)</td>
<td>(0.0970)</td>
<td>(0.0256)</td>
<td>(0.0154)</td>
<td>(0.0124)</td>
</tr>
<tr>
<td>Stafford Limit</td>
<td>-0.0636***</td>
<td>-0.203***</td>
<td>-0.0710</td>
<td>-0.147</td>
<td>-0.275***</td>
<td>-0.0244*</td>
<td>-0.0214***</td>
</tr>
<tr>
<td></td>
<td>(0.00969)</td>
<td>(0.0351)</td>
<td>(0.0688)</td>
<td>(0.104)</td>
<td>(0.0264)</td>
<td>(0.0144)</td>
<td>(0.00087)</td>
</tr>
</tbody>
</table>

Notes: The probability of having a private loan decreased for almost all graduate student types. Robust standard errors. Controls include those for gender, age, budget, EFC, budget, school type, year in school and program.

Table 4: Treatment Intensity: Amount borrowed outside Stafford Program

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COA - Limit</td>
<td>0.221***</td>
<td>0.193***</td>
<td>0.221***</td>
<td>0.199***</td>
<td>0.221***</td>
<td>0.214***</td>
<td>0.221***</td>
<td>0.210***</td>
</tr>
<tr>
<td></td>
<td>(0.0421)</td>
<td>(0.0311)</td>
<td>(0.0423)</td>
<td>(0.0340)</td>
<td>(0.0421)</td>
<td>(0.0373)</td>
<td>(0.0423)</td>
<td>(0.0365)</td>
</tr>
<tr>
<td>post \times COA -</td>
<td>0.00458</td>
<td>0.0118</td>
<td>-0.00880</td>
<td>-0.0140</td>
<td>-0.205***</td>
<td>-0.197***</td>
<td>-0.185***</td>
<td>-0.187***</td>
</tr>
<tr>
<td>Limit</td>
<td>(0.0577)</td>
<td>(0.0399)</td>
<td>(0.0571)</td>
<td>(0.0413)</td>
<td>(0.0427)</td>
<td>(0.0383)</td>
<td>(0.0432)</td>
<td>(0.0377)</td>
</tr>
<tr>
<td>Controls</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Excludes 2012</td>
<td>20452</td>
<td>20452</td>
<td>11305</td>
<td>11305</td>
<td>20452</td>
<td>20452</td>
<td>11305</td>
<td>11305</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Students with access to PLUS loans do not borrow more above the Stafford limit, but they do replace private with PLUS loans almost one for one. Standard errors clustered at group first year level. Controls include those for gender, race, EFC, school type, survey-year year in school FE, program FE. Amounts are in 2008 dollars. Sample is restricted to students who face a cost of attendance beyond the Stafford limit.
Table 5: Treatment Intensity: Compare to Undergraduates

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COA - Limit</td>
<td>post × COA - Limit</td>
<td>graduate × COA - Limit</td>
<td>post × graduate × COA - Limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.138*** (0.00738)</td>
<td>-0.00572 (0.0109)</td>
<td>0.0823* (0.0425)</td>
<td>0.0115 (0.0584)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.121*** (0.00741)</td>
<td>-0.00310 (0.00944)</td>
<td>0.0771** (0.0314)</td>
<td>0.0166 (0.0401)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.121*** (0.00820)</td>
<td>0.0155* (0.00820)</td>
<td>0.0836** (0.0346)</td>
<td>0.0146 (0.0414)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0585*** (0.0123)</td>
<td>-0.00257 (0.0123)</td>
<td>0.162*** (0.0420)</td>
<td>0.0027 (0.0442)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0485*** (0.0120)</td>
<td>-0.00190 (0.0120)</td>
<td>0.166*** (0.0378)</td>
<td>0.0018 (0.0404)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0489*** (0.00588)</td>
<td>0.0315*** (0.00588)</td>
<td>0.167*** (0.0367)</td>
<td>0.219*** (0.0384)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: The replacement of private loans with PLUS loans is graduate student specific. Standard errors clustered at group first year level. Controls include those for gender, race, EFC, school type, survey-year year in school FE, program FE. Amounts are in 2008 dollars. Sample is restricted to students who face a cost of attendance beyond the Stafford limit.

Table 6: Summary of Credit Scores

<table>
<thead>
<tr>
<th></th>
<th>(1) Mean Credit Score: All Borrowers</th>
<th>(2) Median Credit Score: All Borrowers</th>
<th>(3) Median Credit Score: Borrowers with Private Loan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate Students</td>
<td>644</td>
<td>652</td>
<td>672</td>
</tr>
<tr>
<td>Health A</td>
<td>709</td>
<td>725</td>
<td>710</td>
</tr>
<tr>
<td>Health B</td>
<td>692</td>
<td>705</td>
<td>702</td>
</tr>
<tr>
<td>Other</td>
<td>672</td>
<td>681</td>
<td>697</td>
</tr>
</tbody>
</table>

Notes: Credit scores before borrowing in the 2011 - 2014 academic year. All borrowers includes students who are not categorized as graduate students. Median scores suggest advantageous selection into federal loans.

Table 7: Extra Amount Paid for Federal Loans

<table>
<thead>
<tr>
<th></th>
<th>(1) Amount over 10 Years</th>
<th>(2) Monthly Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students with Rate &lt; PLUS</td>
<td>4,162</td>
<td>35</td>
</tr>
<tr>
<td>Students with Rate &lt; Stafford</td>
<td>3,462</td>
<td>29</td>
</tr>
<tr>
<td>Other Students with Rate &lt; PLUS</td>
<td>4,612</td>
<td>38</td>
</tr>
<tr>
<td>Other Students with Rate &lt; Stafford</td>
<td>3,471</td>
<td>29</td>
</tr>
<tr>
<td>Health A Students with Rate &lt; PLUS</td>
<td>13,178</td>
<td>111</td>
</tr>
<tr>
<td>Health A Students with Rate &lt; Stafford</td>
<td>12,539</td>
<td>104</td>
</tr>
<tr>
<td>Health B Students with Rate &lt; PLUS</td>
<td>5,965</td>
<td>50</td>
</tr>
<tr>
<td>Health B Students with Rate &lt; Stafford</td>
<td>5,952</td>
<td>50</td>
</tr>
</tbody>
</table>

Notes: Sample is restricted to graduate student borrowers. Estimates use same predicted interest rates in Figure 7. For students with a predicted rate below the PLUS rate I restrict to those who likely borrowed PLUS loans. Similarly, for those with a predicted rate below the Stafford rate I restrict to those who likely borrowed unsubsidized Stafford loans.
Table 8: Estimated coefficients of relative risk aversion

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>Health A Students</td>
<td>0.46</td>
<td>0.30</td>
</tr>
<tr>
<td>Health B Students</td>
<td>0.70</td>
<td>0.43</td>
</tr>
<tr>
<td>Other: Assuming Law</td>
<td>1.89</td>
<td>1.08</td>
</tr>
<tr>
<td>Other: Assuming Masters</td>
<td>0.84</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Notes: Estimated coefficients of risk aversion that rationalize borrowing federal loans over private loans. Sample is restricted to students who have at least one predicated private interest rate below the relevant federal rate. Left panel uses borrowing from the 2011 - 2014 year and the right panel uses more recent credit reports to estimate the total borrowed.

Table 9: Consumption value of federal loans

<table>
<thead>
<tr>
<th>γ</th>
<th>Health A</th>
<th>Health B</th>
<th>Other - Law</th>
<th>Other - Masters</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ = 0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>γ = 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed Borrowing 2011 - 2014</td>
<td>[302, 1558, 4070]</td>
<td>[50, 302, 553]</td>
<td>[-201, 50, 50]</td>
<td>[50, 50, 302]</td>
</tr>
<tr>
<td>Estimated Total Borrowed</td>
<td>[2563, 4322, 6834]</td>
<td>[301, 804, 1809]</td>
<td>[-201, 50, 302]</td>
<td>[50, 50, 1307]</td>
</tr>
<tr>
<td>γ = 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed Borrowing 2011 - 2014</td>
<td>[1809, 5075, 10101]</td>
<td>[302, 804, 2312]</td>
<td>[50, 50, 553]</td>
<td>[50, 302, 1307]</td>
</tr>
<tr>
<td>Estimated Total Borrowed</td>
<td>[3819, 6583, 11106]</td>
<td>[804, 1558, 3317]</td>
<td>[50, 302, 1307]</td>
<td>[50, 553, 2060]</td>
</tr>
</tbody>
</table>

Notes: Consumption value from having federal loans each year. Sample is restricted to students who have at least one predicated private interest rate below the relevant federal rate. Calculations based on the total amounts borrowed from 2011 - 2014.

Table 10: Modifications & Robustness: Estimated coefficients of relative risk aversion

<table>
<thead>
<tr>
<th></th>
<th>Health A</th>
<th>Health B</th>
<th>Other - Law</th>
<th>Other - Masters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Year by year</td>
<td>[0.05, 0.15, 0.33]</td>
<td>[0, 0.28, 0.60]</td>
<td>[0.38, 0.78, 1.40]</td>
<td>[0, 0.50, 0.93]</td>
</tr>
<tr>
<td>2. Assuming above median</td>
<td>[0.43, 0.50, 0.65]</td>
<td>[3.71, 9.60, 15]</td>
<td>[2.10, 15, 15]</td>
<td>[1.38, 2.55, 15]</td>
</tr>
<tr>
<td>3. Assuming below median</td>
<td>[0, 0.10, 0.40]</td>
<td>[0, 0.08, 0.55]</td>
<td>[0.53, 0.83, 1.23]</td>
<td>[0, 0.55, 0.85]</td>
</tr>
<tr>
<td>4. Assume above median &amp; PAYE**</td>
<td>[0.33, 0.40, 0.53]</td>
<td>[1.08, 4.63, 15]</td>
<td>[1.28, 2.75, 15]</td>
<td>[0.73, 1.60, 2.98]</td>
</tr>
<tr>
<td>5. Variable private interest rate</td>
<td>[15,15,15]</td>
<td>[6.78,15,15]</td>
<td>[15,15,15]</td>
<td>[15,15,15]</td>
</tr>
<tr>
<td>6. Allow for default</td>
<td>[0.15,0.30,0.45]</td>
<td>[0.15,0.43,0.78]</td>
<td>[0.63,1.08,1.75]</td>
<td>[0.30,0.73,1.18]</td>
</tr>
<tr>
<td>7. Increase Minimum consumption</td>
<td>[0.18, 0.30, 0.48]</td>
<td>[0.18, 0.45, 0.80]</td>
<td>[0.63, 1.10, 1.78]</td>
<td>[0.30, 0.73, 1.18]</td>
</tr>
<tr>
<td>8. Allow for tax on forgiven portion</td>
<td>[0.25, 0.38, 0.53]</td>
<td>[0.43, 0.68, 1.05]</td>
<td>[0.78, 1.18, 1.80]</td>
<td>[0.53, 1.00, 1.48]</td>
</tr>
<tr>
<td>9 Family income</td>
<td>[0.25, 0.35, 0.53]</td>
<td>[0.28, 0.53, 0.95]</td>
<td>[0.65, 1.05, 1.75]</td>
<td>[0.33, 0.63, 1.08]</td>
</tr>
</tbody>
</table>

Notes: Estimated coefficients of risk aversion changing the model assumptions from Table 8. Estimates are based on observed borrowing from 2011 - 2014.
** Assuming all students eligible and enroll in PAYE (pay 10% of income for a maximum of 20 years toward federal loans)
References


—, “Private Student Loans,” 2012.


Rosenblatt, RA and CH Andrilla, “The Impact of US Medical Students’ debt on Their Choice of Primary Care Careers: An Analysis of Data from the 2002 Medical School Graduation Questionnaire,” Academic Medicine, 2005.


A Data Appendix

A.1 Sample of Borrowers

I focus on people who borrowed student loans between January 2011 - September 2014 aged 24 - 35 in September 2014. These students would have been 21 - 32 when borrowing for their education. An academic year ($t$) is defined as July of year $t − 1$ to June of year $t$. For example the 2012 academic year includes July 2011 - June 2012. Credit data is generally organized in archives. One archive is a snapshot of an individual’s credit report on that date. Any loans or assets that were opened within the 10 years of an archive date will appear in that snapshot. For each archive I see the most recent 24 months of balance, loan amount and repayment data in each archive. I focus on the September 2014 archive. Unfortunately, loans borrowed before July 2010 cannot be categorized into private or federal loans.

When cleaning the data I focus on students who are borrowing new loans and whose loan amounts and accounts can be clearly identified. In order to do this I also drop students whose loans go “bad” within 6 months of opening. While these students are interesting, they are not the relevant population for this paper. I also drop students whose initial amount borrowed is difficult to determine.

Student loans can be transferred across banks or between different branches of banks a number of times. When a loan is transferred a new account is opened for that same loan, with another lender, and the same open date. I attempt to track transferred accounts by using the transfer months and the amount borrowed. I do allow for increases in the amount borrowed in the 12 months that I can track these changes. I drop students whose accounts are transferred, but I am unable to match the transferred account to the newest version of the account. By dropping students whose transferred loans I cannot follow I drop about 3.43% of the student-academic year combinations.

Finally, there are some students whose original loan amount is over the maximum Stafford amount anyone can borrow. I drop students whose first loan amount is this value upon opening. Some of this may be due to lenders reporting multiple Stafford loans in one trade, but I cannot determine the type of student or loans borrowed when this occurs. This could also be due to students consolidating their federal loans. This leads me to drop about 1.2% of my sample.

After cleaning I retain 84% of the “good” student-academic year combinations in my sample (meaning they did not go into default or a bad status within 6 months of opening), a large majority of my sample.
A.2 Alternative Student Types

Throughout this analysis I assume that a student falls into the Health A, Health B or Other category if they have been categorized as being in one of these groups in any of the years in which they borrow (from 2011 - 2014). As previously described, in the event of a tie I give preference to Health A, Health B and then Other students. In this section I show that when this definition changes the percentage of students that fall into each category does not change much.

As an alternative I categorize students in one other way. I give students a category in the year that a type has been identified and assume they fall into that type for following years. When doing this I also allow for students to first be identified as an Other student who then pursues a Health A or Health B program. Table A.1 describes the percentage of student-years that fall into each category based on this definition. Overall, the percentage of Other student-year combinations decreases by 2.2 percentage points. The percentage of Health B student-year combinations decreases by 0.2 percentage points and the percentage of Health A combinations decreases by 0.23 percentage points.

Table A.1: Summary of Credit Data: Alternative Student Type

<table>
<thead>
<tr>
<th></th>
<th>(1) Percent Graduate</th>
<th>(2) Health A Graduate</th>
<th>(3) Health B Graduate</th>
<th>(4) Other Graduate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>24.8</td>
<td>0.87</td>
<td>0.97</td>
<td>18.8</td>
</tr>
<tr>
<td>2012</td>
<td>27.4</td>
<td>1.30</td>
<td>1.46</td>
<td>27.3</td>
</tr>
<tr>
<td>2013</td>
<td>32.0</td>
<td>1.47</td>
<td>1.64</td>
<td>29.1</td>
</tr>
<tr>
<td>2014</td>
<td>34.3</td>
<td>1.75</td>
<td>1.90</td>
<td>32.8</td>
</tr>
<tr>
<td>Total</td>
<td>28.8</td>
<td>1.31</td>
<td>1.46</td>
<td>26.5</td>
</tr>
<tr>
<td>NPSAS 2012</td>
<td>28.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPSAS 2012 with Stafford Max</td>
<td>3.7</td>
<td>1.7</td>
<td>27.2</td>
<td></td>
</tr>
<tr>
<td>NPSAS 2012 All Graduate Borrowers</td>
<td>6.7</td>
<td>6.3</td>
<td>87.0</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Column 1 describes the percent of total borrowers in the sample, each academic year, who can be classified as graduate students. Columns 2 - 4 describe the percentage of graduate students who can be classified into finer groups of students. To make this categorization I assume that students who borrow exactly $40,500 in federal loans are Health A students, those who borrow exactly $33,000 fall into the Health B category and those who borrow exactly $20,500 fall into the Other category.

A.3 Calculating Interest Rates

Since the data spans from September 2012 - August 2014, but the loans I focus on can be opened as early as July 2010 and late as June 2014, some loans have the full 24 months of data and others have significantly less. For each loan I try to back out an interest rate using each of the formulas below. I combine the results from these formulas to create the likely stream of interest rates. The formula used depends on whether loans are in repayment or deferred. When loans are deferred simple interest is accrued and once in repayment loans function like any other loan. In the equations below $t$ indexes a month.
First is the standard equation to back out an interest rate month to month:

\[
Rate_{t+1} = 12\left(\frac{Balance_{t+1} + Payment_{t+1} - \Delta \text{AmtBorrowed}_t}{Balance_t}\right).
\] (8)

Next I use a method that allows for the fact that some loans may have capitalized over, or were not updated for, \(n\) months

\[
Rate_{t+n} = \frac{Rate_{t+1}}{n}.
\] (9)

As previously mentioned, loans have a simple interest rate when deferred. Payment during the deferred period can complicate the calculated interest rate. To allow for payments during deferment I estimate the following:

\[
Rate_t = \frac{\text{InterestAccrued}_t}{\text{Principal}_{t-1} \times \text{Months}_t}
\] (10)

where

\[
\text{InterestAccrued}_t = Balance_t + Payment_t \times \text{Principal}_{t-1} - \Delta \text{AmtBorrowed}_t + \text{InterestPaid}_t
\].

Using the data I create the following:

- \(\text{Principal}_t\)
  - First I back out the principal of the loan over time using the original loan (OLA) and amounts.
  - For loans borrowed after September 2012 I can see the initial amounts borrowed and call this the initial principal amount. When balances are below the amount borrowed I this is the new principal amount.
  - For loans borrowed before September 2012 I must make assumptions about the principal in the first month I see (September 2012)
    * If balance < OLA : I assume the Balance is the current principal
    * If balance > OLA: Assume balance is such that no payments occurred and the principal is the OLA
    * 40% of loans that are deferred in September 2012 and were borrowed before 09/2012 have balance = OLA in which case the OLA is assumed to be the principal
• **PrincipalPaid**: Amount of principal that was covered by the payment. If a payment occurs and the principal decreases then I can calculate the fraction of the payment that went toward the principal amount.

• **InterestPaid**: Amount of interest that the payment covered.
  - If the principal does not change then all of the payment went toward the principal
  - If the balance is not equal to the principal then all the interest has not been paid

• **Months**: Using the payment and principals, I can count the number of months that interest has been accruing.

• When OLA changes (which can occur in an academic year) and Months > 1 the above formula changes slightly because interest has accrued for M months on the initial principal and is accruing at the same rate on the added principal. Failing to take this into account can yield underestimates of the interest rate. In these cases the formula becomes:

\[
Rate(t) = \frac{InterestAccrued_t}{Principal_t \times Months_t + NewHC_t \times Months_t}
\]

  - **Principal**: Principal before the high credit change
  - **NewHC**: Change in high credit
  - **Months**: Months since the change in high credit

Finally, I also make use of the reported scheduled payments and loan terms to calculate the interest rates associated with each loan. I solve for Rate in the following equation:

\[
ScheduledPayment_t = \frac{HighCredit_t \times \frac{Rate_t}{12}}{(1 - (1 + \frac{Rate_t}{12})^{(-TermLength)})}
\]

For loans that are deferred I assume that the scheduled payment is the interest that has accrued and estimate the interest rate as

\[
Rate_t = 12 \times \frac{ScheduledPayment_t}{HighCredit_t}
\]

For each of these formulas I create a set of 23 indicators that describes whether the rate I back out will be reliable based on the available inputs. Thus, when combining rates I do not include rates that were backed out using insufficient data. For loans that are not deferred I use Equation 9 to back out the interest rates followed by 11 if the previous formula yields no result. For deferred loans I use Equation 10 and incorporate Equation 12 if no rate has been estimated.
Table A.2 summarizes the estimated interest rates, winsorized at the 2% level, using the methodology described above for graduate students who borrowed private loans. Interest rates are summarized for the 2011 and 2012 academic years combined. The table also depicts private loan interest rates in the 2011 and 2012 academic years from the CFPB’s sample of private loans data.

When comparing these samples there are important differences to note. While the credit sample contains all loans originated in the 2012 academic year (July 2011 through June 2012) the CFPB sample only contains loans originated from August - December 2011 in that year. The CFPB sample contains 9 major lenders that contributed to the sample while the credit data contains all lenders that indicate lending a student loan. Therefore, this sample contains many of the smaller lenders such as local credit unions.

Table A.2: Summary of Private Loan Interest Rates in 2011 - 2012 Academic Years

<table>
<thead>
<tr>
<th></th>
<th>(1) Credit Data</th>
<th>(2) CFPB Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>25th Percentile</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Median</td>
<td>0.0803</td>
<td>0.0799</td>
</tr>
<tr>
<td>75th Percentile</td>
<td>0.098</td>
<td>0.09625</td>
</tr>
<tr>
<td>Mean</td>
<td>0.087</td>
<td>0.076</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.0539</td>
<td>0.026</td>
</tr>
<tr>
<td>N</td>
<td>132985</td>
<td>66237</td>
</tr>
</tbody>
</table>

Table A.2 shows that the credit data and CFPB samples have a similar medians of 8.03% and 7.99%, respectively. The interquartile ranges (IQR) are also similar with the CFPB sample having an IQR of 3.625% and the credit data having an IQR range of 3.8%. The mean and standard deviation of the interest rates in the credit data are larger than in the CFPB sample. Some of this difference may be due to calculation issues that result from my assumptions or from the data that is reported. This difference may also result from the fact that the credit sample contains smaller lenders who may service different populations of borrowers. For example, schools may negotiate terms for foreign students with local private lenders or some private lenders may be willing to lend to “riskier” students that large private lenders may not service. These differences may also contribute to the higher mean interest rates calculated off of credit data. Winsorizing the sample at the 10% level yields a standard deviation of 3.54% and mean of 8.27%, closer to what is in the CFPB sample.

---

65 In general, most loans have an open date in August or September of the academic year in which they are borrowed.

66 Credit sample of private student lenders are lenders that the author has found not to be: Department of Education direct loans, Perkins loans, Institutional loans.
A.4 Supplemental Data Sources

I use a number of data sources to conduct my analysis. The main data sources for this paper are the Equifax Inc. data and the National Postsecondary Student Aid Surveys from 2004, 2008 and 2012 summarized in Section 3. I also use data from the Integrated Postsecondary Education Data System (IPEDS) and the American Community Survey (Ruggles et al., 2015).

IPEDS

IPEDS contains yearly information on universities in the United States and Title IV participating universities (meaning those that participate in federal financial aid programs). Within IPEDS I specifically make use of the award, enrollment and tuition information. Enrollment and tuition data is used to study changes in graduate student enrollment and costs after the introduction of graduate PLUS loans as in Section D.1.

Award data describes the degrees that are awarded by university each year and is used to model the probability that students are enrolled in specific programs based on their zip code. While using enrollment information by university and degree program would be more helpful, IPEDS only contains enrollment information on Lawyers, Dentists and Medical students who make up a part of the programs in which I am interested. More importantly, for students that I can categorize as falling in the “Health A” and “Health B” programs I cannot update the probability they are enrolled in specific programs given this information. Since these are the students I can model more accurately I use the award information, from the 2014 academic year, and assume that the percentage of degrees awarded by a university is the same as the percentage of students enrolled in that degree. The correlation between the probability that students are enrolled in dental, medical or law programs using the award data and using the enrollment data is larger than 0.7 for each degree type at the university and state levels. Using award level data tends to underestimate the probability students are enrolled in these programs.

ACS

I use the 2013 American Community Survey 5-year estimates to model the wage distribution borrowers may face upon graduation. I focus on full time workers with graduate degrees, age 25 - 64, and calculate income distributions at the state level by occupation and age group. I use a total of 5 age groups that represent ages 25 - 28, 29 - 32, 33 - 36, 27 - 40 and 41-64. Allowing for more age groups does not much change the wages for ages 41+ and does not change the estimated risk aversion thresholds. Age functions as a proxy for experience. The first age group is used to model the first four years of work, the second to model the following four years, etc. While imperfect, this
methodology enables me to model a 30 year work life for each individual.

For each age group I calculate the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Because these age groups are somewhat fine, I do not always have more than 10 observations for a state-occupation-age combination. In these instances I estimate the percentiles for that state-occupation combination (for all ages) using the census bureau division of which the state is part. For example, if there are 9 observations in the Iowa’s 25-28 Health A group then I model all of the age groups for Health A in Iowa using the West North Central Division which includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota. There are a total of 9 census bureau divisions.

One benefit of the ACS is its relatively large sample size of over 500,000 observations after restricting to full-time workers with a graduate degree, ages 25 - 64. The ACS also contains detailed information on the age, state and occupations for each worker enabling me to separate physicians from dentists, pharmacists, etc. Guvenen (2009) shows there is a large variance in the relationship between income and experience among those with a college education. It is likely that this is true for those with a graduate education as well. By modeling multiple wage paths for each occupation-state I allow for some heterogeneity in the population.

The ACS also has its limitations. The biggest limitation stems from the fact that it contains cross sectional data. Due to this fact, I am unable to model transitory shocks. I am also unable to allow for movement across percentiles, borrower movement to different locations (or states), and the fact that future occupations and loans may be jointly determined. Unfortunately, available panel data like the PSID or the NLSY have very few graduate students. More importantly, the degree and occupation information is not as detailed as what is available in the ACS making it impossible to separate physicians from pharmacists, for example.

B Out of Sample Estimation

In order to find the specification that best predicts the interest rates students receive in the private market for student loans I make use of OLS regressions, lasso regression and random forest techniques with k-fold cross validation. These techniques are geared toward finding the best out of sample predictions. I estimate private loan interest rates as a function of variables lenders may use to price loans using these methodologies and use the estimated coefficients to predict the interest rates students who did not borrow private loans would have received had they borrowed private loans.

I use OLS to model interest rates as a function of variables lenders may use when pricing loans.
In particular I use student type, credit score, other credit report attributes and the interactions between these variables. I also include the probability that students are in specific school and programs based on the universities that are within 11 miles of their zip code, the probability students are in particular programs (medical, dental, etc) based on their zip code, county or state. To determine which model has the best out of sample fit I use 5-fold (k-fold) cross validation. With 5-fold cross validation the regression is estimated on 80% of the sample and fit to the remaining 20% of the sample 5 times. I average the out of sample root mean squared error (RMSE) for each trial to determined which model yields the lowest RMSE and has the best out of sample fit. With this methodology I find that including the probability that students are in specific schools and programs based on universities that are within an 11 mile radius of students’ zip codes when borrowing reduces the RMSE. For students whose zip codes are not 11 miles from a university, including the probability that students are enrolled in specific programs (medical, dental, etc) based on the state they live further reduces the RMSE.

After employing the k-fold methodology I focus on the model with the lowest average RMSE and use lasso regression analysis, a shrinkage technique, to predict interest rates. Lasso regression constrains the absolute value of the regression coefficients and is useful when dealing with highly correlated predictors. Once again I use 5-fold cross validation to evaluate the out of same RMSE. I find that employing a lasso regression does not improve the overall fit relative to OLS. Thus, I do not predict interest rates using this method. Lasso regression analysis is particularly useful when the ratio of observations to variables is very low, which is not the case in my sample.

I have also used the same predictors in a random forest technique. Using tree-based models allows for situations in which the relationship between the dependent variable and a predictor is conditional on the value of other predictors. This allows for more freedom in the “shape” of the model, and allows for more complex dependencies. I once again use 5-fold cross validation to evaluate the out of sample RMSE and to compare to the OLS cross validation results. The random forest technique does reduce the out of sample RMSE slightly relative to the OLS model.

To determine whether the random forest technique is preferable to the OLS model I compare the out of sample predictions from both models. To do this I estimate the OLS model on 80% of the private loan sample and estimate the predicted interest rates on the remaining 20% of the sample. I do this five times and Table B.1 depicts the fraction of predictions that are correct using this specification. The table also shows how this prediction compares to the true fraction of individuals whose rate is below the government rates. I implement the same out of sample procedure using the random forest estimates, the results of which also shown in Table B.1.

Overall, among private loans not used to estimate interest rates by OLS, 28.9% of trades have a
rate that is below the Stafford rate and 42.6% of trades have a rate below the PLUS rate. The out
of sample predictions find that 17.2% of trades have a predicted rate below the Stafford rate and
41.3% have a predicted rate below the PLUS rates. These results indicate that the OLS predictions
yield rates that are slightly higher than what is observed in the data. Overall, 65 - 71% of the
categorizations based on these predicted interest rates are accurate. Table B.1 also indicates that
the out of sample prediction using the random forest technique is similar to that from the OLS
model. This is likely because I already incorporate many fixed effects into the OLS model. The
percentage of correct categorizations from the random forest technique is very similar to that from
the OLS model, thus I focus on the OLS model.

For the main results of this paper I focus on the OLS model of private interest rates. This
specification includes credit score, the square and cube of credit score, presence of a cosigner,
student type, academic year fixed effects, month borrowed fixed effects, presence of a trade that is
30 days past due within two months of borrowing, presence of a derogatory trade within 6 months
of borrowing, the age of the oldest trade and the number of open trades. The model also includes
controls for the probability that students are enrolled in specific programs (school and degree) for
zip codes within 11 miles of a university, the probability students are enrolled in certain degrees
based on their state if zip code probabilities are unavailable, lender fixed effects for the 3 largest
lenders, and interactions between academic year, lender, student type and credit score. Once
collinear variables are dropped the OLS model estimates 1,484 coefficients using approximately
239,000 observations. Winsorizing the sample at the 5% or 10% level significantly reduces the out

### Table B.1: Summary of Private Loan Interest Rates in 2011 - 2012 Academic Years

<table>
<thead>
<tr>
<th></th>
<th>(1) Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OLS Results</strong></td>
<td></td>
</tr>
<tr>
<td>True Percent Below Stafford Rate</td>
<td>28.9</td>
</tr>
<tr>
<td>True Percent Below PLUS Rate</td>
<td>42.6</td>
</tr>
<tr>
<td>Estimated Percent Below Stafford Rate</td>
<td>17.2</td>
</tr>
<tr>
<td>Estimated Percent Below PLUS Rate</td>
<td>41.3</td>
</tr>
<tr>
<td>Estimated Correctly Categorized: Above or Below Stafford</td>
<td>71.1</td>
</tr>
<tr>
<td>Estimated Correctly Categorized: Above or Below PLUS</td>
<td>64.5</td>
</tr>
<tr>
<td><strong>Random Forest Results</strong></td>
<td></td>
</tr>
<tr>
<td>True Percent Below Stafford Rate</td>
<td>32.8</td>
</tr>
<tr>
<td>True Percent Below PLUS Rate</td>
<td>48.5</td>
</tr>
<tr>
<td>Estimated Percent Below Stafford Rate</td>
<td>14.2</td>
</tr>
<tr>
<td>Estimated Percent Below PLUS Rate</td>
<td>40.5</td>
</tr>
<tr>
<td>Estimated Correctly Categorized: Above or Below Stafford</td>
<td>70.2</td>
</tr>
<tr>
<td>Estimated Correctly Categorized: Above or Below PLUS</td>
<td>65.8</td>
</tr>
</tbody>
</table>

Notes: Comparison of OLS predictions to predictions from a random forest model and the true interest rates. True percent is the average true categorization among the samples that were not used for prediction. These are the same individuals as those in the estimated samples.
of sample mean squared error, but in practice using these specifications to predict interest rates does not change the estimated interest rates by much. Thus I focus on the coefficients estimated using the sample winsorized at the 2% level.

Focusing on a 10% sample of all students, I find that failing to account for lender specific pricing does reduce the percentage of students whose predicted rate is below the federal rate. In this case, I find that 29%, 40% and 48% off the Other, Health A and Health B students have predicted rates below the PLUS interest rates. While lower than in the main results, this is substantially larger than the 3 - 5% of students who have any private loan. When excluding lender the distribution of interest rates among those with a predicted rate below the federal rates is similar to the distribution of predicted rates when allowing for pender specific pricing.

B.1 Selection

When estimating the prices of loans out of sample, one potential issue may be selection. More specifically, one may worry that there is selection among those who borrower private loans based on factors that the econometrician does not observe. In the case of auto loans and mortgages this may very well be the case as agents assess the home being bought or interview applicants. In the market for student loans major lenders have online applications and standardized forms that students fill out. The details of those applications may be checked, but otherwise there are no interviews and person-to-person interactions are not necessary. Additionally, the Private Student Loan Report (Consumer Finance Protection Bureau, 2012b) contains underwriting information and indicates that the observables I focus on are largely used by private lenders. One observable I am missing is the programs students attend, which I account for by including the probability students are enrolled in particular programs based on location. Thus, it is unlikely that lenders use additional observables when lending to borrowers. Another possible reason selection may be worrisome is if there is little to no overlap between the students who borrow federal loans and those who borrow private loans.

In an effort to assess whether there is a selection issue I predict interest rates using a Heckman two-step correction and the OLS model on a random 7% subsample of loans. The instrument used in the Heckman two-step is age, since age cannot legally be used when pricing loans. When estimating the OLS and Heckman correction I modify the variables used in estimation and include the probability students are enrolled in general programs (medicine, dental, etc) based on their zip codes rather than using the probability they are enrolled in specific programs (for example, Stanford Medical). I also exclude the lender specific controls. While controlling for specific programs does reduce out of sample RMSE, it does so by less than 5% and the correlation between the OLS
estimates I use and the estimated interest rates using the model with controls for specific programs (excluding lender) is 0.82. I find the predicted interest rates using the Heckman correction are very similar to those from the OLS regression. The correlation between the predictions is over 0.99 and less than 1% of loans are categorized differently when comparing to the Stafford or PLUS interest rates. Moreover, the coefficient on the inverse mills ratio is not statistically significant in the second step of the correction. Overall, these results suggest that selection is not much of an issue in my model of predicted interest rates. It is true that a smaller percentage of private loan borrowers fall into the category of subprime borrowers (with a credit score below 600 points). Overall about 32% of federal loan borrowers and 16% of private loan borrowers fall into the subprime category. To account for this issue I also estimate the main OLS regression restricting to borrowers who are not subprime, and fit the model to those who are not subprime. When doing this I find that the correlation between the predicted interest rates using this method and using the coefficients estimated from all observations is 0.98. Categorization of students as having a predicted interest rate below the federal rates is again very similar to what I find when using the main OLS model, with all observations.

C Modeling Variable Interest Rates

In this section I describe the method used to model risk associated with variable interest loans. I model yearly log libor 3 month interest rates from 2000 - 2015 using an AR(1) process. The Tauchen method enables me to use the coefficient on the lag interest rate and the mean squared error of the regression to discretize interest rates into multiple states. See Tauchen (1985) for details on the discretization. As a result, the method yields the values of the states and the corresponding transition matrix between states. I discretize interest rates into two states (high and low) and also into three states (high, medium and low). When allowing for two states I find that the low state corresponds to an interest rate of 0.3986 and the high state has an interest rate of 3.5734. The probability of staying in the same state is 0.9517 and the probability of transitioning to a different state the next year is 0.0483.

Allowing for three states yields a middle interest rate of 1.1934. In the 3 state scenario the high and low states are the same as in the 2 state scenario. The corresponding transition matrix is

$$ T = \begin{bmatrix}
0.7555 & 0.2402 & 0.0043 \\
0.1661 & 0.6678 & 0.1661 \\
0.0034 & 0.2402 & 0.7555
\end{bmatrix} $$

where the top row represents the probability of moving from the low state to the low state, middle state and high states respectively. In both the 2- and 3-state scenarios the lowest state of
0.3986 corresponds most with the LIBOR rates available when students first borrowed their loans. I use backward induction to solve for the expected utility associated with private loans when borrowing during the low state. In this case I assume students expect loans to accrue at the low interest rate while they are deferred. The results are very similar if I assume they accrue at the high interest rate while deferred, a more unrealistic and much stronger assumption.

When modeling the risk associated with variable interest rates I assume students are not considering the income driven repayment plan to assess how much variable interest rates may factor into the decision to borrow federal loans. In this scenario, consumption in the 11th year onward is equal in both the private and federal loan cases. Thus the final period is the 10th year, which has the following value functions (in the two state case):

\[ V_{10}^H = u(w - \text{payment}^H) \]
\[ V_{10}^L = u(w - \text{payment}^L). \]

The high and low value functions in the previous periods can be solved as:

\[ V_t^H = u(w - \text{payment}^H) + p^{HL}V_{t+1}^L + p^{HH}V_{t+1}^H \beta \]
\[ V_t^L = u(w - \text{payment}^L) + p^{LL}V_{t+1}^L + p^{LH}V_{t+1}^H \beta \]

and \( V_t^L \) represents the expected utility from borrowing a private loan. I compare this expected utility to that of borrowing a federal loan under the standard 10 year repayment plan.

\section*{D Changes in Borrowing, Tuition and Enrollment}

In this section I consider how access to PLUS loans changes students’ probability of borrowing outside the Stafford limit, loan to budget ratio, the total amount borrowed, tuition and enrollment.

\subsection*{D.1 Borrowing}

If students were credit constrained, due to an adverse credit history or federal loan limits, then the amount borrowed and loan to budget ratio should increase after the introduction of graduate PLUS loans and rising costs may lead students to borrow more. Enrollment, which I address in Section D.5, may also increases.

To do this I estimate Equations 1 and 2 in which \( y_{it} \) is an indicator for whether students borrow outside the Stafford program, the total amount borrowed and the loan to budget ratio. Table D.1
summarizes raw and regression adjusted estimates by student group from Equation 1. Rows 1 and 2 show that the probability of borrowing beyond the Stafford limit increased between the 2004 and 2008 - 2012 surveys for all student types. The regression adjusted increase (row 2) is highest among Health students, but is only statistically significant for Health A (column 2) and masters students (column 6). Some of this increase may be due to the decrease in Stafford limit and increase in COA in real terms. Among graduate students as a whole, there was a 2.2 percentage points (pp) increase in the probability of borrowing above the Stafford limit, even after controlling for COA and EFC. When focusing on students whose COA is above their Stafford limit, as in row 3, the raw difference in probability of borrowing above the Stafford limit seems to have increased. The increase is only statistically significant for Masters students once controls are included.

Table D.1: Difference in loan use by program

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw: Prob Borrow &gt; Stafford Limit</td>
<td>Total</td>
<td>Health A</td>
<td>Health B</td>
<td>1st P</td>
<td>Health B</td>
<td>Other</td>
<td>1st P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression Adjusted: Prob Borrow &gt; Stafford Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0042***</td>
<td>0.130***</td>
<td>0.0627***</td>
<td>0.212***</td>
<td>0.0459***</td>
<td>0.0178*</td>
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<td>(0.00507)</td>
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<td>(0.00936)</td>
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<tr>
<td>Raw: Prob Borrow &gt; Stafford Limit, students with COA &gt; Stafford Limit</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.0055***</td>
<td>0.130***</td>
<td>0.0627***</td>
<td>0.212***</td>
<td>0.0459***</td>
<td>0.0178*</td>
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</tr>
<tr>
<td>(0.00409)</td>
<td>(0.0169)</td>
<td>(0.0216)</td>
<td>(0.0172)</td>
<td>(0.00652)</td>
<td>(0.00407)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw: Amount Borrowed</td>
<td>Total</td>
<td>Health A</td>
<td>Health B</td>
<td>1st P</td>
<td>Health B</td>
<td>Other</td>
<td>1st P</td>
</tr>
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<tr>
<td>Regression Adjusted: Amount Borrowed</td>
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<tr>
<td></td>
<td>1271.9</td>
<td>491.3</td>
<td>422.2</td>
<td>167.1</td>
<td>562.3</td>
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<td>(211.2)</td>
<td>(114.8)</td>
<td>(184.7)</td>
<td>(169.8)</td>
<td>(351.4)</td>
<td>(252.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw: Loan to Budget</td>
<td>Total</td>
<td>Health A</td>
<td>Health B</td>
<td>1st P</td>
<td>Health B</td>
<td>Other</td>
<td>1st P</td>
</tr>
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</tr>
<tr>
<td></td>
<td>0.0108***</td>
<td>0.0026***</td>
<td>0.0041</td>
<td>0.0020*</td>
<td>0.0019**</td>
<td>0.0018*</td>
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<tr>
<td>(0.0176)</td>
<td>(0.0233)</td>
<td>(0.0148)</td>
<td>(0.0204)</td>
<td>(0.0196)</td>
<td>(0.00889)</td>
<td></td>
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<tr>
<td>Raw: Loan to Budget, Borrowers</td>
<td>Total</td>
<td>Health A</td>
<td>Health B</td>
<td>1st P</td>
<td>Health B</td>
<td>Other</td>
<td>1st P</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression Adjusted: Loan to Budget, Borrowers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0108***</td>
<td>0.0026***</td>
<td>0.0041</td>
<td>0.0020*</td>
<td>0.0019**</td>
<td>0.0018*</td>
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</tr>
<tr>
<td>(0.0176)</td>
<td>(0.0233)</td>
<td>(0.0148)</td>
<td>(0.0204)</td>
<td>(0.0196)</td>
<td>(0.00889)</td>
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</tr>
<tr>
<td>Total Students</td>
<td>36023</td>
<td>1654</td>
<td>620</td>
<td>917</td>
<td>2199</td>
<td>16465</td>
<td>14168</td>
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<tr>
<td>Borrowers</td>
<td>15760</td>
<td>1375</td>
<td>529</td>
<td>659</td>
<td>1722</td>
<td>7396</td>
<td>4079</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors. Each cell is the value on an indicator for post for a different regression. The sample of students in each regression is defined by the columns. Regression adjusted difference includes controls for gender, age, budget, EFC, budget, school type, year in school and program.

Furthermore, Figures D.1a - D.2b depict the estimated δg coefficients from Equation 2, a DD framework in which undergraduates are the base category. Each point shows how the probability of borrowing above the Stafford limit differs relative to undergraduate borrowing, and the post estimate in Figure D.1a shows how undergraduate borrowing changed in the post period. While Table D.1 indicates that the probability of borrowing above the Stafford limit increases in the post period for graduate students, Figures D.1a and D.1b show this increase is less than or no different from the increase in among undergraduates. These results suggest that access to PLUS loans has not necessarily increase borrowing above the Stafford limit.

While raw differences are large, the regression adjusted differences in amount borrowed are modest. Among all graduate students there was an increase of $347, less than 5% of the average amount borrowed in 2004. The breakdown by student type reveals a statistically significant increase
only among non-health first professionals. In the post period these students borrow $1,657 more on average than similar who did not have access to PLUS loans. Neither of these increases is statistically significant at the 5% level and indicates a modest increase in overall borrowing.

Loan to budget ratios also increased slightly after the introduction of PLUS loans. Row 8 and column 1 of Table D.1 shows that the regression adjusted increase is 1.9pp among all graduate students. Row 8 shows that most students types do not exhibit a statistically significant increase in the loan to budget ratio, this is particularly true when the sample is restricted to borrowers as in row 10. Only Health A students have a statistically significant increase of 4pp. Comparing to undergraduates as in Figure D.2 shows that the raw (panel a) and regression adjusted (panel b) increase in loan to budget ratios for graduate students is not statistically different from that for undergraduate students. This supports the finding that PLUS loans did not lead students to borrow more of their budget through loans.
Figure D.1: Difference in probability borrow above Stafford limit relative to undergraduate borrowers

Notes: Change in probability of borrowing above the Stafford limit by student type. Base category is undergraduate students. Controls in D.1b include race, age, gender, EFC, school type, first year school fixed effects, program fixed effects, have kids, dependent, and married.
(a) Raw difference in loan to budget ratio

(b) Regression adjusted difference in loan to budget ratio

Figure D.2: Difference in loan to budget ratio relative to undergraduate borrowers

Notes: Changes in loan to budget ratios by student type. The base category is undergraduate students. Controls in D.2b include race, age, gender, EFC, school type, first year of graduate school fixed effects, program fixed effects, have kids, dependent, and married
D.2 Tuition

Former Secretary of Education, William Bennett, famously stated that increases in federal student aid would lead universities to increase tuition. There are a number of studies that focus on the “Bennett hypothesis” in the context of undergraduate programs, for example Cellini and Goldin (2014). In this section, I test the Bennett hypothesis in the graduate setting using a differences-in-differences framework. The control group that I use is undergraduate tuition and fees.

To analyze changes in tuition and fees after the introduction of the policy I use data from IPEDs which contains in-state and out-of-state tuition and fee information for first-professional and graduate programs across the United States. Tuition and fees for undergraduate students is the average among undergraduates in all majors and programs. Similarly, the tuition and fees for master and PhD (graduate) students is also the average paid among all these students. First professional programs report tuition and fees separately for first year students.

![Tuition & Fees](image)

**Figure D.3: Average tuition and fees**

Notes: Average tuition and fees for undergraduate, graduate (master and PhD), and first professional programs. Values are in 2002 dollars.

Figure D.3 depicts the average tuition and fees for in-state and out-of-state undergraduate, graduate and first professional programs from 2002 to 2006. The figure shows that, for both in-state and out-of-state tuition, the difference in tuition paid between undergraduate and graduate students is relatively constant. Similarly, the trends seem to be constant though the figure indicates...
that each specialty may be on its own time trend. Given this pattern, I estimate the following equation to evaluate whether the introduction of PLUS loans led to an increase in tuition and fees:

\[ y_{ipt} = \alpha + T_t + s_s + p_p + \beta X_i + \delta_p PostXProgram_g + \epsilon_{ipt}. \]  

There are two outcomes of interest in Equation 13: log in-state tuition and fees and log out-of-state tuition and fees. In the above equation, \( T_t \) represents a year fixed effect, \( s_s \) a school (or city) fixed effect and \( p_p \) a program fixed effect. The matrix \( X_i \) contains school characteristics such as the type of school, a program specific time trend, the academic calendar used (semester, quarter, etc), library facilities and whether the school is historically black. The coefficients of interest, \( \delta_p \), represents the change in tuition and fees in the post period for each program, relative to undergraduate programs.

### D.3 In-State Tuition & Fees

Table D.2 presents the difference-in-difference estimates of the change in log in-state tuition from the 2002 - 2012 relative to that for undergraduate students. All specifications include year and specialty fixed effects as well as controls for school type, calendar system used, library status and whether the school is historically black. Specifications 1 and 2 include city fixed effects while specifications 3-5 include school fixed effects. Specifications 2, 4 and 5 allow for a specialty specific time trend and specification 5 restricts the sample to years before the Great Recession.

The breakdown by program indicates there are statistically significant increases in log tuition among some, but not all, graduate programs. While specification 1 indicates that tuition increased for most graduate programs, once a specialty specific time trend has been incorporated, as in specification 2 of Table D.2, the increase in tuition is statistically significant for Theology, Chiropractic and Podiatry programs. The preferred specification includes a specialty specific time trend and school fixed effects as in specifications 4 and 5. In specification 4 tuition and fees after the introduction of the PLUS program increased by 10.1 log points (lp) on average for chiropractic programs and 12.4lp on average for podiatry programs. The highest increase is among the specialties which have the fewest programs. For example, in 2012 there were 15 Chiropractic programs and 10 Podiatry programs. Law and theology programs have a more modest increases of 2.14lp and 2.67lp, respectively. These increases are statistically significant at the 5% level.

In specification 5 I turn to the period immediately after the introduction of PLUS loans, and before the Great Recession, to understand how prices changed immediately after the policy change.

---

67 The results when looking at levels is similar.
I still find that tuition increased for Chiropractic, Podiatry, Law and Theology programs – though at a smaller rate. Specification 5 of Table D.2 indicates that tuition increased by 11.4lp among Chiropractic programs and 4.9lp among Podiatry programs. Immediately after the introduction of PLUS loans Law programs increased tuition and fees by about 2.2lp and Theology programs increased tuition by 3.2lp. These results are statistically significant at the 5% level, and confirm that “rare” programs disproportionately increased in-state tuition after the introduction of PLUS loans. Among more common programs, law is the only specialty that increase in-state tuition more than undergraduate programs on average in the immediate years following grad PLUS introduction.
D.4 Out-of-State Tuition & Fees

Focusing on out-of-state tuition and fees yields results that are similar to those from in-state tuition. Table D.3 presents little indication that log out-of-state tuition increased among graduate programs as a whole. Once again, in Table D.3 specifications 1 and 2 incorporate city fixed effects while specifications 3-5 include school fixed effects. Specifications 2, 4 and 5 also include a specialty time trend.

The estimated coefficients from Table D.3 specification 4 indicate that once again the increase in tuition and fees is highest among Chiropractic and Podiatry programs. Unlike with in-state tuition and fees, Law and theology programs do not seem to have a statistically significant increase in out-of-state tuition and fees. Specification 4 of Table D.3 indicates that the tuition for Chiropractic programs increased by about 8.3 lp, though this is only significant at the 10% level, and that tuition increased for Podiatry programs by 10.4 lp. This increase is statistically significant at the 5% level. Surprisingly, veterinary programs seem to have decreased out-of-state tuition by 4.7 lp in the years after graduate PLUS programs were introduced.

Restricting to years before the recession, as in specification 5, indicates that immediately after the introduction of PLUS loans, graduate programs as a whole did not change tuition in a way that was statistically different from undergraduate programs. In the years immediately following the introduction of graduate PLUS programs Chiropractic programs exhibit a statistically significant increase of 10 lp in out-of-state tuition. Podiatry programs exhibit an increase of 2.6 lp that is statistically significant at the 10% level. Surprisingly, law programs do not seem to have increase out-of-state tuition in the years following the introduction of the graduate PLUS loan program. Overall, out of state tuition for few programs changed in a way that it is statistically different from undergraduate tuition immediately after the introduction of PLUS loans.
Table D.3: Out of State log Tuition and Fees

<table>
<thead>
<tr>
<th></th>
<th>(1) Log Tuition</th>
<th>(2) Log Tuition</th>
<th>(3) Log Tuition</th>
<th>(4) Log Tuition</th>
<th>(5) Log Tuition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad × post=1</td>
<td>0.0169**</td>
<td>0.00216</td>
<td>0.00447</td>
<td>-0.00660</td>
<td>-0.00544</td>
</tr>
<tr>
<td></td>
<td>(0.00767)</td>
<td>(0.00708)</td>
<td>(0.00641)</td>
<td>(0.00760)</td>
<td>(0.00689)</td>
</tr>
<tr>
<td>Chiro × post=1</td>
<td>0.00727</td>
<td>0.118**</td>
<td>0.119**</td>
<td>0.0837*</td>
<td>0.100**</td>
</tr>
<tr>
<td></td>
<td>(0.0306)</td>
<td>(0.0564)</td>
<td>(0.0571)</td>
<td>(0.0466)</td>
<td>(0.0472)</td>
</tr>
<tr>
<td>Dental × post=1</td>
<td>0.132***</td>
<td>-0.0117</td>
<td>0.000289</td>
<td>-0.0234</td>
<td>-0.0175</td>
</tr>
<tr>
<td></td>
<td>(0.0249)</td>
<td>(0.0208)</td>
<td>(0.0213)</td>
<td>(0.0193)</td>
<td>(0.0201)</td>
</tr>
<tr>
<td>Medicine × post=1</td>
<td>0.04177**</td>
<td>-0.0336**</td>
<td>-0.0269*</td>
<td>-0.0311</td>
<td>-0.0269</td>
</tr>
<tr>
<td></td>
<td>(0.0185)</td>
<td>(0.0158)</td>
<td>(0.0141)</td>
<td>(0.0240)</td>
<td>(0.0240)</td>
</tr>
<tr>
<td>Optometry × post=1</td>
<td>-0.0224</td>
<td>-0.0287</td>
<td>0.0119</td>
<td>-0.0277</td>
<td>0.00191</td>
</tr>
<tr>
<td></td>
<td>(0.0331)</td>
<td>(0.0253)</td>
<td>(0.0184)</td>
<td>(0.0300)</td>
<td>(0.0231)</td>
</tr>
<tr>
<td>Pharmacy × post=1</td>
<td>0.117***</td>
<td>-0.00555</td>
<td>-0.00718</td>
<td>-0.00667</td>
<td>-0.00284</td>
</tr>
<tr>
<td></td>
<td>(0.0166)</td>
<td>(0.0149)</td>
<td>(0.0155)</td>
<td>(0.0164)</td>
<td>(0.0170)</td>
</tr>
<tr>
<td>Podiatry × post=1</td>
<td>-0.00813</td>
<td>0.0268</td>
<td>-0.0143</td>
<td>0.104**</td>
<td>0.0261*</td>
</tr>
<tr>
<td></td>
<td>(0.0420)</td>
<td>(0.0301)</td>
<td>(0.0191)</td>
<td>(0.0408)</td>
<td>(0.0144)</td>
</tr>
<tr>
<td>Veterinary × post=1</td>
<td>0.0396*</td>
<td>-0.0607***</td>
<td>-0.0454*</td>
<td>-0.0471**</td>
<td>-0.0353*</td>
</tr>
<tr>
<td></td>
<td>(0.0211)</td>
<td>(0.0234)</td>
<td>(0.0232)</td>
<td>(0.0207)</td>
<td>(0.0180)</td>
</tr>
<tr>
<td>Law × post=1</td>
<td>0.0468***</td>
<td>0.00632</td>
<td>0.0135</td>
<td>0.00837</td>
<td>0.0108</td>
</tr>
<tr>
<td></td>
<td>(0.0128)</td>
<td>(0.0122)</td>
<td>(0.0112)</td>
<td>(0.00895)</td>
<td>(0.00814)</td>
</tr>
<tr>
<td>Theology × post=1</td>
<td>0.00181</td>
<td>0.0163</td>
<td>0.0180</td>
<td>0.0149</td>
<td>0.0183</td>
</tr>
<tr>
<td></td>
<td>(0.0152)</td>
<td>(0.0129)</td>
<td>(0.0121)</td>
<td>(0.0128)</td>
<td>(0.0120)</td>
</tr>
</tbody>
</table>

| Specialty Time Trend | x | x | x | x | x |
| City FE             | x |   | x |   |   |
| School FE           |   | x |   | x |   |
| Restricted Sample   |   | x |   | x |   |
| Observations        | 68674 | 68674 | 68674 | 47853 | 47853 |
| $R^2$               | 0.695 | 0.695 | 0.873 | 0.704 | 0.886 |

Standard errors in parentheses
*p < 0.1, **p < 0.05, ***p < 0.01

Notes: Standard errors are clustered at the unitid level (school identifier). All specifications include year and program fixed effects, school type, calendar system used, whether school is historically black and library status.

D.5 Enrollment

The introduction of PLUS loans is only applicable to students who need to borrow beyond the Stafford limit, generally first-professional students. Given the increased borrowing limit, a natural question is to understand whether total enrollment increased in graduate, or first professional, programs. Using IPEDS data I address this question by studying total enrollment using a differences-in-differences strategy in which undergraduate students function as a control group, similar to that used for tuition. The assumption that the difference in graduate and undergraduate enrollment are the same before the introduction of PLUS loans may be somewhat strong, but, failing to see a change relative to undergraduate students may be all the more surprising.

IPEDS includes total undergraduate enrollment and graduate enrollment (including first pro-
fessional) from 2011 onward and total undergraduate, first professional (a subset of graduate) and other graduate enrollment until 2009. To estimate the effect on graduate student enrollment I estimate the following equation:

\[ y_{int} = \alpha + T_t + s_s + Type_n + \beta X_i + \delta_n Post_t \cdot Type_n + \epsilon_{int}. \] (14)

Where \( T_t \) is a year fixed effect, \( s_s \) is a city or school fixed effect, \( Type_n \) is an indicator for students type \( n \) (undergraduate, graduate or first professional) and the coefficient of interest \( \delta_n \) describes how enrollment changed after the introduction of PLUS loans for graduate and first professional students relative to undergraduate students. The dependent variable of interest, \( y_{int} \), is log enrollment in school \( i \) of type \( n \) in year \( t \).\(^{68}\) Once again \( X_i \) includes school specific controls such as school fixed effects, school type and in some specifications a student type (aggregate, not school specific) time-trend.

Table D.4 depicts the estimated change in graduate enrollment, relative to undergraduate enrollment, from 2001 to 2013. Specifications 1 and 2 allow for city fixed effects while specifications 3 - 5 include school fixed effects. Models 2, 4 and 5 include a student type time trend and the last specification restricts the sample to years before the recession. Failing to include a student type time-trend biases the estimates downward and implies that enrollment actually decreased after the introduction of PLUS loans. Once the time trend is incorporated along with a school fixed effect specification 4 indicates that graduate student enrollment increased by 3.6 log points relative to undergraduate enrollment. When the sample is restricted to pre-recession years, however, specification 5 indicates that the change in total graduate enrollment differ from undergraduate enrollment. The increases documented in specification 4 can largely be attributed to years after the Great Recession rather than the introduction of graduate PLUS loans. These results indicate that overall graduate enrollment didn’t change after the introduction of PLUS loans.

Table D.5 breaks enrollment down into graduate students in first professional programs and other graduate students (Doctoral and Master’s students). Because these enrollments are not reported in more recent IPEDs years, the sample is restricted to the pre-recession years. After incorporating school fixed effects and a student type time trend the estimates in Table D.5 show that enrollment did increase slightly, by 2 percentage points, for masters and doctoral students relative to undergraduate students. First professional enrollment seems to have increased by about 2 lp as well, but this result is not statistically significant. These results are only statistically significant at the 10% level. This table, along with Table D.4, confirm that total enrollment after the

\(^{68}\)I focus on the unduplicated headcount provided by IPEDS. I get similar results when using Fall Enrollment and including controls for programs students pursue.
introduction of graduate PLUS loans did not increase much relative to undergraduate enrollment. More importantly, enrollment into the fields that make the most use of graduate PLUS loans did not increase.

Table D.4: Change in Log Enrollment

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate x Post</td>
<td>-0.0893***</td>
<td>0.00283</td>
<td>-0.113***</td>
<td>0.0355**</td>
<td>0.00505</td>
</tr>
<tr>
<td></td>
<td>(0.0176)</td>
<td>(0.0169)</td>
<td>(0.0150)</td>
<td>(0.0145)</td>
<td>(0.0157)</td>
</tr>
<tr>
<td>Student Type</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Time Trend</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City FE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School FE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted Sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>91633</td>
<td>91633</td>
<td>91633</td>
<td>91633</td>
<td>64636</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.648</td>
<td>0.648</td>
<td>0.900</td>
<td>0.900</td>
<td>0.906</td>
</tr>
</tbody>
</table>

Notes: Standard errors are clustered at the unitid level (school identifier). Sample includes 2001 - 2018 academic years. All specifications include year and school type fixed effects.

Table D.5: Change in Log Enrollment: Pre-Recession

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate x Post</td>
<td>-0.0297*</td>
<td>0.0253</td>
<td>-0.0382***</td>
<td>0.0202</td>
</tr>
<tr>
<td></td>
<td>(0.0172)</td>
<td>(0.0190)</td>
<td>(0.0148)</td>
<td>(0.0166)</td>
</tr>
<tr>
<td>First Professional x Post</td>
<td>-0.0186</td>
<td>0.0181</td>
<td>-0.0903***</td>
<td>0.0204</td>
</tr>
<tr>
<td></td>
<td>(0.0238)</td>
<td>(0.0293)</td>
<td>(0.0210)</td>
<td>(0.0249)</td>
</tr>
<tr>
<td>Student Type</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Time Trend</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City FE</td>
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</tr>
<tr>
<td>School FE</td>
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</tr>
<tr>
<td>Restricted Sample</td>
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<td></td>
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<td>N</td>
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<td>68395</td>
<td>68395</td>
<td>68395</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.645</td>
<td>0.645</td>
<td>0.890</td>
<td>0.890</td>
</tr>
</tbody>
</table>

Notes: Standard errors are clustered at the unitid level (school identifier). Sample includes 2001 - 2018 academic years. All specifications include year and school type fixed effects.

To determine whether there is substitution across graduate degree programs I use the fall enrollment information in IPEDS. Fall enrollment contains information on enrollment in 9 possible categories for each university—Education, Engineering, Law, Life Sciences, Mathematics, Physical Science, Dentistry, Medicine and Business Management and Administration. These categories are not separated into Ph.D, Masters or First Professional programs but are still useful to evaluate whether students shift toward more expensive programs – in particular Law, Medical or Dental programs. Program enrollment is only available for even academic years.

Table D.6 shows how the share of graduate students in each category changed in the post period. I include the 2000 - 2008 academic years and controls for school type, a year time trend and school
fixed effects. The indicator on post shows how total share of graduate enrollment in each of these programs changed in the years that PLUS loans were available. The results indicate that most of these programs did not see a statistically significant change in graduate enrollment. This is especially true in columns 3, 7 and 8 which show the share of enrollment into law, dentistry and medical programs respectively. The first professional programs are also more expensive than the other programs depicted in Table D.6. Columns 1, 4 and 9 indicates that there is some substitution away from education and life science programs and toward business programs. Overall there is very limited evidence of substitution toward more mostly programs. Due to the limited number of seats in graduate programs, however, it is difficult to truly assess whether demand for these programs increase without more information on the applications and acceptances for each program.

Table D.6: Change in share of graduate students enrolled by program

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>post</td>
<td>-0.0146***</td>
<td>0.00445</td>
<td>-0.00230</td>
<td>-0.00555***</td>
<td>-0.00129</td>
<td>-0.000734</td>
<td>-0.00195</td>
<td>-0.00412</td>
</tr>
<tr>
<td>(0.00566)</td>
<td>(0.00418)</td>
<td>(0.00813)</td>
<td>(0.00176)</td>
<td>(0.000935)</td>
<td>(0.00123)</td>
<td>(0.00313)</td>
<td>(0.00591)</td>
<td>(0.00415)</td>
</tr>
<tr>
<td>N</td>
<td>10025</td>
<td>2953</td>
<td>1817</td>
<td>4620</td>
<td>3348</td>
<td>3384</td>
<td>348</td>
<td>812</td>
</tr>
<tr>
<td>R²</td>
<td>0.868</td>
<td>0.927</td>
<td>0.972</td>
<td>0.955</td>
<td>0.980</td>
<td>0.976</td>
<td>0.975</td>
<td>0.975</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* p < 0.1, ** p < 0.05, *** p < 0.01
Notes: Share of students in business programs increased while that for those in life sciences decreased. No change in the share of students pursuing medical or law degrees. Standard errors are clustered at the unitid level (school identifier). Sample includes 2001 - 2018 academic years. All specifications include time trend and school type fixed effects.

E Cost Benefit Analysis

While the benefits of IBR are clear, this paper has not yet considered the costs associated with offering an income-based repayment option to borrowers. To assess the cost of the program, I calculate present discounted value of payments from each of the 7 wage paths and weight them by the same probabilities I used when modeling expected utility. This yields the present value of the expected IBR payments from each borrower. I then subtract this from the present discounted value of the federal loan payments, assuming borrowers follow the standard repayment plan, for each borrower. The difference describes the “cost” of the IBR program relative to the standard repayment plan.

Results are similar when including city fixed effects or state fixed effects instead of school fixed effects. Results are also similar when excluding year fixed effects and including the 2012 and 2014 academic years.

When comparing graduate enrollment in business to undergraduate log enrollment in business I find that the increase is statistically significant at the 10% level. Similarly, the decrease in life science enrollment is larger among graduate students though I do not find a difference in enrollment into education programs between graduate and undergraduate students.
When doing this I find that, in fact, the present value of IBR payments is higher than those from the standard repayment plan for many borrowers. The median Health A student pays an extra $31,278 on average while the median Health B student pays an extra $1,783. The median Other: Law and Other: Masters borrower pays an additional $3,868 and $3,035, respectively. Modeling the wage paths using family income yields slightly lower profits to the government (relative to the standard repayment plan) of $24,976, $1,357, $2,975 and $1,531 for the median Health A, Health B, Other Law and Other Master’s borrower, respectively. Modeling family income, and including the part-time and unemployed graduates, yields even smaller profits to the government. I still find that the median Health A student pays an extra $20,011 and that the median Other student (assuming they are all in law) pays an extra $1,834. The median Health B and Other student (assuming they are all Masters students) cost the government $1,895 and $1,107 compared to the standard repayment plan. While allowing for unemployment and part time work will likely increase the cost of the median Masters and Health B borrowers and decrease the profit from Health A and Law borrowers, overall, the extra amount paid by Health A workers will likely stay large.\footnote{Even if all Health A workers expect to earn below the median for full-time Health A workers, the expected profit for the median Health A borrower is $7,350. This again excludes part-time workers and the unemployed.}

While IBR disproportionately benefits Health A workers, it is also most profitable to offer such a plan to these exact same workers.

Income-based repayment is valuable to many borrowers. By extending the loan repayment period, and allowing payments to differ based on income, the expected interest rates borrowers will pay each month is different from that given by the government. These expected interest rates are also lower in the first years of repayment and increase as the payments increase. For each borrower in the sample from Section 6.2 I estimate the expected number of years in repayment for the total amount borrowed from 2011 - 2014. The median expected repayment length for Health A, Health B, Other: Law and Other: Masters borrowers is 21, 16, 12, and 16 years, respectively. I treat each borrower’s expected years of payments as the repayment period for the loan and calculate the implied expected interest rate for each year of repayment. Averaging the implied interest rates over the first 10 years indicates that instead of paying an interest rate of 6.8-7.9% the average implied interest rate for the median Health A student is only 1.85%. The average implied interest rate (for the first 10 years) is 5.49%, 6.90% and 5.90% for the median Health B, Other Law and Other Master’s student, respectively.\footnote{Estimates are even lower for the average student in each category.} These rates are closer to those offered in the private market for student loans. When using family income the expected years in repayment decrease slightly to 18, 14, 12 and 13 years for Health A, Health B, Other Law and Other Masters borrowers. As a result the implied 10 year interest rates increase to 3.51%, 6.26%, 7.14% and 6.56% for the median
Health A, Health B, Other Law and Other Masters borrowers respectively. These estimates stem from wage paths that focus on full-time workers and do not allow for unemployment. Thus, the expected repayment lengths would likely be higher and the implied 10 year interest rates lower when including all workers in the wage paths. Since these workers will be making payments for more than 10 years with IBR, I can also calculate the expected average interest rate paid over the life of the loans rather than just the first 10 years. To do this, I simply calculate and average the implied interest rate each year for each wage path. I then weight the seven averages by the probability of facing these wage paths. This calculation indicates that the expected rate for the median Health A, Health B, Other Law and Other Masters borrowers is 6.30%, 6.04%, 7.50% and 6.80%.73 These are higher than the interest rates over the first 10 years because the payments increase over time and the borrowers are paying more in interest.

F Additional Figures & Tables

Table F.7: Summary of Credit Data: Student Type

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent Graduate</td>
<td>Health A</td>
<td>Graduate</td>
<td>Health B</td>
</tr>
<tr>
<td>2011</td>
<td>24.8</td>
<td>1.24</td>
<td>1.31</td>
<td>22.1</td>
</tr>
<tr>
<td>2012</td>
<td>27.4</td>
<td>1.59</td>
<td>1.73</td>
<td>30.2</td>
</tr>
<tr>
<td>2013</td>
<td>32.0</td>
<td>1.63</td>
<td>1.77</td>
<td>31.0</td>
</tr>
<tr>
<td>2014</td>
<td>34.3</td>
<td>1.75</td>
<td>1.90</td>
<td>32.8</td>
</tr>
<tr>
<td>Total</td>
<td>28.8</td>
<td>1.54</td>
<td>1.66</td>
<td>28.7</td>
</tr>
<tr>
<td>NPSAS 2012*</td>
<td>27.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPSAS 2012 with Stafford Max*</td>
<td>3.7</td>
<td>1.8</td>
<td>26.7</td>
<td></td>
</tr>
<tr>
<td>NPSAS 2012 All Graduate Borrowers*</td>
<td>6.9</td>
<td>6.4</td>
<td>86.6</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Column 1 describes the percent of total borrowers in the credit sample, each academic year, who are classified as graduate students. Columns 2 - 4 describe the percentage of graduate students who are classified into finer groups of first professionals. To classify students I assume that students who borrow exactly $40,500 in federal loans are Health A students, those who borrow exactly $33,000 fall into the Health B category and those who borrow exactly $20,500 fall into the Other category.

* Restricting to borrowers in the NPSAS 2012 ages 24 - 35.

73 Estimates are lower for the average student in each category.
Table F.8: Summary of Credit Data: Percent with Private Loan

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent with Private</th>
<th>Percent Graduates with Private</th>
<th>Percent without Government</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>8.6</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td>2012</td>
<td>7.3</td>
<td>5.4</td>
<td>3.9</td>
</tr>
<tr>
<td>2013</td>
<td>6.3</td>
<td>5.0</td>
<td>4.2</td>
</tr>
<tr>
<td>2014</td>
<td>6.8</td>
<td>5.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Total</td>
<td>7.4</td>
<td>5.0</td>
<td>4.2</td>
</tr>
<tr>
<td>NPSAS 2012: Age 24 - 35 in Dec 2014</td>
<td>11.2</td>
<td>5.8*</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Notes: The first column shows the percentage of all students in the credit data with a private loan by academic year. The middle column depicts the percentage of students categorized as graduate students with a private loan by academic year. The final column shows the percentage of students who have no federal loan by academic year. The last row in the table depicts these percentages in the NPSAS 2012 for comparison.

* Graduate students who borrow over $12,500

Table F.9: Health A Estimates: Assuming Private Lenders Offer Deferment

<table>
<thead>
<tr>
<th>Consumption Value: γ</th>
<th>25th Percentile</th>
<th>Median</th>
<th>75th Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ = 0</td>
<td>-3186</td>
<td>-2184</td>
<td>-1182</td>
</tr>
<tr>
<td>γ = 0.5</td>
<td>-954</td>
<td>302</td>
<td>2060</td>
</tr>
<tr>
<td>γ = 1.0</td>
<td>302</td>
<td>2563</td>
<td>6583</td>
</tr>
<tr>
<td>Baseline with 4-year Deferment</td>
<td>0.30</td>
<td>0.58</td>
<td>1.18</td>
</tr>
<tr>
<td>Assume Earn Above Median</td>
<td>0.73</td>
<td>1.13</td>
<td>2.63</td>
</tr>
<tr>
<td>Assume Earn Below Median</td>
<td>0</td>
<td>0.03</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Notes: Rows 1 - 4 depict the baseline CRRA thresholds and consumption values as in Tables 8 & 9, assuming private lenders allow 3-year deferment. Row 5 allows for 4-year deferment. Rows 6 and 7 estimate these thresholds assuming borrowers expect to earn above the median and below the median as in Rows 2 & 3 in Tables 10.
Figure F.4: Wage path examples

Notes: The figure shows 2 examples of the wage paths I use when modeling students’ expected future incomes. Panel (a) depicts the wage paths for Other students in Delaware, assuming they are in law programs. Panel (b) shows the wage path for Other students in Delaware, assuming they are pursuing a Masters degree. The wage paths depict the 5th (bottom most line), 10th, 25th, 50th, 75th, 90th and 95th (topmost line) wage percentiles by age group.