Go Big or Buy a Home:
The Effects of Student Debt on Human Capital and Wealth Accumulation

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Abstract. Do financial constraints affect educational and career choices? Using restricted-access survey data that follow successive waves of college graduates, we show that higher levels of college debt have significant effects on graduate school enrollment and completion years after graduation. This attendance gap can be explained by financial rather than academic reasons. Also, we find that higher levels of college debt induce an anticipation in decisions such as marriage and first-time home-ownership. We develop a life-cycle model with endogenous human capital accumulation, career choice and housing, to analyze the impact of the recent increase in student debt and the introduction of a budget-neutral student loan forgiveness plan. Our results highlight the importance of financial constraints on young workers as determinants of long-run human and physical capital accumulation.

Keywords: Student Loans, Human Capital, Housing.

JEL codes: I22, E24, J32, J38, R21

1 Introduction

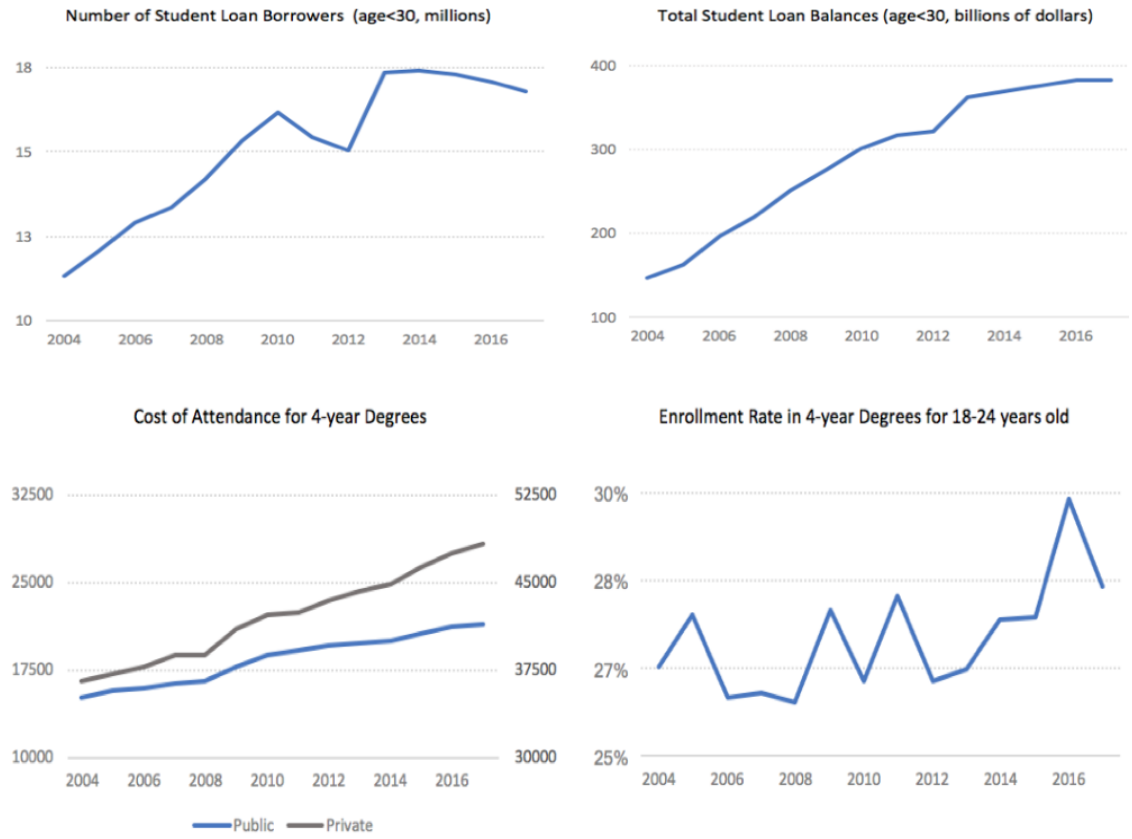
Between 2004 and 2018, the outstanding stock of student debt more than tripled in the United States, becoming the second-largest form of household debt after mortgages. Whereas home-ownership rate for young households declined continuously in the 2000s (see **Figure 9** in Appendix), as of December 2018 there were 44 million student loan borrowers who owed $1.46 trillion in total. Most of this vast increase in student debt has been attributed to the substantial rising cost of college over the last decade. Since 2004, tuition at four-year colleges increased at an average rate of 3% per year. While student debt has surely helped to moderate the impact of higher costs on college enrollment, more students leave now from college with student debt and with higher amounts of debt (**Figure 1**). Thus, student debt is now more likely to be a burden for a higher percentage of college graduates and surely a relevant factor they take into account in their economic and financial decisions.

Our first goal in this paper is to empirically examine the contribution of student borrowing to the secular decline in home-ownership, and to the current dynamics in social mobility. More generally, we ask: how does student debt affect career choices, earnings, and wealth accumulation over the life cycle? We use restricted - access data from the 2008 wave of the Baccalaureate and Beyond Longitudinal Study (B&B) that covers a representative sample of college graduates. The focus of our analysis is the effects of undergraduate student borrowing on individuals' graduate school attendance, career paths and first-time home-ownership.

A fundamental challenge in analyzing the impact of student loans on post-graduation outcomes is that the amount borrowed may be determined by unobserved individual ability or different expectations, which in turn would also affect career and asset choices. We deal with this endogeneity by introducing an instrument based on supply-side variations in college-aid policies. Using this empirical strategy, we find that higher levels of student debt have a negative and significant effect on graduate school attendance and completion four years after college graduation. We also find that college loans have a significant impact on individuals' households formation and wealth accumulation: higher levels of student debt cause to anticipate first-time home-ownership and marriage. This effect is compensated on the intensive margin - more indebted graduates end up buying less expensive houses.

To discipline our empirical findings and analyze the relative importance of different frictions, we develop a Ben-Porath life-cycle model enriched by career choices and housing decisions. The model is estimated by Simulated Method of Moments using a combination of data from B&B and Census. In our model, workers can access a different career path by enrolling in graduate school. Available careers differ in the way productivity, and thus compensation, is linked to accumulated human capital. While in some career paths additional experience or human capital translates into higher productivity, in others the marginal contribution of this investment is lower over all of the life cycle. After college, individuals enter the labor market and are heterogeneous in ability, student debt, human capital and initial liquid wealth. They sequentially decide labor and human capital investment, savings, and non-housing and housing consumption while they pay for student debt (if any). At any point, they can enroll in graduate school.

Figure 1: Evolution of student debt, tuition and college enrollment



Note: authors calculations. Sources: Federal Reserve Bank of New York (FRBNY), the College Board Annual Survey of Colleges and U.S. Bureau of Labor Statistics (Census).

We show that, by introducing career heterogeneity and post-schooling credit constraints, student debt plays a key role in explaining inequality throughout the life-cycle. College graduates with higher student debt sort into careers with lower compensation for human capital accumulation, and then experience lower earnings growth. A key factor in this sorting result is the increased preference for earnings front-loading induced by student debt. Two frictions are crucial in determining these results: binding credit constraints for leveraged households and limited ability to transfer human capital across careers.

The model has also implications for the effects of borrowing on home-ownership. A first, intuitive channel, would point at higher borrowing causing reduced home-ownership. On the other hand, career choice induced by the initial debt position is able to counterbalance this effect. The model is able to reproduce the finding that home-ownership for workers that started their career with student debt is relatively higher. This result is driven by the fact that borrowers sort into careers that imply a flatter income profile. This reduces their income volatility, as those careers are mechanically less loaded on (risky) investments in human capital. More in general, unconstrained graduates who choose a career with a steeper earnings path (as is the case for those who enroll in graduate programs) at the same time are more likely to postpone their entry into home-ownership. By this channel, student debt

has the apparently counter-intuitive effect of anticipating entry into home-ownership. In addition, housing becomes a relatively more attractive investment for workers whose income growth is lower. As workers age, those into careers characterized by a steeper income path eventually catch up on home-ownership.

The paper is organized as follows. **Section 2** summarizes the literature, **Section 3** describes the data and presents the empirical results, **Section 4** provides an overview of the model and the life-cycle choices of individuals, **Section 5** calibrates and estimates the model to observed data patterns, **Section 6** presents the main results of the model, **Section 7** concludes with some policy discussion and future work.

2 Related Literature

This paper relates to the strand of research that aims at assessing the extent to which initial labor market conditions have strong effects on long term outcomes for earnings and wealth accumulation, as in **Oreopoulos, Von Wachter and Heisz (2012)**. In particular, it places itself inside the literature that attempts to identify the impact of student loans on labor market outcomes after college. While research on student loans mostly relied on reduced form estimates, the broader literature on long-term consequences of early career decisions is often based on structural models. In this work, we aim at bringing two branches of this literature together.

Isolating the effects of student debt on post-graduate choices is made complex by student debt being typically negatively selected, as pointed out by **Looney and Yannelis (2015)**. The empirical evidence on how student debt affects earnings mostly points to a positive relationship, at least in the short-run[1]. Based on a natural experiment in an elite university, **Rothstein and Rouse (2011)** show that student debt causes college graduates to choose jobs with an initial higher salary and reduces the probability that they choose "public" low-paid jobs. **Luo and Mongey (2019)** find that a version of these results generalizes to the cross-section of the U.S. colleges. In particular, they find that higher student debt causes college graduates to take jobs with higher wages, lower job satisfaction, and more on-the-job search.

Using a difference-in-difference approach, **Gerald and Smythe (2019)** study the impact of student debt on various labor market outcomes (income, hourly wages, and hours worked). They conclude that indebted students have initial higher earnings due to higher work hours rather than higher wage rates. **Chapman (2015)** finds that exogenously increasing the loan burden of a college graduate by $1,000 increases their income by $400-$800 one year after graduation. **Field (2009)** shows that law students who were offered loans were more likely to accept jobs in higher-paying corporate law rather than public interest law.

Nonetheless, higher initial earnings may not necessarily lead to higher lifetime earnings if they are not followed by further human capital investment (**Becker (1962), Ben-Porath (1967), Hause (1972) and Mincer (1974)**). In this line of thought, **Fos, Liberman and Yannelis (2017)** investigate the effects of student debt on additional human capital investment measured as graduate school enrollment. They find that

[1]For empirical studies that conclude a negative or neutral effect of student debt on earnings see: **Weidner (2016)**, **Akers (2012)** , **Zhang (2013)**.

a $4,000 increase in student debt reduces the likelihood of enrollment in graduate school by 1.5 percentage points. In this paper, we contribute to this literature by considering general labor market outcomes for a nationally representative sample of college graduates. We also provide a unified framework for analyzing the relationship between student debt, earnings and human capital investment after college.

Another set of empirical articles have analyzed the role of student loans on first-time home-ownership. Controlling for multiple factors, **Houle and Berger (2015), Cooper and Wang (2014) and Gicheva and Thompson (2014)** show that student debt reduces the likelihood of homeownership for young households. This negative relationship likely reflects the underwriting process of a mortgage contract. First, student loans are due when borrowers have the least capacity to pay, leaving borrowers with a lower disposable income and less room for savings towards the down payment of a house. Second, and specially after the financial crisis, the inclusion of student loan payments in the debt-to-income ratio implies that some agents may delay home purchase until they can qualify for a (larger) mortgage.

Using administrative data and tuition-induced variation in student debt, **Bleemer et al. (2017)** find that the recent increase in student debt could explain between 11 and 35 percent of the decline in young's homeownership over 2007-2015. Using a similar approach, **Mezza et al. (2016)** estimate that a $1,000 increase in student debt decreased first-time homeownership by approximately 1.5 p.p. for public 4-year college graduates who left school between 1997 and 2005. We contribute to this literature by providing evidence of the effects of student debt on first-time homeownership using new data on college graduates. In addition, we rationalize this relationship in a quantitative life-cycle framework.

Our analysis also relates to the literature that study student loan program design within a quantitative framework. For example, **Ionescu (2009)** finds that repayment flexibility increases college enrollment significantly, whereas relaxation of eligibility requirements has little effect on enrollment or default rates. In a similar framework, **Ionescu and Simpson (2016)** find that tuition subsides increase aggregate welfare by increasing college investment and reducing default rates in the private market. **Johnson (2013)** also shows that tuition subsidies provide larger increases in college enrollments than increasing borrowing limits. Compared to this literature, our model provides a more detailed characterization of college graduates career choices and post-schooling wealth accumulation.

In a related paper, **Di Maggio, Kalda and Yao (2019)** examine the effect of student debt forgiveness on individual credit and labor market outcomes. Using hand-collected lawsuits filings matched with individual credit bureau information, they find that borrowers experiencing the debt relief shock reduce their overall indebtedness by 26%. They also find that borrowers' probability to change jobs increase after the discharge and this leads to an increase in earnings by more than $4000 over a three year period. We examine the effects of an hypothetical student debt forgiveness plan on both earnings and first-time home-ownership.

Finally, our paper relates to the literature that analyzes how initial conditions affect lifetime inequality. In particular, this literature focuses on the importance of initial conditions relative to shocks over the life-cycle. **Huggett, Ventura and Yaron (2011)** study how heterogeneity in initial wealth and human capital affect lifetime

inequality by modelling earnings growth through a Ben-Porath production function. They find that initial conditions, as measured at age 23, determine more than 60 percent of variation in lifetime utility, and that the majority of this variation is determined by initial human capital differences. In a similar framework, **Heathcote, Storesletten and Violante (2014)** use a model with heterogeneous preferences and productivity, and conclude that productivity is the primary driver of earnings inequality.

The question has been addressed in the search and matching literature as well. Using a model with directed search and heterogeneous asset holdings, **Griffy (2019)** finds the opposite: initial wealth plays a crucial role in determining life-cycle inequality rather than heterogeneity in skills. This difference is caused by the inclusion of frictional labor markets, which makes wealth have a first order effect on earnings. In a similar vein, **Eeckhout and Sepahsalari (2019)** show that there is positive sorting between workers with net asset holdings and more productive firms. In this article, we focus on college graduates and also find that initial wealth (student debt) plays a crucial role in life-cycle decisions. Differently from this strand of literature, we model the labor market as career paths with different additional human capital requirements. We also include housing as a mechanism through which career choices could interact with financial constraints and affect lifetime wealth.

3 Data and Empirical Analysis

3.1 Description of Data

Our main source of data comes from the restricted-use dataset from the National Center for Education Statistics (NCES) Baccalaureate and Beyond Survey (**B&B**). The survey follows several cohorts of bachelor's degree recipients over time and contains a mix of administrative and self-reported data about their workforce participation, income, student debt, graduate school enrollment and homeownership (among many other variables).

B&B draws its cohorts from the National Postsecondary Student Aid Study (NPSAS), which collects data from large, nationally representative samples of postsecondary students and institutions to examine how students pay for postsecondary education. B&B samples are representative of graduating seniors in all majors. The first cohort was drawn from the 1993 NPSAS and followed up in 1994, 1997, and 2003. The second cohort was drawn in 2000 and followed up in 2001. The third cohort was drawn from the 2008 NPSAS sample. This group was followed up in 2009 and 2012 and was interviewed again in 2018.

The analysis focuses on the last cohort since student debt was negligible in the first cohort and the second one was only followed one year after graduation. We restrict the sample to students who received a bachelor's degree in the 2007-08 academic year and responded to all interviews (2007-08, 2009, and 2012). Among these individuals, we focus on first-time students that attended only one four-year public or private non-profit institution and graduated at age 21-26. After imposing these restrictions, we also remove all colleges for which we do not have more than 3 observations - this is

Table 1: Summary Statistics

	B&B 08/09/12		CPS
	Full Panel	Restricted Panel	Restricted
Outcomes			
2009			
Current primary job salary	29000	26661	28264
2012			
Current primary job salary	41895	41333	40708
Home-ownership	37%	31%	39%
With a Graduate Degree	22%	24%	26%
Debt			
% Indebted	66%	63%	
Federal debt balance	11425	10009	
Total debt balance	16619	14302	
Institutional Characteristics			
% attended public inst.	60%	60%	
% attended highly selective inst.	30%	34%	
Individual Characteristics			
White	73%	75%	
Male	42%	43%	
Expected Family Contribution	13823	14511	
Field of study: Social Sc. or Business	38%	34%	
College Obs.	1441	745	
Individual Obs.	14249	7910	

Source: Baccalaureate and Beyond Longitudinal Study 2008/2012 and CPS 2009-2012.

necessary since we will use an instrument that is based on institution-level variation.

In order to verify that the representativeness of the sample is not affected after restrictions, **Table 1** provides statistics for the whole sample and for the restricted-sample. As the table shows, our restrictions do not significantly change the outcomes of interest. The table also provides CPS statistics for individuals with at least a BA degree and aged 21-26 in 2009 and 25-30 in 2012. Measures of earnings for Baccalaureate & Beyond for college graduates are similar to the one in Census. As we can see, the average earning for a college graduate in the restricted sample was $28,282 right after college, while $42,380 four years after graduation. Around 34 percent owned a house and approximately 32 percent had a Graduate Degree by 2012.

3.2 Empirical Estimation

We are interested in estimating the following equation:

$$y_{i,j,t} = \alpha + \beta d_{i,j,2008} + \Gamma X_i + \Pi W_j + \epsilon_{i,j} \tag{1}$$

where $y_{i,j,t}$ is the outcome variable of choice at time t for a college graduate student i that attended college j, $d_{i,j,2008}$ is the cumulative amount of loans (federal and private) borrowed for undergraduate degree at time of graduation, X_i is a set of individual controls (gender, ethnicity, dependency status, major of study, and SAT), and W_j captures college fixed-effects (grouped by sector and selectivity of college). We consider a number of outcome variables: working status, graduate school attendance, earnings, and home-ownership.

The main hypothesis behind Equation (1) is that increased levels of borrowing could induce a debt overhang problem for investment in additional human capital after college (measured as enrollment in post-baccalaureate education) or for other forms of capital accumulation (primarily the purchase of the first home). At the same time, measuring the impact of student debt at different horizons for earnings provides evidence about the effects of debt at different stages of the life-cycle.

The constant term in Equation (1) represents the average outcome for the reference group. We define the reference group as: white, dependent, male, low SAT score, studied social sciences, and, attended a low selective public college (see **Appendix 1. Data** for how these variables are constructed).

Isolating the causal effect of student debt is challenging, as borrowing is hardly an exogenous variable in students' decisions. First, there may be a correlation between the level of debt an individual takes on and the quality of the college attended. To address this issue, we include college fixed effects that vary on the sector of the college (private or public) and the selectivity of admission (open admission, low, medium or highly selective).

However, even within a college there may be a correlation between the level of debt an individual takes on and individual's ability. On the one hand, if low-ability students are less likely to receive merit-based aid, post-college outcomes will reflect the latent negative correlation between ability and borrowing. On the other hand, high-ability students with higher earnings expectations could be more willing to borrow, resulting in debt being positively selected.

We address this in two ways. First, we include a rich set of individual controls that account for individual's ability and characteristics that are pre-determined at college entry. Second, as unobserved students' characteristics could be still relevant in determining access to different forms of aid, we construct an instrument for student debt that vary within-colleges and is correlated with undergraduate debt.

In the next section, we argue that cross-sectional differences in college policies can be exploited as exogenous variation in student debt, independent of unobserved factors such as ability or earning expectations, or of strategic behavior such as sorting into more generous colleges.

3.3 Instrumental Variable: Grant-to-Aid

The cost of attendance of college can be defined using the following equation:

$$cost_{i,j,t} = grant_{i,j,t} + loan_{i,j,t} + other_{i,t} \tag{2}$$

where $cost_{i,j,t}$ depends on both institution and individual characteristics, $grant_{i,j,t}$ is the total yearly amount of institutional grants an individual receive, $loan_{i,j,t}$ is the yearly amount of debt a student borrows for attending institution j, and, $other_{i,t}$ are other sources of funding that are not college-related [2].

We then can rewrite Equation (2) as follows:

$$cost_{i,j,t} - other_{i,t} = grant_{i,j,t} + loan_{i,j,t} \tag{3}$$

We focus on the right-hand side of equation (2) and define the college grant-to-aid ratio using the ratio of the value of total institutional grants issued by the college to the sum of institutional grants and loans received by the students in a given college in the last year of college enrollment (2007/08) [3]:

$$X_j = \frac{grant_{j,07}}{(grant_{j,07} + loan_{j,07})}$$

On average, institutional grants together with loans account for 77 percent of external funding for college (total grants and loans) and, among this funding, institutional grants account for 60% of the funding. Thus, differences in institutional grants have a large impact on the amount of funding for many students. The hypothesis is that, if a college has a lower (higher) average grant-to-aid ratio, then students should borrow more (less) relative to colleges with higher (lower) grant-to-aid policies, all else equal.

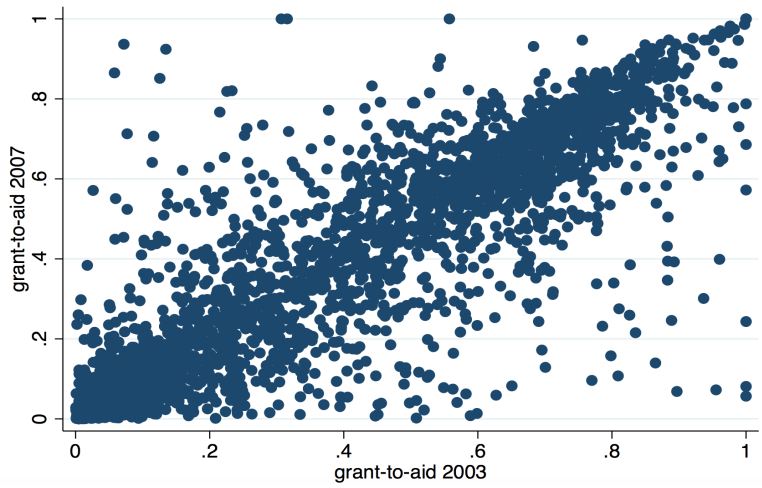
The main challenges to our identifying assumption is that foreseeable differences in future grant-to-aid policies of colleges could affect students' college choices at application stage. Students' choice at the application stage, if influenced by grant policy, could induce selection in our sample. However, as **Luo and Mongey (2019)** show, around 80 percent of freshmen students list only one college in their FAFSA college application list and less than 4 percent list more than five colleges. Thus, college choice does not seem to be determined by selection on financial aid offered after admission.

Moreover, as **Figure 2** shows, there is yearly variation in grant-to-aid college policies. These changes might come from surprise returns to university endowments - for instance, Harvard University endowment value declined 29.5% as investment returns reached -27.3% during the financial crisis. On the other hand, they might

[2] The composition of net tuition cost will also depend also on state and federal grants; in order to insulate our experiment from changes in the instrument due, for instance, to reductions in state funding following deteriorated fiscal positions, we only consider grants coming from the academic institution. Thus, the variable *other* will include state and federal grants as well as personal and family savings

[3] Data for constructing the instrument is publicly available from The Integrated Postsecondary Education Data System (IPEDS), and covers all Title IV institutions, i.e. all institutions that process U.S. federal student aid

Figure 2: Evolution of Grant-to-Aid



Note: authors calculations. Sources: IPEDS.

Table 2: First Stage Regression on $Debt_{2008}$ / 10000

Grant to Aid 07/08	-1.2***
	[0.2]
Constant	1.65***
	[0.1]
Inst. Controls	Yes
Individual Controls	Yes
Observations	7910

Standard errors in brackets.

come from unexpected large donations - for example, take Michael Bloomberg's $1.8 billion donation in support of financial aid at John Hopkins University in 2018, that eliminated the need to borrow for prospective and - most importantly, for our case - current students.

We estimate the model by two stage least squares. Therefore, it is important that there is significant variation and correlation of the instrument with student debt across institutions. **Table 2** shows that such condition is satisfied. Column (1) shows the results from the first-stage regression without any control. The results imply that there is a significant variation in grant-to-aid policy across colleges that can be used to explain variation in cumulative student debt at the time of graduation. This variation is even more pronounced once we include both institutional and individual controls (Column (2)). In **Appendix 2**, we report the first stage for an alternative set of instruments, and for different sample restrictions.

3.4 Empirical Results

3.4.1 Employment and Education

Results from the estimation of Equation (1) are given in **Table 3 - 6** for different outcomes of interest. **Table 3** focuses on employment choices. The first column shows the IV estimate on percentage of months between 2007-08 bachelor's degree completion and the 2009 interview that the respondent was employed. As we can see, the estimate shows that college graduates with higher amounts of debt spend more time working right after college graduation.

In particular, on average, an increase in $10,000 in student loans increases the percentage of months employed by about 9 percent. This difference remains four years after graduation (see column (3)). This is consistent with evidence in other studies that suggests student loans to be affecting search behavior - see for instance **Ji (2016)**. Columns (2), (4) provide results from the OLS estimation. Conditioning on all the individual and institutional controls, the correlation of student debt with work status is statistically but not economically significant.

Table 4 focuses on enrollment choices. Column (1) shows the results on a logit regression on enrollment in any additional degree program since bachelor's degree as of 2012: indebted graduates are less likely to enroll in additional education. In particular, an increase in $10,000 in student debt reduces the log-odds of being enrolled in additional education by -0.6. It is not surprising then, that by 2012 those with higher student debt are less likely to have completed graduate school (Column (3)).

Table 3: The effects of Student Debt on Time Employed

	Employed (2009)		Employed (2012)	
	IV	OLS	IV	OLS
	(1)	(2)	(3)	(4)
$Debt_{2008}$ / 10000	8.7***	0.6**	8.6***	0.6**
	[3.2]	[0.3]	[2.9]	[0.2]
Constant	66.2***	77.2***	60.3***	71.0***
	[4.9]	[2.2]	[4.6]	[2.1]
Inst. Controls	Yes	Yes	Yes	Yes
Ind. Controls	Yes	Yes	Yes	Yes
Observations	7910	7910	7910	7910

Standard errors in brackets.

Table 4: The effects of Student Debt on Additional Education

	Enrolled Grad School		Graduate Degree		Financial Reasons	
	IV	OLS	IV	OLS	IV	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
$Debt_{2008}$ / 10000	-0.6***	-0.0	-0.6***	-0.0**	0.9***	0.2***
	[0.2]	[0.0]	[0.1]	[0.0]	[0.2]	[0.0]
Constant	0.8**	0.0	-0.4	-1.1***	-1.2***	-0.3*
	[0.3]	[0.1]	[0.3]	[0.2]	[0.3]	[0.2]
Inst. Controls	Yes	Yes	Yes	Yes	Yes	Yes
Ind. Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7910	7910	7910	7910	5327	5327

Standard errors in brackets.

In order to get a deeper understanding of the reasons behind labor market and graduate school participation results, we focus on those respondents that reported that postponed applying for graduate school in 2007-2008. In particular, we run a Logit version of equation (1) on a variable that indicates whether the respondent reported that postponed applying to graduate school for financial reasons (as opposed to academic reasons). As we can see in Columns (5), higher levels of student loans induce students to postpone graduate school due to financial reasons.

3.4.2 Earnings

Once we turn our attention to the earnings side our IV estimates show that, on average, student loans have a negative effect on annual earnings. This result is consistent with the finding shown above, that higher debt implies lower additional human capital accumulation after college. Column (3) of **Table 5** implies that, on average, increasing a student's debt by $10,000 would lead to a decrease in earnings of $5,601 4 years after graduation.

While part of this result is certainly coming from less indebted students being, as shown above, more likely to pursue further education (and then reap the benefits some years after), we cannot rule out another channel represented by the choice of different career paths within the same educational requirements: for instance, a career with a steeper earnings process could be also characterized by the need to do some internship work after graduation before getting a full-time position.

Table 5: The effects of Student Debt on Earnings

	2009		2012	
	IV	OLS	IV	OLS
	(1)	(2)	(3)	(4)
$Debt_{2008}$ / 10000	-1524	-264	-5601**	-168
	[1733]	[174]	[2675]	[277]
Constant	26499***	24819***	42958***	35714***
	[2826]	[1502]	[4045]	[1991]
Inst. Controls	Yes	Yes	Yes	Yes
Ind. Controls	Yes	Yes	Yes	Yes
Observations	7910	7910	7910	7910

Standard errors in brackets.

3.4.3 Household Formation

Table 6 shows the results of the estimation for home-ownership, housing value conditioned on home-ownership and marriage. Understanding the impact of borrowing on first entry into home-ownership, being it inextricably linked with other life choices as career and household formation [4], is an important piece for validating our main hypothesis. Under the instrumental variable specification, we find that an increase in $10,000 in student debt increased the odds of being home-owner four years after graduation by 0.5. The effects of student debt on home-ownership predicted by the IV estimation are opposite to the OLS estimates.

Such a positive effect is consistent with indebted students working more initially after graduating. However, the increase on the extensive margin has an interesting implication once one takes a closer look, to analyze the intensive margin. Column (3) shows that, on average, an increase in $10,000 in student debt decreases the value of the house owned by $57211. Column (5) shows the effects of debt on marriage. Given that marriage and home-ownership decisions are usually made jointly, we find a similar positive effect of debt on marriage.

[4]See **Chang (2018)** on the secular decline in home-ownership and its relationship with the changing pattern in household formation.

Table 6: The effects of Student Debt on Homeownership and Marriage

	Homeownership (2012)		House Value (2012)		Marriage (2012)	
	IV	OLS	IV	OLS	IV	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
$Debt_{2008}$ / 10000	0.5***	-0.0**	-57211**	-9384***	0.4*	0.0
	[0.2]	[0.02]	[31474]	[2130]	[0.2]	[0.0]
Constant	-1.6***	-0.9***	242222***	187874***	-1.4***	-0.9***
	[0.3]	[0.1]	[40878]	[15011]	[0.3]	[0.2]
Inst. Controls	Yes	Yes	Yes	Yes	Yes	Yes
Ind. Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7910	7910	2317	2317	7910	7910

Standard errors in brackets.

3.4.4 Robustness

As a first robustness check, we include two additional controls: the state where the college is located and the cumulative GPA of the respondent at the time of graduation. Since GPA is itself an updated signal of individual's ability at the time students graduate from college and surely an important factor for post-baccalaureate education and employment status, we find relevant to see whether our results still hold when including this control. At the same time, we also include the location of the college to control for additional college fixed effects.

Secondly, we also modify our measure of student debt. First, we further restrict the sample to those that graduated with college debt. We find this exercise important as student debt might have an important non-linearity around zero. In addition, we also consider federal college debt instead of total debt (which includes private debt and debt given to the parents (PLUS)).

Third, we consider as an alternative instrument both the institutional grant-to-aid at enrollment and the change in institutional grant-to-aid until graduation year:

$$Z_j = (\frac{grant_{j,07}}{(grant_{j,07} + loan_{j,07})} - \frac{grant_{j,03}}{(grant_{j,03} + loan_{j,03})})$$

We then restrict the sample to those who started their BA in 2003-2004 and graduated in 4 years. By adding this restriction, we make sure that the instrument fully captures changes in college policies between enrollment and graduation for all individuals. Thus, we would expect that students attending colleges that increase (decrease) their grant-to-aid policies during enrollment borrow less (more) relative to colleges without policy changes.

Table A1 shows the first-stage estimates and **Table A2** show the 2SLS estimates. Under all these alternative estimations, the coefficients on the first-stage regression are still significant and most of the second-stage point estimates are consistent with the baseline estimation.

Overall, our empirical findings suggest that indebtedness has larger effects on the

accumulation of human capital, as it impacts graduates' choice of further education. At the same time, however, unconstrained graduates who choose a career with a steeper earnings path (as is the case for those who enroll in graduate programs) at the same time are more likely to postpone their entry into home-ownership. By this channel, student debt has the apparently counter-intuitive effect of anticipating entry into home-ownership. We will discuss the role of each channel in detail in the model section, and use estimates of deep parameters to investigate what determines the reduced form results.

4 The Model

The model described in this section builds on important contributions to the human capital literature, as the career choice model of **Keane and Wolpin (1997)** and the **Ben-Porath (1967)** model presented in **Huggett, Ventura and Yaron (2011)**, extended to include student debt and housing.

A unit measure of finitely-lived college graduates enter the labor market and are heterogeneous in student debt (d), human capital (h) and initial liquid wealth (k)[5]. Each household lives for T periods deterministically. During working age, workers can decide to enroll in grad school: if they do, they access a different career path. Workers also sequentially decide labor and human capital investment within their career, savings and housing and non-housing consumption while they pay for student debt (if any).

4.1 Setting

Preferences. Each agent maximizes expected lifetime utility over non-durable consumption (c) and housing services (s):

$$u(c,s) = \frac{(c^{\zeta_1} s^{1-\zeta_1})^{1-\sigma}}{1-\sigma} \tag{1}$$

where c>0 and s=1+ζ_2, where ζ_2 is the housing service from owned housing.

Labor Income. When individuals work, hourly earnings are priced competitively to reflect their marginal productivity. Assuming a representative firm that uses human capital from workers in both careers and a linear production function, earnings are given by the human-capital augmented number of hours worked multiplied by the equilibrium rental rate (R_t).

$$w_{j,t}(l_t, h_t) = R_t l_t \beta_j h_t \tag{2}$$

Workers are also exposed to unemployment risk: they can be separated from their job with probability ρ; while unemployed, they earn home production b, but cannot invest in human capital, so that $h_{t+1} = h_t$. When workers retire, they are assigned pension

[5] In the simulation, the distribution of initial liquid wealth is calibrated to match after-college parental transfers documented in **Haider and McGarry (2018)**

transfers that are proportional to their last earnings.

Careers and human capital. We restrict career choice to two different paths. In each career path, their compensation is equal to the marginal product of hours. Formally, normalizing rental rate $R_t = 1$, we get hourly wage $\tilde{w}_j = \beta_j h_j$, with $j = \{B, G\}$. The two paths differ in how workers' human capital accumulation translates into productive human capital. Human capital is less productive ($\beta_B < \beta_G$) for workers without graduate school education. Therefore, assuming workers make identical human capital investments, differences in earnings would grow as workers accumulate human capital.

After the career choice is made, individuals sequentially choose how much hours to work (l_t) and invest in further human capital ($1-l_t$). Human capital evolves according to the following Ben-Porath law of motion:

$$h_{t+1} = e^{z_{t+1}}(h_t + a((1-l_t)h_t)^{\alpha}), \quad z_{t+1} \sim N(\mu_z, \sigma_z^2) \tag{3}$$

which depends on individual's ability (a) and with risk coming from human capital idiosyncratic shocks. The Ben-Porath formulation implies that switching to the "steeper" career path that follows graduate school has three contrasting effects on human capital investment decisions. On the one hand, since earnings in the steeper career path loads more on human capital, investments are riskier. Formally, comparing variances of hourly wages: $\text{Var}(\tilde{w}_G) = \beta_G^2 \text{Var}(h) > \beta_B^2 \text{Var}(h) = \text{Var}(\tilde{w}_B)$.

Additionally, higher marginal product of human capital gives weaker incentives for graduate school educated worker to invest in human capital because of a simple wealth effect. On the other hand, $\beta_G > \beta_B$ generates a strong substitution effect, in that every unit of consumption today that is foregone in order to invest in human capital generates higher returns in the future. The third effect seems to be dominant in the data, suggesting that difference in career paths are amplified by endogenous human capital investment.

Graduate School. Individuals can enroll in graduate school while in working age: if they do, they attend for two years, and then start to work in their new career. While enrolled, human capital grows in every period at rate g_D, and workers consume using a combination of their liquid savings and a fixed benefit b_{grad}. They also get non-monetary utility ξ, which summarizes the amenity value of being in school as opposed to working.

Also, while they can switch careers at any point, they would lose all the human capital associated with it if they do. This friction implies that sorting choices made at the beginning of a worker's career can become hard to reverse as professional experience is accumulated, yielding longer term costs due to permanent under-investment in human capital.

Financial Markets. Agents can save in liquid assets k. Workers are allowed to borrow short term, using the rate r_-, but they face a credit card borrowing constraint that can depend on their current income (ϕ). If $k > 0$, savings yield a constant risk-free rate r_+.

Student Loans. There are several options for repaying student loans, but the traditional and still most common is the 10-year fixed payment plan. Similar to a

mortgage, the borrower makes constant payments over 120 months until the balance of principal and interest is paid off. Student loan payments (P_τ) can be obtained as:

$$P_\tau = \frac{d_0}{\frac{(1+r_d)^\tau - 1}{r_d(1+r_d)^\tau}} \tag{4}$$

where d_0 is the student debt at the time of college graduation and r_d is the gross interest rate on student loans. If a worker enrolls in graduate school, payments are suspended. Graduate school debt is added to the students' balance, debt is consolidated and a new standard repayment plan is started, giving the worker 120 months to repay the full amount.

Housing. Workers can buy a house at any moment of their life - except when they are enrolled in graduate school - as long as their life span is long enough that they can cover the 30-year mortgage and they have enough liquid assets to use as a down-payment. If a worker chooses not to own their house, she has to rent (P_r). The rental price is tied to the price of the house, P_o, and is set to match a given price-to-rent ratio. Individuals can ask for a 30-year fixed mortgage (m) to pay the price of the house (P_o).

There is no possibility of default or asking for a second mortgage. Home-ownership is treated as an absorbing state, so if an individual is homeowner in a given year, then it will stay as homeowner at all future dates. Apart from mortgage payments, home-ownership involves benefits that individuals can't get from renting (such as tax deductions) and additional expenses (insurance and manteinance). We include these expenses (and benefits) as δ.

At the time of buying the house, individuals face two borrowing constraints: **(1)** they must make a down-payment (1-λ), **(2)** their monthly debt payments (student and mortgage debt) cannot exceed a proportion of their income (ψ). We assume that both constraints must be enforced at origination only.

Individuals must always pay the mortgage payment (P_λ):

$$P_\lambda = \frac{(1-\lambda)P_o}{\frac{(1+r_d)^{30} - 1}{r_d(1+r_d)^{30}}} \tag{5}$$

4.2 Recursive formulation

We will illustrate the problem for agents of different stages of life, as the recursive formulation will differ according to it. The unit of time is two quarters. The choice is motivated by several facts: it corresponds to the length of the initial grace period (when student loan payments must not be made), it allows for a reasonable accounting of separation risk, and yet it reduces the time dimension enough so that we can solve and estimate the model. We denote future values in recursive expressions by adding a $\prime$ to them.

Retired workers:

At retirement age $t = t_R$, workers are assigned pension transfers (p) that are proportional to their last earnings (w_{t_R-1}). Retired workers make consumption and saving decisions using their savings from working age (k_{t_R-1}). If they are home-owners (o), they have to pay the residual parts of their mortgage (m) in equal payments (P_λ) until mortgage debt is fully paid off. Otherwise, if they are renters (r), they need to rent and pay P_0 every period. Retired workers cannot buy a house, as mortgage duration exceeds their life expectancy. We assume no bequests and terminal condition for liquid assets to be equal to zero.

Recursive Problem for renters, for $t = t_R, ..., T$, is :

$$V_{r,t}(k, w) = \max_{k'} u(c, s) + \beta V_{r,t+1}(k', w) \tag{6}$$
$$c + k' + P_r = (1 + r) \cdot k + pw_{t_R-1}$$
$$m = 0, k_T = 0,\ k' \geq \phi(pw_{t_R-1}),\ c \geq 0,$$

The Problem for home-owners for $t = t_R, ..., T$, with mortgage payment P_λ is:

$$V_{o,t}(k, w, m) = \max_{k'} u(c, s) + \beta V_{o,t+1}(k', w, m') \tag{7}$$
$$c + k' + (P_\lambda + \delta) = (1 + r) \cdot k + pw_{t_R-1}$$
$$m' = (1 + r_d)m + P_\lambda \leq 0$$
$$k_T = 0,\ k' \geq \phi(pw_{t_R-1}),\ c \geq 0$$

In both cases, $r = r_+$ if $k \geq 0$, and $r = r_-$ otherwise. P_λ is the mortgage payment as defined in equation (5) and depends on the down-payment the homeowner chose at the time the mortgage was originated.

Workers (without student loans):

Agents enter working age ($t = 1, ..., t_{R-1}$), and face two discrete choices every period: which career to pursue, i.e. whether to enroll in graduate school ($j = \{B, G\}$), and whether to buy a house or not ($H = \{r, o\}$),. Workers' problem entails saving and choosing how much hours to work (l) and invest in further human capital (1-l) in every period. Human capital investment is risky and subject to an independent and identically distributed idiosyncratic shock every period (z). Earnings are given by the human-capital augmented number of hours worked multiplied by the equilibrium rental rate as defined in (2).

Workers are also exposed to unemployment risk: while working (e=1), they can be exogenously separated from their job with probability ρ; while unemployed (e=0), they earn home production b, but cannot invest in human capital, so that $h' = h$. In order to ask for a mortgage and thus become a homeowner, workers have to satisfy the down-payment (λ) and at the same time satisfy the debt-to-income constraint (ψ).

Once the mortgage is approved, the payments (P_λ) are fixed for the next 30 years as defined in (5).

The recursive problem for renters without graduate school education, while employed, is thus:

$$V_{r,t}(k,h,e) = \max_{k',l} \{u(c,s) + \beta\mathbb{E}[EV_{t+1}(k',h',e')]\} \tag{8}$$

$$EV_t(k,h,e) = \max_{H,G} \left\{V_{r,t}(k,h,e), V^g_{r,t}(k,h,d_g,s), V_{o,t}(k,h,e,m), V^g_{o,t}(k,h,d_g,s,m)\right\}$$

$$c + k' + P_r = (1+r)k + w_j(l,h)$$

$$h' = e^{z'}(h + a((1-l)h)^\alpha)$$

$$m' = (-\lambda P_o)[\mathbb{1}_{\frac{P_\lambda + P_\tau}{w_j} \leq \psi}][\mathbb{1}_{H=o}]$$

$$k' \geq \phi w_j,\ c \geq 0$$

where V^g is the value function of a worker enrolled in grad school, and the states s, d^g indicate respectively periods of attendance and consolidated student loan balances. Unemployed workers' problem is analogous, with earnings replaced by b and no human capital investment decision. Unemployed workers can find a job in the same career with probability $1-\rho$.

Home-owners with housing payment P_λ face the following problem:

$$V_{o,t}(k,h,m,e) = \max_{k',l} u(c,s) + \beta\mathbb{E}\Big[EV_{o,t+1}(k',h',m',e')\Big] \tag{9}$$

$$EV_{o,t}(k,h,m,e) = \max_{G} \left\{V_{o,t}(k,h,e,m), V^g_{o,t}(k,h,d_g,s,m)\right\}$$

$$c + k' + (P_\lambda + \delta) = (1+r)\cdot k + w_j(l,h)$$

$$h' = e^{z'}(h + a((1-l)h)^\alpha)$$

$$m' = (1+r_d)m + P_\lambda \leq 0$$

$$k' \geq \phi w_j,\ c \geq 0$$

If the worker is in the first period of home-ownership, P_λ equals to the down-payment required to buy the house. After that period, housing payments are determined by the mortgage equation (5), as before.

At this point we want to characterize the recursive problem of the graduate-school educated worker. For simplicity, we will characterize only the problem of the renter. Define $\bar{S}$ as the number of periods required to get the degree. For $s \leq \bar{S}$:

$$V^g_{r,t}(k,h,d_g,s) = \max_{k'} \left\{u(c,s) + \beta\mathbb{E}[V^g_{r,t+1}(k',h',d'_g,s')]\right\} \tag{10}$$

$$c + k' + P_r = (1+r)k + b_{\text{grad}}$$

$$h' = h\cdot(1+g_D)$$

$$k' \geq 0,\ c \geq 0$$

When $s > \bar{S}$, the recursive problem is analogous to the problem of a worker with student loans, conditional on career earnings' slope β_j, which is treated below.

Workers (with student loans):

Workers that enter the labor market with any positive amount of student debt ($d_0 > 0$) are by default enrolled in a 10-year fixed rate repayment plan, indicated by $\tau = 0$ [6]. Workers don't have the option of defaulting or deferring on student loan payments. An employed renter would solve:

$$V_{r,t}(k,h,j,d,e) = \max_{k',l} \{u(c,s) + \beta\mathbb{E}[EV_{t+1}(k',h',d',e')]\} \tag{11}$$

$$EV_t(k,h,d,e) = \max_{H,G} \left\{V_{r,t}(k,h,d,e), V^g_{r,t}(k,h,d_g,s), V_{o,t}(k,h,e,d,m), V^g_{o,t}(k,h,d_g,s,m)\right\}$$

$$c + k' + (P_\tau + P_r) = (1+r)\cdot k + w_j(l,h)$$

$$h' = e^{z'}(h + a((1-l)h)^\alpha)$$

$$d' = (1+r_d)d + P_\tau \leq 0$$

$$m' = (-\lambda P_o)[\mathbb{1}_{\frac{P_\lambda + P_\tau}{w_j} \leq \psi}][\mathbb{1}_{H=o}]$$

$$k' \geq \phi w_j,\ c \geq 0$$

Home-owners in working age with mortgage payment P_λ face the following problem:

$$V_{o,t}(k,h,m,d,e) = \max_{k',l} u(c,s) + \beta\mathbb{E}\Big[EV_{o,t+1}(k',h',d',m',e')\Big] \tag{12}$$

$$EV_{o,t}(k,h,m,d,e) = \max_{G} \left\{V_{o,t}(k,h,d,e,m), V^g_{o,t}(k,h,d_g,s,m)\right\}$$

$$c + k' + (P_\tau + P_\lambda + \delta) = (1+r)\cdot k + w_j(l,h)$$

$$h' = e^{z'}(h + a((1-l)h)^\alpha)$$

$$d' = (1+r_d)d + P_\tau \leq 0$$

$$m' = (1+r_d)m + P_\lambda \leq 0$$

$$k' \geq \phi w_j,\ c \geq 0$$

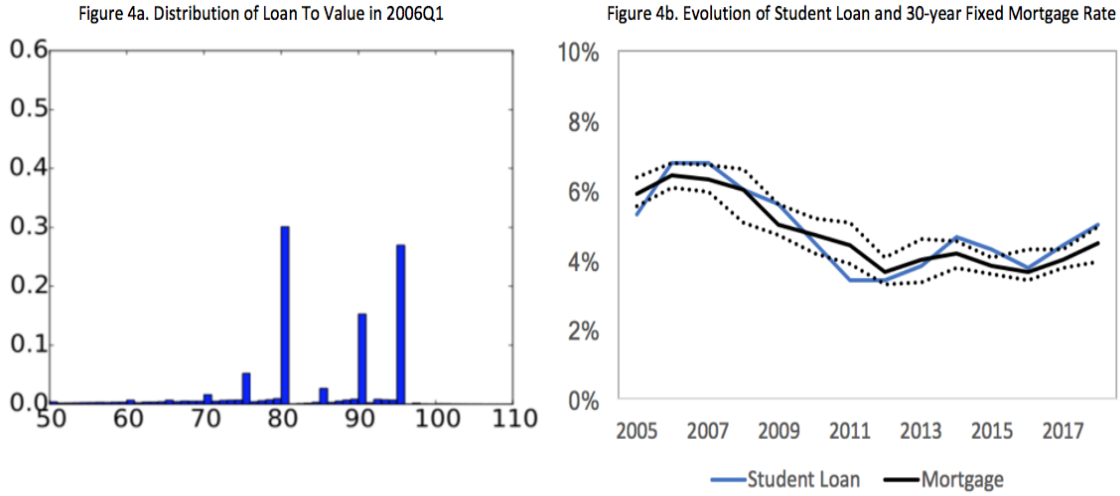
Where P_τ is the student debt payment as defined in equation (4).

5 Calibration and Estimation

In this section, we discuss how we determine the parameters required for the analysis. We set these parameters in two ways. First, we set some parameters from elsewhere in the literature or by using data estimation (**Table 7**). The remaining parameters are estimated using indirect inference through the model.

[6] In this subsection both workers with undergraduate and graduate debt are treated together, assuming workers choose to consolidate their student loans at the day of graduation

Figure 3: Loan to Value and Interest Rate on Student loan and Mortgage debt



Note: Figure 4a shows the distribution of the Loan To Value at origination in 2006Q1 (taken from **Greenwald (2018)**). Figure 4b shows the evolution of the federal student loan interest rate and the lowest, average and highest mortgage rate for a 30-year Fixed mortgage rate. Sources: Fannie Mae Single Family Dataset, Federal Student Aid, U.S. Department of Education, and, Freddie Mac's Primary Mortgage Market Survey (PMMS).

5.1 External Parameters

Timing. Each period time in the model represents two quarters. Individuals start making decisions when they graduate from college. After finishing college, they start working and repaying their student debt. Agents retire at the age of 65 and die when they are 80.

Preferences. Preferences are set using standard calibration in the macroeconomics literature. The yearly discount factor is set to be 0.99. We set the constant relative risk aversion in the utility function to 2.

Career and Human Capital. Following **Huggett, Ventura and Yaron (2011)**, we set the mean shock of human capital to 0.029 with 0.075 variance and the production function parameter α to 0.66. We assume that, when unemployed, worker gains access to unemployment benefits that sum up to b calibrated to the Federal poverty threshold for an individual living alone in 2008 ($991 USD a month).

Labor Income. We set the rental rate to a yearly rate of 5% of the house price, and pension to be 45 percent of the last earned income. Finally, exogenous separation risk is set to 6 percent per period.

Financial Markets and student debt. The annual interest rate for student loans and a 30-year fixed-rate mortgage is fixed to the 2004-2008 average rate of 6 percent (see **Figure 3b**). The risk-free interest rate for savings is set at 0 following null real returns after 2008 and credit card borrowing rate is fixed at an annual 10 percent. We set a credit card borrowing limit of $-\$5,000$, targeting a median rate of credit limit to annual labor income for college graduates of 20 percent.

Housing. We set the price of the house at the median home price in the U.S.

Table 7: Calibrated Parameters

	Parameter	Value	Description
Preferences			
	β	0.99	Discount Rate
	σ	2	Risk Aversion
Careers, Human Capital			
	a	0.5	Learning Ability
	α	0.66	Ben-Porath Production Function
	μ_z	0.029	Mean Shock of Human Capital
	σ_z	0.075	Riskiness of Human Capital Investment
Labor Income			
	p	0.45	Pension Rate
	ρ	0.06	Separation Probability
	b	\$991	Home Production (monthly)
Financial Markets, Student Debt			
	ϕ	$-$\$ 5,000	Credit Card Borrowing Limit
	r^+, r^-	$\{0.01, 0.05\}$	Interest on liquid assets
	r_d	0.035	Interest on student loans and mortgages
	τ	10	Years for Fixed Repayment Plan
Housing			
	P_o	\$ 250,000	House price
	λ	$\{0.20\}$	Downpayment (fraction of house price)
	ψ	0.43	Debt-to-Income Ratio

(\$200,000). The rental price per year is set at 5% of the house value to match the price-to-rent ratio (20). To calibrate the additional costs of homeownership, we compare 2015 ACS data for the median gross rent (rent and utilities) and median homeownership cost (mortgage payments, real estate taxes, insurance and utilities) in each state. We find that the median cost to own a home is 50% more than the median cost to rent each month.

The parameters that determine the LTV and DTI are chosen to match institutional features of the US mortgage market. For the LTV parameter, fix a downpayment constraint of $0.2 \cdot P_o$. This value is intended to reflect the distribution of the LTV in Freddie Mac data, which has two masses point around 80% and 90% (see **Figure 3a)**, where the first mass point is typically populated by younger buyers and thus seems more appropriate for pinning down the problem of first home-ownership. In order to qualify for a Qualified Mortgage under CFPB guidelines, a borrower's total debt-to-income ratio, including the mortgage payment and all other recurring debt payments, cannot exceed 43 percent (Consumer Financial Protection Bureau 2013). Thus, we set the DTI parameter to 43%.

Finally, we have to make choices regarding the starting values of liquid assets, experience and student debt. We assume students leave college with zero liquid assets, but receive an exogenous transfer ε_k from their parents, where $\log \varepsilon_k \sim \mathcal{N}(\mu_k, \sigma_k)$. Parameters of the log-normal are calibrated to match parental transfers, as documented in **Haider and McGarry (2018)**, that report an average transfer of $\$15,275$ with the average being $\$27,247$ conditional on considering only

Table 8: Estimated Parameters

Parameter	Description	Value	Standard Dev.
ξ	Amenity Value of Grad School	\$75171.38	-
g_s	Grad School HC growth	4.4%	-
β_G	Skills Premium	12.7%	-
ζ_1	Elasticity to Housing Service	0.605	-
ζ_2	Housing Service	1.544	-

the 56% of graduates that receive a positive amount from their parents. We also calibrate the initial level of human capital to match the standard deviation of earnings after graduation at \$22.152 from CPS data. Finally, we match an average debt balance of \$16.619, as reported by B&B in 2008 [7] .

5.2 Estimation

Parameters $\Theta = \{\xi, g_s, \beta_G, \zeta_1, \zeta_2\}$ are jointly estimated by Simulated Method of Moments. Let Let x_i be an i.i.d. data vector, $i = 1, ..., n$, and $y_{is}(\Theta)$ be an i.i.d. simulated vector from simulation s, so that $i = 1, ..., N$, and $s = 1, ..., S$. The goal is to estimate Θ by matching a set of simulated moments, denoted as $h(y_{i,s}(\Theta))$, with the corresponding set of actual data moments, denoted as $h(x_i)$. Define:

$$g_n(\Theta) = \frac{1}{n}\left[\sum_{i=1}^{n} h(x_i) - \frac{1}{S}h(y_{i,s}(\Theta))\right] \tag{13}$$

Building $g_n(\Theta)$ in this case faces an important challenge. In classic SMM estimation, exploration of the state space requires the model to be solved more than 10000 times. In the case of a model with a large state space like ours, this could be computationally expensive [8]. To overcome the curse of dimensionality, we discretize the parameter space using sparse grids (see **Bungartz and Griebel (2004)**). A similar approach in structural modelling as been using in the context of maximum likelihood estimation, see for instance **Heiss and Winschel (2008)**. By using functions with support restricted to a neighborhood of each point to build $h(y_{i,s}(\Theta))$, our approach is suitable for approximating the parameter-moment mapping even in cases of sharp behavior, like large fluctuations of the gradient (see **Stoyanov (2013)**. Having $h(y_{i,s}(\Theta))$ at hand, we can construct an objective function that looks like:

$$\hat{\Theta} = \arg\min_{\Theta} g_n'(\Theta)\hat{W}_n g_n(\Theta) \tag{14}$$

where $\hat{W}_n$ is a positive definite matrix that converges in probability to a deterministic positive definite matrix W. We will use an identity matrix for W for now. Finding a solution to (14) faces the issue of the possible presence of many local minima: to make

[7] The figure is composed by a percentage of 66% of borrowers, with cumulative average balances of \$22.560

[8] Using a cluster with 144 CPUs, we manage to obtain a full solution of the model and simulate it in about 14 minutes.

Table 9: Target Moments

Moments	Mean		Std. Deviation	
	Data	Model	Data	Model
A. Sample Means				
Debt-to-Income at age 27[a]	0.67	0.65	-	-
Home-ownership ratio at age 38[c]	1.0	0.648	-	-
B. Regression Coefficients				
Home-ownership, constant[b]	0.474	0.464	-	-
Home-ownership, slope[b]	0.019	0.023	-	-
Graduate to Bachelor earnings ratio, constant[b]	1.108	1.24	-	-
Graduate to Bachelor earnings ratio, slope[b]	1.71	1.629	-	-

Sources:
a = B & B 2008 - 2012;
b = Current Population Survey, years 2000-2018, individuals with at least a bachelor degree, age 23-66, working full time
c = Current Population Survey, years 2000-2018, ratio between individuals with a bachelor degree and grad school education

sure our solution is robust, we re-start our optimization routine using multiple sets of starting values. Each routine solves its problem using a Nelder-Mead algorithm. Having an estimate of $h(y_{i,s}(\Theta))$ also allows us to obtain standard errors of parameter estimates, as they can be calculated knowing that

$$\text{aVar}\left(\hat{\Theta}\right) = \left(1 + \frac{1}{S}\right)\left[\frac{\partial g_n(\Theta)}{\partial \Theta} W \frac{\partial g_n(\Theta)}{\partial \Theta'}\right]^{-1} \tag{15}$$

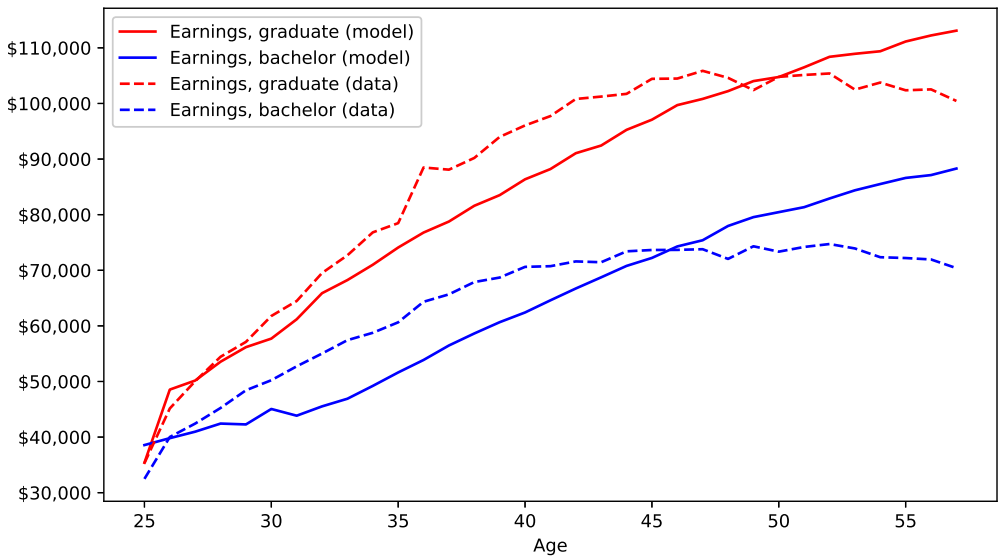
We want to match the empirical income profiles, the enrolment and the home-ownership rates of individuals in working age. To do so, we take households with at least a BA degree, older than 23 years old from 2000-2018 Census data. We then separate the sample between those workers that obtained more than a bachelor degree at some point and those with only a bachelor degree. We use earnings in 2012 dollars, conditional on workers having a full time job, to calculate the income profiles. The six moments used in our estimation of the 5 parameters are computed as follows: we use the total student loan debt to income ratio at age 27, as we argue it proxies well both enrollment in additional education and the fact that it comes mostly from low-indebted students. We then extract a constant and a linear trend from both the life cycle profiles of earnings and home-ownership. In the first case, we use as a moment the ratio between constant and slope of earning profiles for workers with graduate degree and workers with only a bachelor degree. In the second case, we just aim at matching the overall life cycle profile of home-ownership.

Table 9 displays parameter estimates [9]. The model replicates well overall earnings

[9] The amenity value of grad school is expressed in dollar terms, but does not correspond to ξ. To obtain it, we assume individuals in grad school are renters and have zero net liquid assets. Then the value is obtained by solving for the amount of consumption increase that would yield equivalent flow utility to grad school attendance.

dynamics, as in **Figure 4**. A better fit could be obtained by allowing a constant depreciation rate of human capital, which would induce a stronger concavity in the life cycle profile of earnings. Notice, however, how the model matches pretty well average yearly income growth between age 25-45 (1.9% in the data and 1.9% in our model). An extension of the model could perform the joint estimation of the Ben-Porath production function parameter and a linear depreciation rate of human capital.

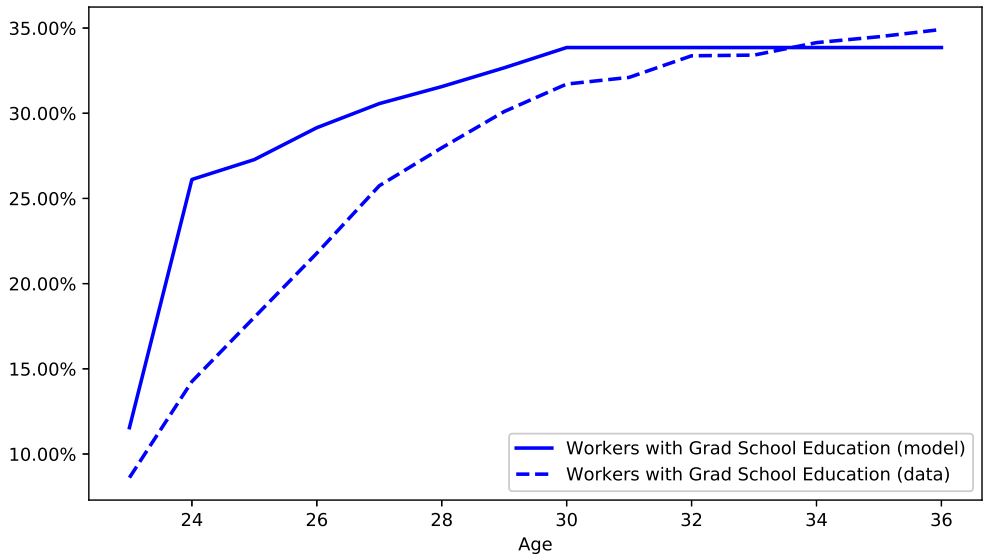
Figure 4: Life Cycle Profiles for Income, Model and Data



Data: Current Population Survey, years 2000-2018, population aged 24-66. Graduate School educated workers are all workers with an academic title higher than a 4-year college degree.

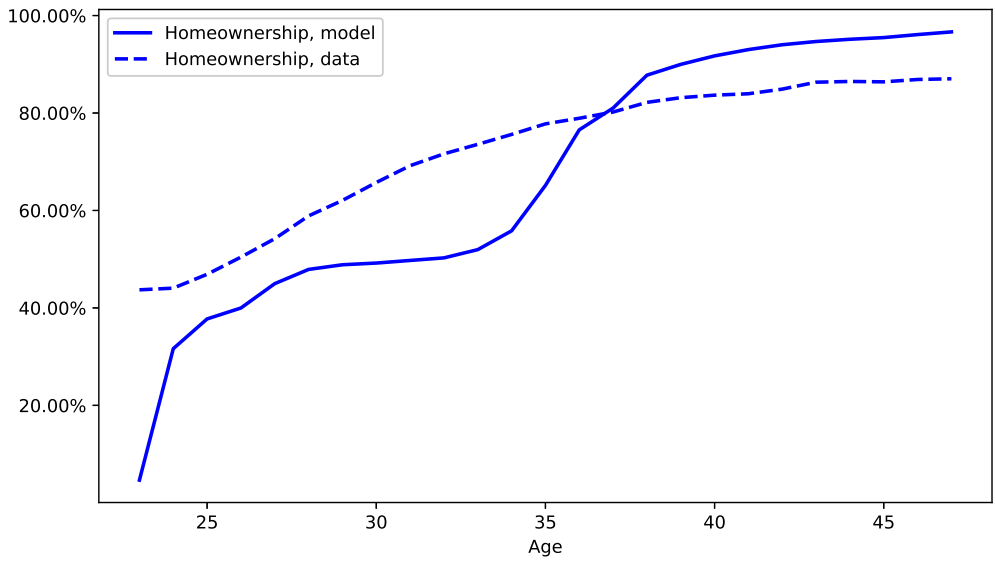
The patterns in enrollment, shown in **Figure 5**, replicates gradual entry into post-graduate studies, and the level slightly more than a third of college-educated workers pursuing further education. Because of the extreme assumption that human capital accumulated while working in one career is destroyed when switching, workers in the model tend to enroll earlier than in the data. The slope in the life-cycle pattern of home-ownership in our model, as in **Figure 6**, is slightly higher than in the data: especially in early years, home-ownership is substantially lower, and then it catches up later in the working life. This can be explained with the absence of bequest shocks, that are present in the data and allow households to anticipate home-ownership by relaxing their own budget constraint. Decomposing the rate of home-ownership by educational level, we can see that the delay in purchases is entirely attributable to workers that pursue graduate studies (see **Figure 7** in **Appendix 4**).

Figure 5: Pattern of Enrollment in Graduate School



Data: Current Population Survey, years 2000-2018, population aged 23-66. Graduate School educated workers are all workers with an academic title higher than a 4-year college degree.

Figure 6: Pattern of Entry into Home-Ownership



Data: Current Population Survey, years 2000-2018, population aged 23-50.

5.3 Identification

The model generates a large number of moments that can be used for estimation. Since interactions between each choice are quite complex, however, a clean identification is not possible. Observing how moments move with parameters around the solution can still provide useful insights on their structural interpretation. As illustrated in **Appendix 3**, the ratio between cumulative student debt (graduate and undergraduate) is moving proportionally to the skill premium on experience, β_G. The difference between the earnings' entry levels, as predictable, are almost monotonically related to the parameter that disciplines human capital accumulation while in graduate school, i.e. g_s. As for home-ownership moments, while the slope of housing purchases varies mostly with the elasticity to housing parameter ζ_2, the level is identified by the housing service parameter ζ_2.

6 Results

In this section, we show the mechanisms behind the interaction between student debt, career choices and housing in our economy. We first analyze the performance of the baseline model in matching the empirical results presented in **Section 3**. We then provide some quantitative results that illustrate the contribution of each friction on the effects of debt on career choices and home-ownership. Finally, we use the model to infer the effects of student debt on human capital and home-ownership in the current environment.

6.1 The Role of Student Debt on Earnings and Wealth

There are two main trade-offs involved in the initial career choice. First, workers that not pursue additional education start with higher disposable income but then have lower income growth compared to the more human capital intensive careers. Second, income paths of bachelor-educated workers are less volatile as human capital accumulation is a risky investment. This is immediate if looking at models' predictions for income, as in **Table 10**. Workers whose undergraduate borrowing is above the median level start with higher earnings, because they are most likely to be working rather than being enrolled. After some years, the sorting effects of student loans start to affect earnings, and thus create a wide and persistent earnings gap.

Table 10: Earning Profiles by Debt Group

Undergraduate Student Loans	Amount Borrowed	
	$< \$22.560$	$> \$22.560$
Age 25	0.90	1.11
Age 28	1.036	0.94
Age 30	1.06	0.92

Simulated results from the model. Ratio of income to average income for the same age.

In absence of frictions to borrowing or to the ability to transfer of human capital across careers, student loans should have no effect on career choices and human capital investment. In our model, the effects of student loans on career choices and lifetime earnings are ultimately the result of three main frictions. First, young workers face credit constraints that limit their ability to self-insure against negative realizations of their human capital investment, or to smooth consumption through prolonged periods of unemployment. Second, human capital is not fully transferable across careers: we assume that any experience accumulated in one career path is lost when the worker transfers to the other career. This makes using the career with a lower loading on human capital as an initial way to earn higher wages and then move on to the graduate school a decision with costs that increase in workers' tenure on the job. Finally, student loans follow a pre-determined fixed repayment schedule and alternative repayment schemes are limited [10].

Table 11: Sorting into Graduate School

Graduate School Enrollment	Student Debt		Total
	$< \$22.560$	$> \$22.560$	
Graduate School Enrollment at Age 25			
Low Skill	45.47%	0.0%	30.16%
High Skill	50.01%	0.0%	32.0%
Overall Graduate School Enrollment			
Low Skill	46.23%	3.9%	33.3%
High Skill	51.25%	7.0%	36.3%

Skill Groups: below and above median human capital level

Table 11 shows how entry into graduate school is affected by borrowing. More indebted students are significantly less likely to enroll. This happens for two reasons: on the one hand, while attending school allows to postpone payments, new debt is added to the existing one. Adding the burden of additional borrowing has compounding effects which put considerable pressure on future disposable consumption, thus discouraging enrollment. On the other hand, workers still have the possibility of starting to repay, while working, and then enrolling when their debt burden has reduced. The value of switching, however, decreases with tenure for two reasons: one is the mentioned non-transferability of human capital across careers. The other is a simpler horizon effect: as the worker gets older, and approaches the age where it would be optimal to start a mortgage, attending graduate school would imply a postponement of entry into home-ownership, reducing the value of additional education [11].

[10] Our empirical analysis is focused on graduates that entered the labor market in 2008: during those years, less than 7% of borrowers enrolled in plans that allowed payments to be linked to earnings. After a series of reforms, enrollment in income-based plans has increased substantially in the following decade.

[11] We are not modelling household formation, and thus we are missing a potential counter-balancing effect, represented by adding a second income stream. However, as suggested by empirical evidence in the previous section, the impact of student debt on household formation goes in the same direction

Table 12: Entry into Home-Ownership

Age of First Purchase	Non Borrowers	Borrowers	
		$< \$22.560$	$> \$22.560$
Group			
All Workers	34	26	29
Only Bachelor[a]	24	25	28

a= includes those who do not enroll in grad school at any point in time

In our model, student loans affect home-ownership through two main channels. On the one hand, highly indebted students are less likely likely to pursue extra education, which has lower returns to human capital, thus lower expected growth but also lower income risk. Thus, housing is a relatively more attractive investment at the start of the working career. On the other hand, student loan borrowers might face more difficulties in satisfying both the down-payment and the debt-to-income requirements for a mortgage. First, since student loan payments reduce workers' disposable income, both investment in human capital and savings will be smaller. Second, higher borrowing sorts workers into less human capital intensive careers, which negatively affects their lifetime earnings.

As shown in **Table 12**, all those effects play a significant role in determining the age at which households purchase their first home. Notice from the second row that, for those workers who don't choose to enroll in graduate studies, borrowing affects home-ownership mostly through the wealth effect. Hence, borrowers enter into home-ownership later, with the delay growing non-linearly in debt balances. In the aggregate, however, the role of graduate school dominates. As we can observe from the first row, the larger share of enrollment of non-borrowers pushes home-ownership to later in life. As balances grow, the two effects compensate each other. Notice, however, how the main effect of borrowing is to affect the slope of the home-ownership age profile.

as the effects on home-ownership. **Chang et al. (2019)** points out that the recent decline in home-ownership can be attributed to delayed household formation, providing additional support to the view that housing purchase and marriage can be considered as a joint choice.

Figure 7: Home-ownership ratio over life cycle

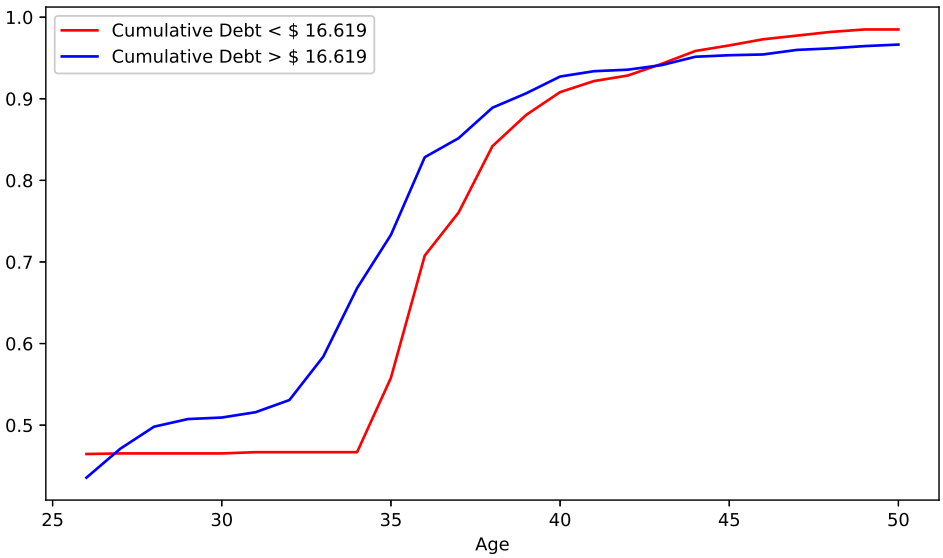


Figure 7 illustrates this fact. Differences in age-earnings profile affect the timing of buying the house. Non-indebted workers initially invest in additional human capital and undertake riskier career paths. In going to graduate school, they face some periods of lower earnings, and subsequently some years of lower disposable income (because they borrow more to pay for graduate school tuition). There is also a consumption smoothing motive that explains later entry into home-ownership. Workers with lower debt balances enter into housing market later because, as they sort into careers with higher income growth, they also find it optimal to delay home-ownership until they can post the down-payment without impacting their disposable income in a substantial way. These two factors cause them to delay buying a house until they can afford it later in the life-cycle. Before that, investment in human capital is more attractive . On the other hand, those who face a lower expected wage growth value housing as a more attractive investment, and then purchase as early as possible.

Looking at disposable income distributions in **Table 11** (in Appendix) helps understanding how the two effects play a role. Workers with post-college education will have higher earnings, but facing the down-payment will still force many of them to compress current consumption substantially. Postponing entry into home-ownership is then consistent with willingness to smooth consumption over time, as their expected consumption growth is larger. On the other hand, workers with only a bachelor degree will have to compress their consumption anyway, through multiple periods of sustained savings or by accepting a period of lower consumption. However, since their expected income growth is lower and more predictable, value of waiting is lower, and thus many opt into an early entry into home-ownership.

6.2 Evaluating the Increase in Student Debt from 2008 to 2017

[[TO BE UPDATED HERE]]

6.3 Evaluating a Radical Policy: Debt Forgiveness for All

[[TO BE UPDATED HERE]]

6.4 A Debt-to-Equity Swap: Income Based Repayment

This section evaluates the impact of the recent increase in student debt on earnings and home-ownership taking into account the introduction of the income-based repayment plan (IBR). IBR plans are available to federal loan borrowers and depend on the borrower's discretionary income. Unlike fixed payment plans, there is no set horizon of loan repayment; instead, the borrower pays 10 or 15 percent of discretionary income each month until the loan is paid off or 20 to 25 years pass, in which case the remaining balance is forgiven (but included as taxable income). To be eligible for these plans, borrowers have to report their income on an annual basis.

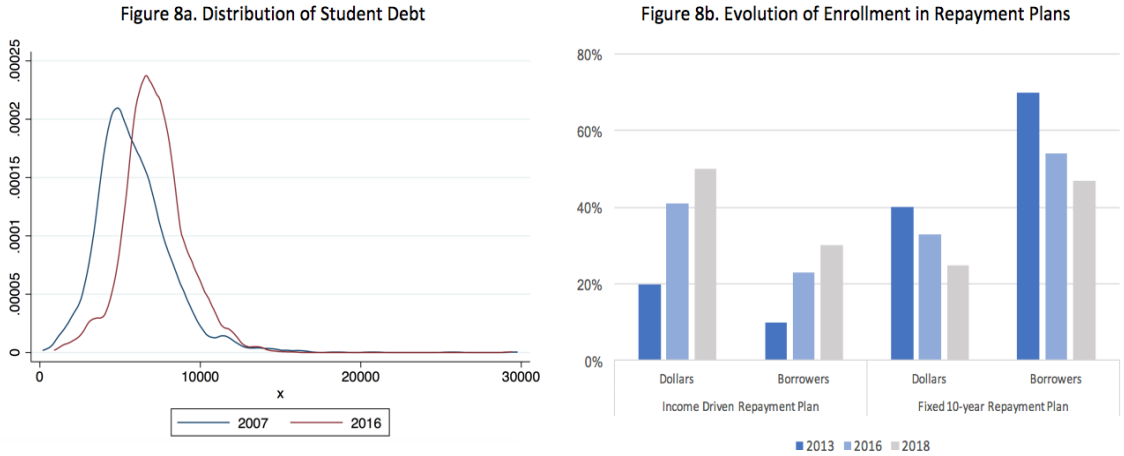
Since 2007/2008, the distribution of student debt has moved significantly to the right (**Figure 8a**). At the same time, income-repayment plans have become more popular. Since 2012, the percentage of borrowers enrolled in income-driven repayment plans has more than triplicated, from less than 10% in 2013 to 30% in 2018 (**Figure 8b**). Additionally, the total balance for those enrolled in an income plan summed to 50% of all federal student debt in 2018. This suggests that most of the individuals who enrolled in IRP had higher-than average student loan balances.

In this an income repayment plan in every period is introduced in the model as a baseline repayment scheme. The income repayment plan is defined to replicate the Pay As You Earn plan introduced in 2012: 10 percent of discretionary income for 20 years. Under the PAYE Plan (p=1), if individuals don't recertify their income annually, their monthly payment returns to the amount they would pay under the Standard Repayment Plan with a fixed repayment period (p=0), based on the loan amount they owed when they initially entered the income-driven repayment plan.

It is not immediately clear how these plans moderate the effects of initial student loan debt. On the one hand, enrollment in income-driven repayment plans reduces the ratio of student loan payments relative to income, increasing disposable income. On the other hand, it can extend the repayment period significantly relative to a 10-year plan, thereby potentially increasing the total interest paid by the student loan borrower over the life of the loan.

[[TO BE UPDATED HERE]]

Figure 8: Evolution of Student Debt and Repayment Plans



Note: Figure 6a shows the distribution of yearly student loans awarded to full-time first-time undergraduates for 2007 and 2016. Figure 6b shows the percentage of student loan borrowers enrolled in repayment plans as well as the percentage amount of student debt each repayment plan represents. Sources: The Integrated Postsecondary Education Data System (IPEDS) and the Federal Student Aid Data.

7 Conclusions

Between 2004 and 2018, the outstanding stock of student debt more than tripled in the United States. In this paper, we address the following question: what are the implications of higher levels of student debt on life-cycle decisions? We find that, on average, graduating with student debt causes higher earnings right after college but lower income growth four years after graduation. We then argue that this negative relationship is the result of student debt influencing career choices of college graduates. In particular, we find that individuals with higher levels of student debt are more likely to sort into careers that typically require less additional human capital after college, and specifically are less likely to enroll in grad school. We also show that student debt has substantial effects on wealth accumulation: indebted students become first-time home-owners earlier. Our findings suggest that student loans induce career sorting based on starting financial conditions. Indebted workers prefer to front-load earnings, but this choice will leave them with limited ways to compensate for the gap in human capital accumulation. This is partly compensated by earlier access into home-ownership, although the size of homes purchased tend to decrease in the size of consolidated student loans.

Several policies have been advocated to help student loan borrowers. However, policy makers need guidance on the type of policies that are likely to be effective, from those that address liquidity constraints of borrowers to policies aimed to forgive a portion of student debt. The main difficulty faced by the existing literature has been the inability to observe detailed information about student debt and decisions over time coupled with the challenge to establish causality between student debt and other choices due to the lack of exogenous variation in the data.

We show that, by introducing career heterogeneity and post-schooling credit constraints, student debt plays a key role in explaining inequality throughout the life-cycle. College graduates with higher student debt sort into careers with lower

compensation for human capital accumulation, and then experience lower earnings growth. A key factor in this sorting result is the increased preference for earnings front-loading induced by student debt. We contribute to the policy debate by showing the merits of two alternative proposals. One, that is re-distributive in nature, is to operate with a widespread forgiveness plan of all undergraduate debt, financed by lump sum taxes to be repayed over an extended period of time by the same cohort whose debt was forgiven. The other, that resembles closely the path chosen so far, aims at alleviating the burden of student debt by linking repayments to earnings. [[RESULTS ON THIS COMING SOON]]

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Appendix 1. Data

In this section we describe in more detail the data sources for the variables covered in Section 3.

A1.a B&B data

We use the restricted-use data and keep observations that have a positive value in the weight variable wte000, which represents the students who received a bachelor's degree in the 2007-08 academic year and responded to all interviews (2007-08, 2009, and 2012). The sample includes approximately 14,500 college graduates. The majority of these variables are available for public-use on-line (https://nces.ed.gov/datalab/powerstats).

We first drop 2% of observations that have missing values in some of the variables of interest. We restrict the sample to those students who attended only one 4-year institution and attended full-time in 2007/2008 (we drop 28% of observations). We also drop those who attended a private non-profit institution (we drop 4% of the remaining observations).

We merge the restricted sample with the institutional data from IPEDS 2004-2007 and drop those institutions in the B&B that are missing in IPEDS (2% of observations). We then restrict to colleges that have at least 5 B&B respondents (we drop 7% of the remaining observations). Finally, we focus on 21-26 years old (we drop 11%). The result is a size sample of 7804. We use and modify the following variables:

Selectivity of College (selectv2): Indicates the level of selectivity of the 2007-08 bachelor's degree-granting institution. Only applies to public and private nonprofit 4-year institutions; other institutions were set to zero. Variable categories are: Not public or private nonprofit 4-year, Very selective, Moderately selective, Minimally selective, and Open admission. We classify them in two groups: low/medium selective (Moderately selective, Minimally selective, and Open admission) and very selective.

School Type (sector4): Indicates the sector of the 2007-08 bachelor's degree-granting institution, using five categories. Variable categories are: Public 4-year, Private nonprofit 4-year, Public 2-year, For-profit, and Others or attended more than one institution.

2012 Current Primary Job Salary (b2cjsal): Indicates the respondent's annualized salary from their current or most recent primary job. Primary job is defined as the respondent's current or most recent job that lasted more than 3 months. We replace with a zero value the earnings of those who were not working at the time of the interview but reported the most recent earnings.

2009 Current Primary Job Salary (b1erninc): Indicates the respondent's income from their current job as of the B&B:09 interview. For respondents with multiple jobs, salary is only for the primary job, the job at which the respondent worked the most hours.

Employment and Enrollment Status in 2009 and 2012 (b1lfp09 and b2lfp12): Indicates the respondent's level of labor force participation and enrollment as of the BB:09 interview. Variable categories are: One full time job, enrolled; One full time job, not enrolled; One part time job, enrolled; One part time job, not enrolled; Multiple jobs, enrolled, Multiple jobs, not enrolled; Unemployed, enrolled; Unemployed, not enrolled; Out of the labor force, enrolled; Out of the labor force, not enrolled.

2012 Current Value of Primary Residence (b2fhomval): Indicates the approximate current value of the respondent's home(s), as reported by the respondent in the B&B:12 interview. We classify as home-owners those observations with a value higher than zero.

Completed Master's Degree Program as of 2012 (b2macmp): Identifies whether the respondent had completed a master's degree program after completing the 2007-08 bachelor's degree, as of the B&B:12 interview.

Cumulative loan amount borrowed for undergraduate through 2007-08 (b1borat): Indicates the cumulative amount borrowed from all sources for the respondent's undergraduate education through June 30, 2008. Does not include Parent PLUS loans.

Field of Study (majors4y): Indicates the respondent's major or field of study, using 10 categories, for the 2007-08 bachelor's degree. Variable categories are: Computer and information sciences; Engineering and engineering technology; Bio and phys science, sci tech, math, agriculture; General studies and other; Social Sciences, Humanities, Health-care, Business, Education and Other Applied. We classify them in three categories: STEM and health-care, Social Sciences and Business, Other.

Parental Education (pareduc): Indicates the highest level of education attained by either of the

respondent's parents. If one parent's education level was unknown, the known level was used. Variable categories are: Did not know either parent's education level, Did not complete high school, High school diploma or equivalent, Vocational or technical training, Less than 2 years of college, Associate's Degree, Bachelor's Degree, Master's Degree and Doctoral degree or equivalent. We classify them in two categories: less than a BA degree and BA degree or higher.

Race/Ethnicity (race): Indicates the respondent's race/ethnicity with Hispanic or Latino origin as a separate category. Variable categories are: White, Black or African American, Hispanic or Latino, Asian, American Indian or Alaska Native, Native Hawaiian, other and More than one race. We classify them into four categories: White, Black or Latino, Asian, Other.

Dependency status in 2007/2008 (depend): Indicates the respondent's dependency status during the 2007-08 academic year. Variable categories are: Dependent and Independent.

Gender (gender): Indicates the respondent's sex. Variable categories are: Male and Female.

A1.b IPEDS data

Using harmonized college identifiers, we merge the B&B individual level data with institution level from the Institutional Post-Secondary Database (**IPEDS**). We use the IPEDS data in order to get information about the cost of attendance as well as the amount of grants and loans at the institutional level. We use the following variables for 2004-2007 from the IPEDS data center (https://nces.ed.gov/ipeds/use-the-data):

Average amount of student loans awarded to full-time first-time undergraduates (loan): Any monies that must be repaid to the lending institution for which the student is the designated borrower. Includes all Title IV subsidized and unsubsidized loans and all institutionally- and privately-sponsored loans. Does not include PLUS and other loans made directly to parents.

Percent of full-time first-time undergraduates awarded student loans (ploan): Percentage of full-time, first-time degree/certificate-seeking undergraduate students who were awarded student loans.

Average amount of institutional grant aid awarded to full-time first-time undergraduates (grant): Scholarships and fellowships granted and funded by the institution and/or individual departments within the institution, (i.e., instruction, research, public service) that may contribute indirectly to the enhancement of these programs. Includes scholarships targeted to certain individuals (e.g., based on state of residence, major field of study, athletic team participation) for which the institution designates the recipient.

Percent of full-time first-time undergraduates awarded institutional grant aid (pgrant): Percentage of full-time, first-time degree/certificate-seeking undergraduate students who were awarded institutional grants (scholarships/fellowships).

Some of the institutions have a missing value in grants or loans and at the same time the percentage of students who were awarded grants or loans is zero. We substitute these observations with a zero value in grants or loans. We then drop any institution that had a missing value in grants or loans in any of the four years.

Given that the total institutional grant and loan amounts are not available for 2004-2007, we construct the total institutional grant-to-aid ratio in the following way:

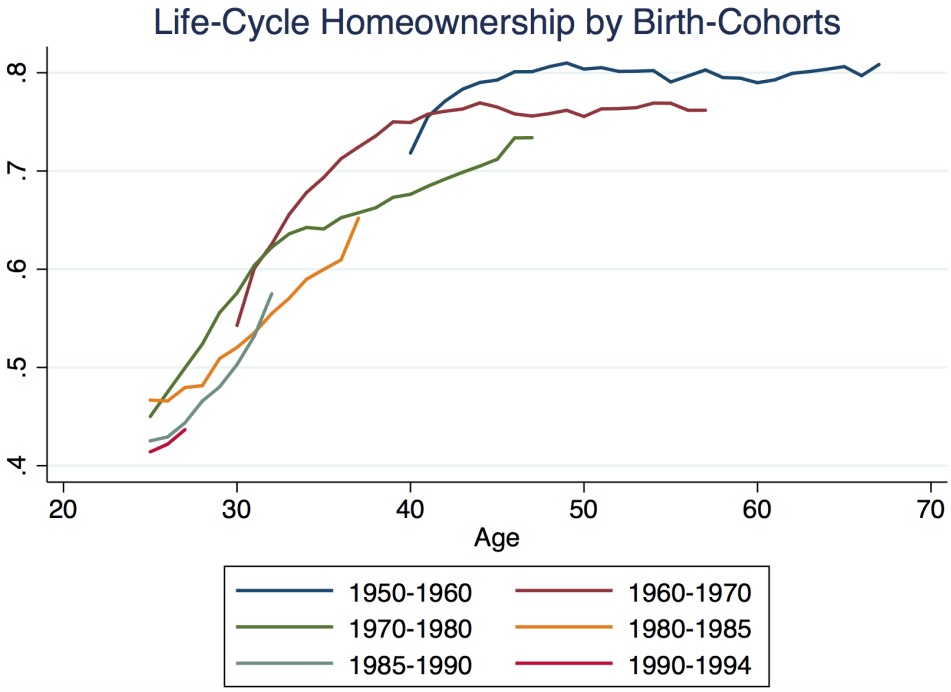
$$aid_{j,t} = ploan_{j,t} loan_{j,t} + pgrant_{j,t} grant_{j,t} = (\frac{TotalDebt_{j,t}}{Indebted_{j,t}})(\frac{Indebted_{j,t}}{Students_{j,t}}) + (\frac{Grant_{j,t}}{Recipient_{j,t}})(\frac{Recipient_{j,t}}{Students_{j,t}})$$

$$X_{j,t} = \frac{(\frac{Grant_{j,t}}{Recipient_{j,t}})(\frac{Recipient_{j,t}}{Students_{j,t}})}{aid_{j,t}}$$

We then replace the institutional grant-to-aid ratio ($X_{j,t}$) with a zero value if the institution did not receive any aid ($aid_{j,t}$) that year.

A1.c Home-Ownership Across Cohorts

Figure 9: Evolution of First-Time Home-Ownership by Cohorts



A1.d Debt distribution

Table 13: Distribution of Cumulated Student Debt

	2008	2012	2016
Percent. Borrowers	66%	67%	63%
p10	$5.000	$7.000	$6.000
p25	$11.000	$15.000	$15.000
p50	$20.000	$27.000	$27.000
p75	$30.000	$40.000	$41.000
p90	$45.000	$56.000	$59.000

Source: NPSAS 2008, 2012, 2016.
For each year, amount still owed on all undergraduate loans for students who graduated at that year and attended only one 4-year institution

Appendix 2. Robustness

Table A1: First Stage Regression

	State Control (1)	GPA Control (2)	Debt>0 (3)	Federal Debt (4)	Change in GTA (5)
Grant to Aid 07/08	-0.9***	-1.2***	-0.5***	-0.8***	
Grant to Aid 02/03					-1.2***
Change in 02/03 - 07/08					-1.0***
Observations	7910	7910	5615	7910	6521

Table A2: Second Stage Regression

	State Control (1)	GPA Control (2)	Debt>0 (3)	Federal Debt (4)	Change in GTA (5)
Employment 2009	13.5***	8.7***	17.4	12.8***	7.7***
Employment 2012	12.3***	8.5***	22.89**	12.6***	5.1*
Enrolled in College	-0.8***	-0.6***	-1.0**	-0.9***	-0.5***
Graduate Degree	-0.8***	-0.6***	-1.5*	-0.8***	-0.4*
Financial Reasons	0.9***	0.8***	1.2*	1.3***	0.8***
Earnings 2009	-1282	-1301	-3678	-2237	-1852
Earnings 2012	-4067	-5450**	-13702*	-8223**	-5217**
Homeownership	0.7***	0.5***	1.06*	0.7***	0.7***
House Value	-29064	-51384***	-	-69993**	-66643*
Marriage	0.4*	0.3*	0.4	0.5*	0.6***
Observations	7910	7910	5615	7910	6521

Appendix 3. Solution Method

A2.a Discrete-Continuous Choices

We illustrate how we take into account discrete choices with the problem of an employed renter with student loans, as in the Bellman Equation (11). For illustrative purposes only, we assume no borrowing constraints. If the worker had no discrete choices to make, the Bellman equation for the optimal consumption of a worker would satisfy the following first order condition known as the Euler equation:

$$0 = u_c'(c, s) - \beta(1 + r)\mathbb{E}\left(u_c'(c', s')\right) \tag{1}$$

However, since at any period the renter worker can choose two discrete choices (to become a homeowner or switch career), the problem at the state vector point $\{a, h, j, d, e, t\}$ involves solving for all the possible combinations of available discrete choices.

Following **Iskhakov et al. (2017)**, we assume instead that the discrete choices are affected by choice-specific taste shocks, $\sigma_e \varepsilon_t$, i.i.d. Extreme Value type I distributed with scale parameter σ_ε as in **McFadden et al. (1973)**.

Taking again the value function in (11). Abstracting from career and repayment choice, and focusing only on the home-ownership decision, the expected value of the future value function becomes:

$$
\begin{aligned}
\mathbb{E}[V'] = \max \mathbb{E}[V_r(k', h', j', m', d', e', t+1)], \mathbb{E}[V_{o,\lambda}(k', h', j', m', d', e', t+1)] = \\
= \max \mathbb{E}[V_r(\cdot, t+1) + \sigma_\varepsilon \varepsilon(o)], \mathbb{E}[V_{o,\lambda}(\cdot, t+1) + \sigma_\varepsilon \varepsilon(r)] = \\
= \sigma_\varepsilon \log \Big(\exp\{V_r(\cdot, t+1)/\sigma_\varepsilon\} + \exp\{V_{o,\lambda}(\cdot, t+1)/\sigma_\varepsilon\} \Big)
\end{aligned} \tag{2}
$$

Thus, the Euler equation for a renter can then be written as:

$$
\begin{aligned}
0 = u_c'(c, s) - \beta(1+r)\mathbb{E}\Big[u_c'(c', s' > 1) \cdot P(s' > 1 | k', h', j', m', d', e') \\
+ u_c'(c', s' = 1) \cdot P(s' = 1 | k', h', j', m', d', e') \Big]
\end{aligned} \tag{3}
$$

where $P(s' > 1)$ and $P(s' = 1)$ are conditional choice probabilities given by the binomial logit formula:

$$
\begin{aligned}
P(s' > 1 | k', h', j', m', d', e') = \frac{\exp\{V_{o,\lambda}(\cdot, t+1)/\sigma_\varepsilon\}}{\exp\{V_{o,\lambda_H}(\cdot, t+1)/\sigma_\varepsilon\} + \exp\{V_r(\cdot, t+1)/\sigma_\varepsilon\}} \\
P(s' = 1 | k', h', j', m', d', e') = \frac{\exp\{V_r(\cdot, t+1)/\sigma_\varepsilon\}}{\exp\{V_{o,\lambda}(\cdot, t+1)/\sigma_\varepsilon\} + \exp\{V_r(\cdot, t+1)/\sigma_\varepsilon\}}
\end{aligned} \tag{4}
$$

A2.b Borrowing constraints

Solving (2) requires taking care of an additional issue. Formally, given the state S and indicating the Euler equation as $\phi : S \times \mathbb{R}^m \to \mathbb{R}$, and the policy function as $k' : S \times \mathbb{R}^m \to \mathbb{R}$, one needs to find policy and multiplier $(k', \mu) \in \mathbb{R} \times \mathbb{R}$ s.t.

$$
\phi(S, k', \mu) = 0 \ , \ k' \geq \phi \perp \mu \geq 0 \tag{5}
$$

Following **Garcia and Zangwill (1981)**, this problem can be transformed into a system of two equations, and can then be solved using standard solution algorithms for root finding.

Define a variable α such that:

$$
\alpha \equiv \begin{cases} \mu, & \text{if } \mu \geq 0, \ k' = \phi \\ -k', & \text{if } \mu = 0, \ k' \geq \phi \end{cases} \tag{6}
$$

and

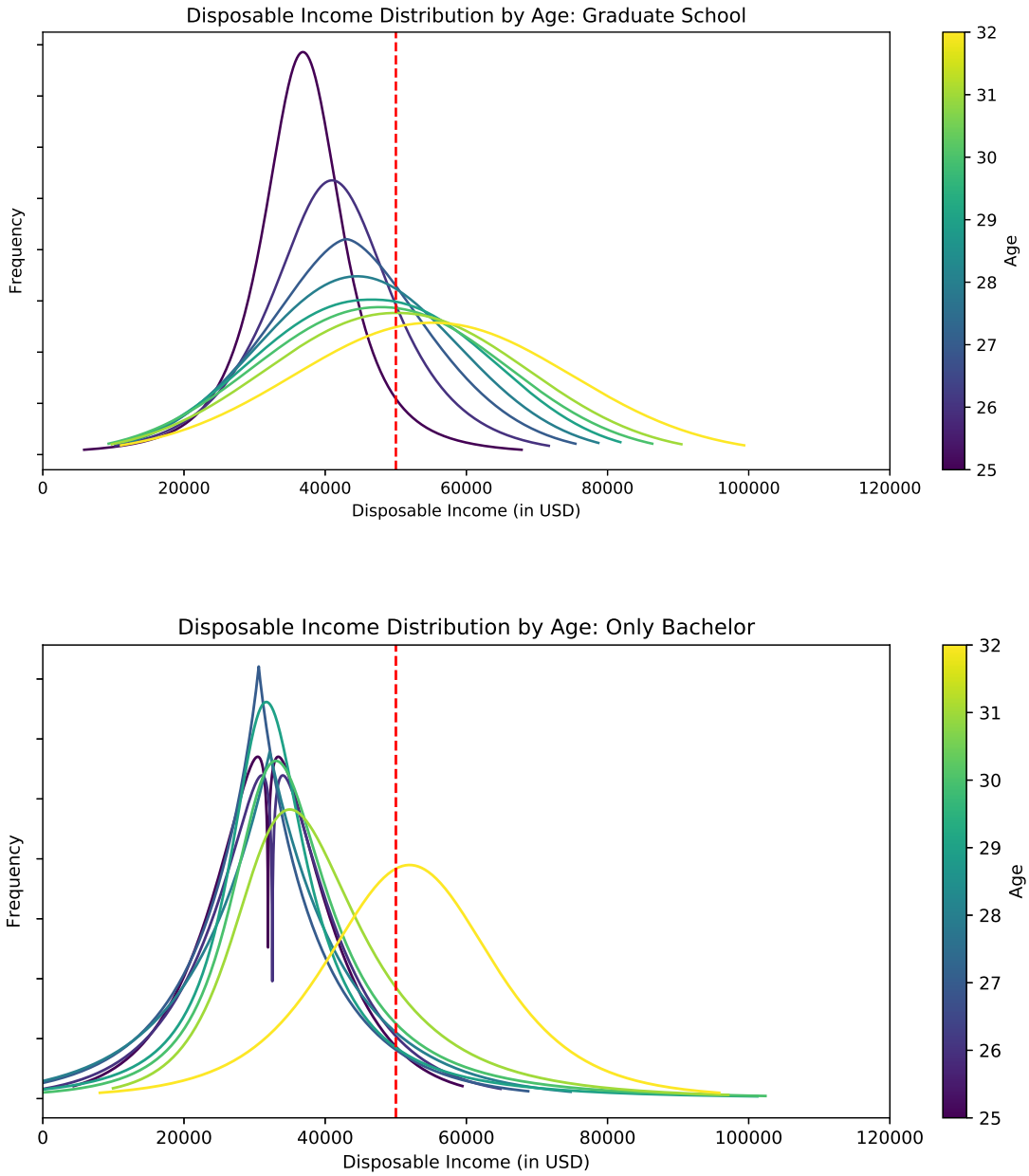
$$
\begin{aligned}
\alpha^+ &= (\max(0, \alpha))^k \\
\alpha^- &= (\max(0, -\alpha))^k
\end{aligned} \tag{7}
$$

where $k \in \mathbb{N}^+$. The variable acts like a "penalty" when the constraint is violated, forcing the algorithm to search in the feasible set. The problem can be rewritten as finding policies and α such that:

$$
\phi(S, k', \alpha^+) = 0 \ , \ k' - \alpha^- = 0 \tag{8}
$$

Appendix 4. Additional Figures

Figure 10: Graduate School Educated Workers and Downpayment Constraint



Distribution of yearly disposable income, i.e. labor wages plus net liquid asset holdings, minus debt payments and housing expenditures for workers with graduate school education. The red line represents the downpayment constraint

Figure 11: Ratio of Student Loan Debt to Income, All Workers

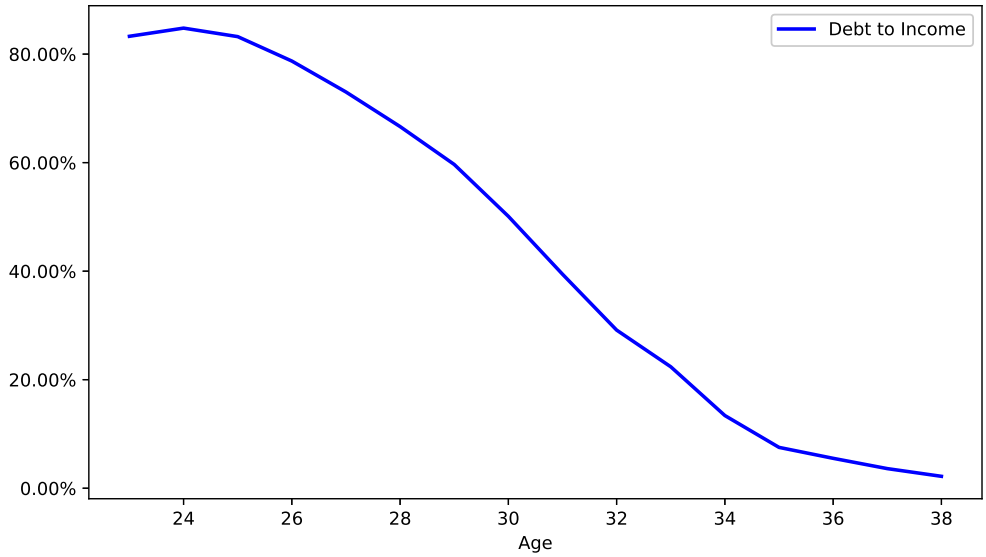
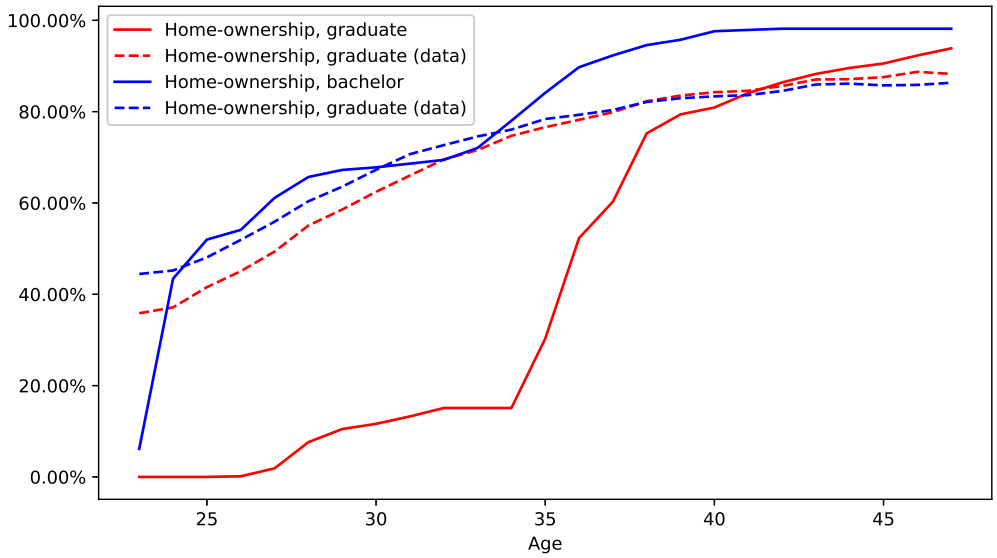
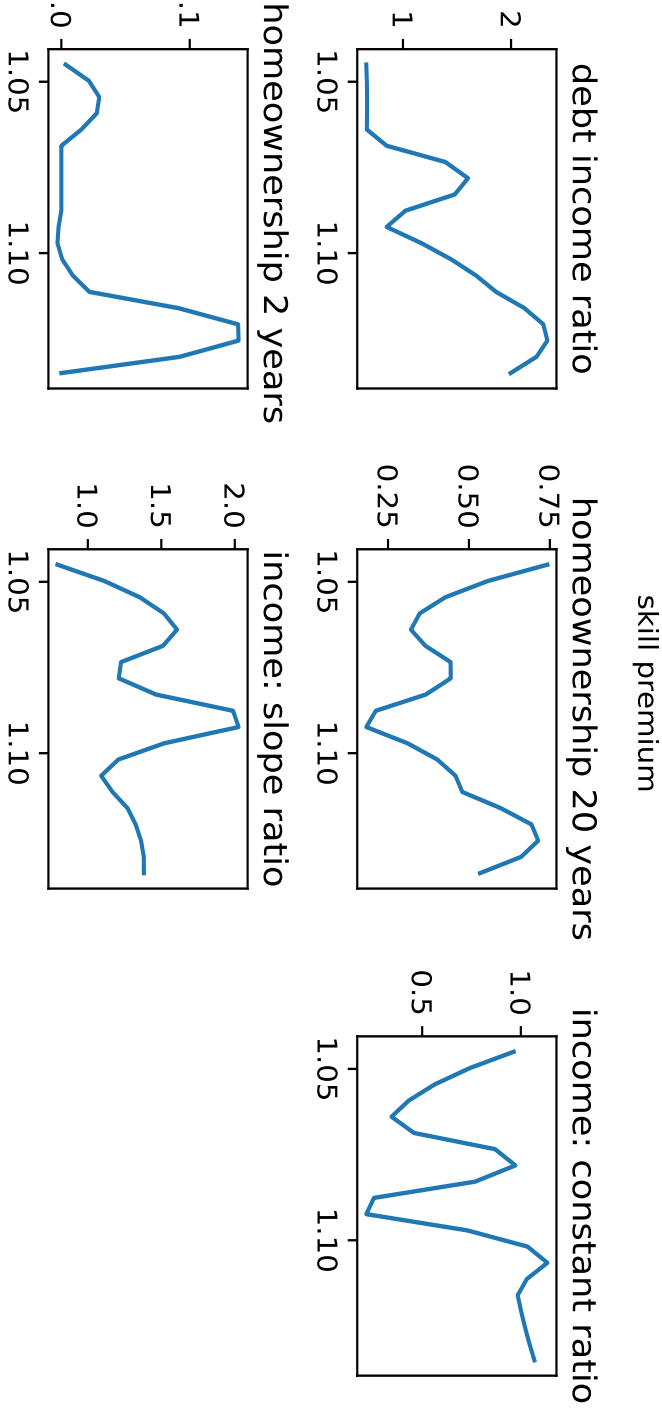


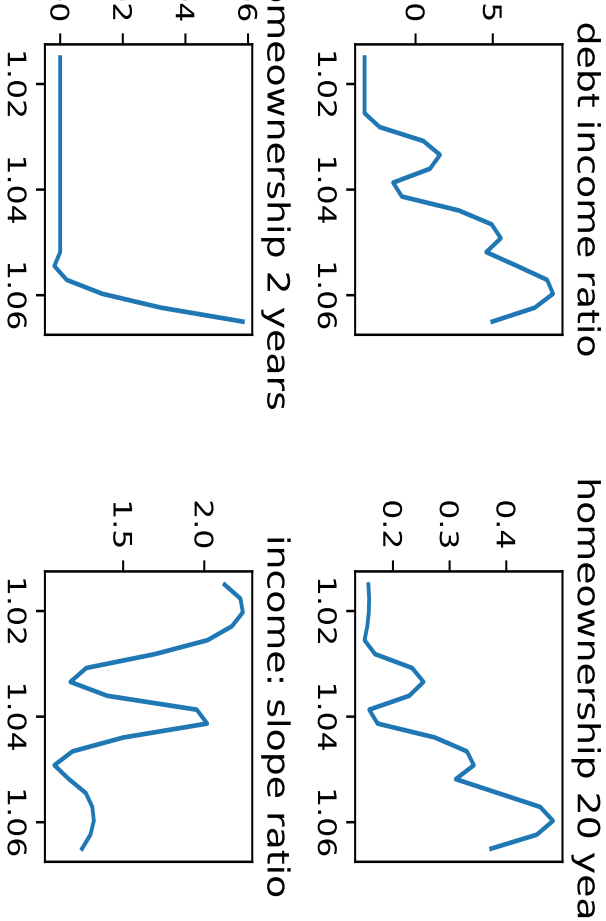
Figure 12: Entry into Home-Ownership by Education

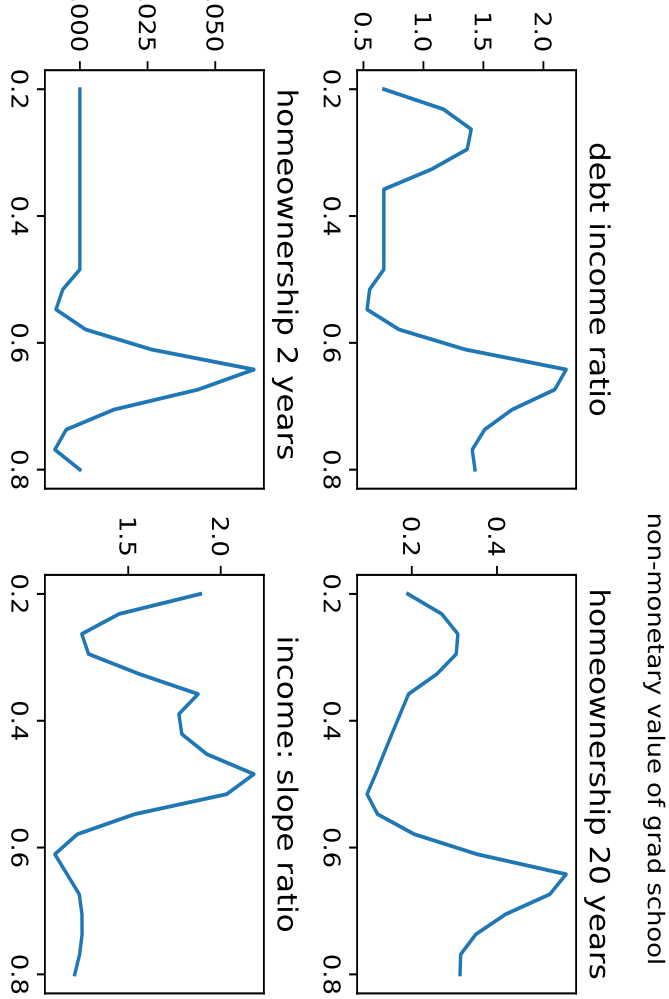


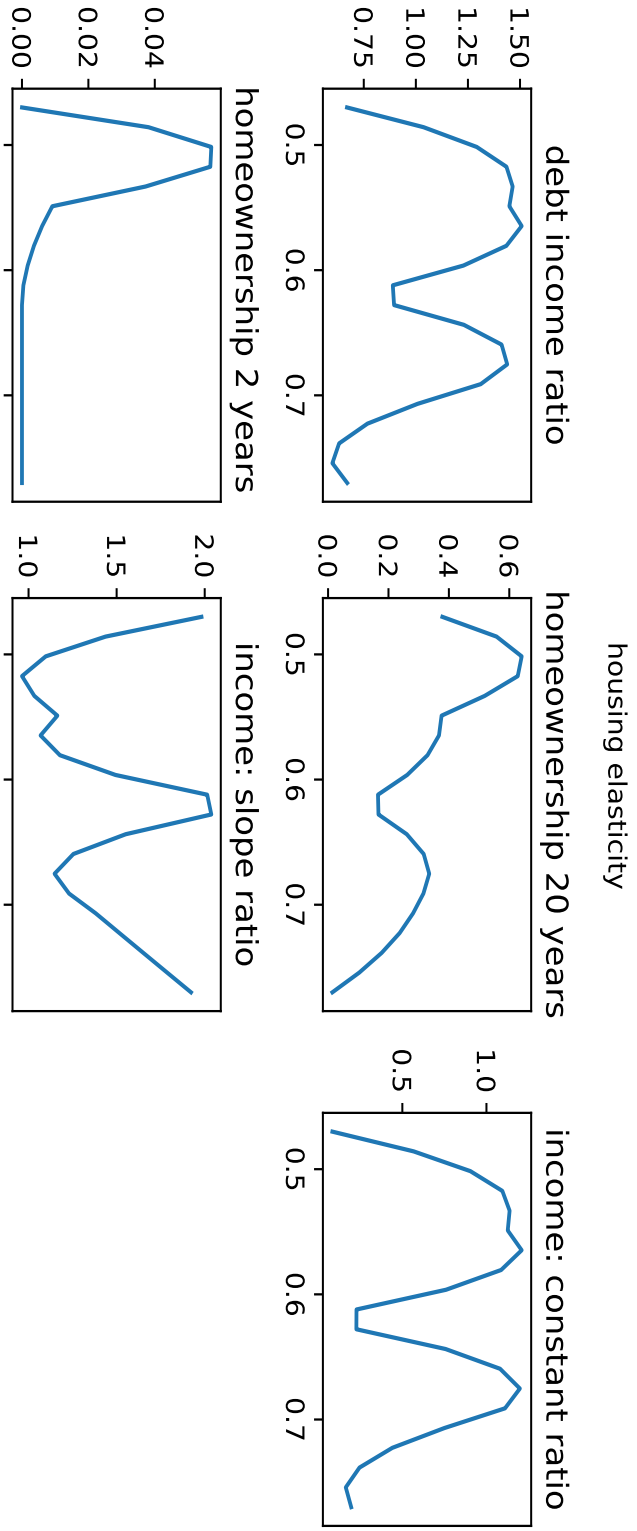
Data: Current Population Survey for workers aged 24-50, years 2000-2018

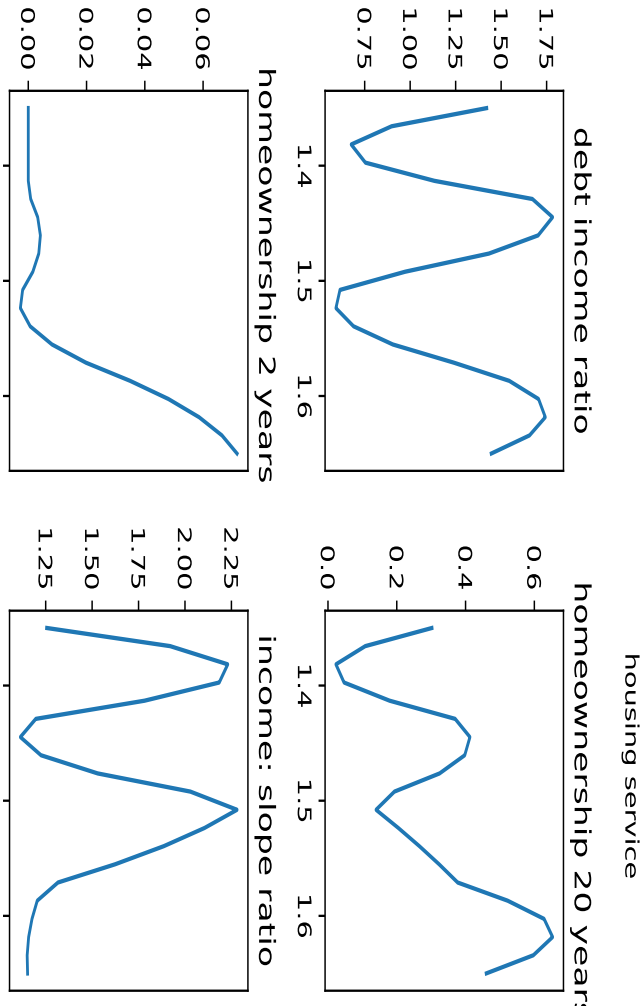
Appendix 5. Identification




grad school hc returns
debt income ratio
homeownership 20 years
income: constant ratio
homeownership 2 years
income: slope ratio


non-monetary value of grad school
debt income ratio
homeownership 20 years
income: constant ratio
homeownership 2 years
income: slope ratio


housing elasticity
debt income ratio
homeownership 20 years
income: constant ratio
homeownership 2 years
income: slope ratio
1.50
1.25
1.00
0.75
0.6
0.4
0.2
0.0
1.0
0.5
0.04
0.02
0.00
2.0
1.5
1.0
0.5
0.6
0.7


housing service
debt income ratio
homeownership 20 years
income: constant ratio
homeownership 2 years
income: slope ratio